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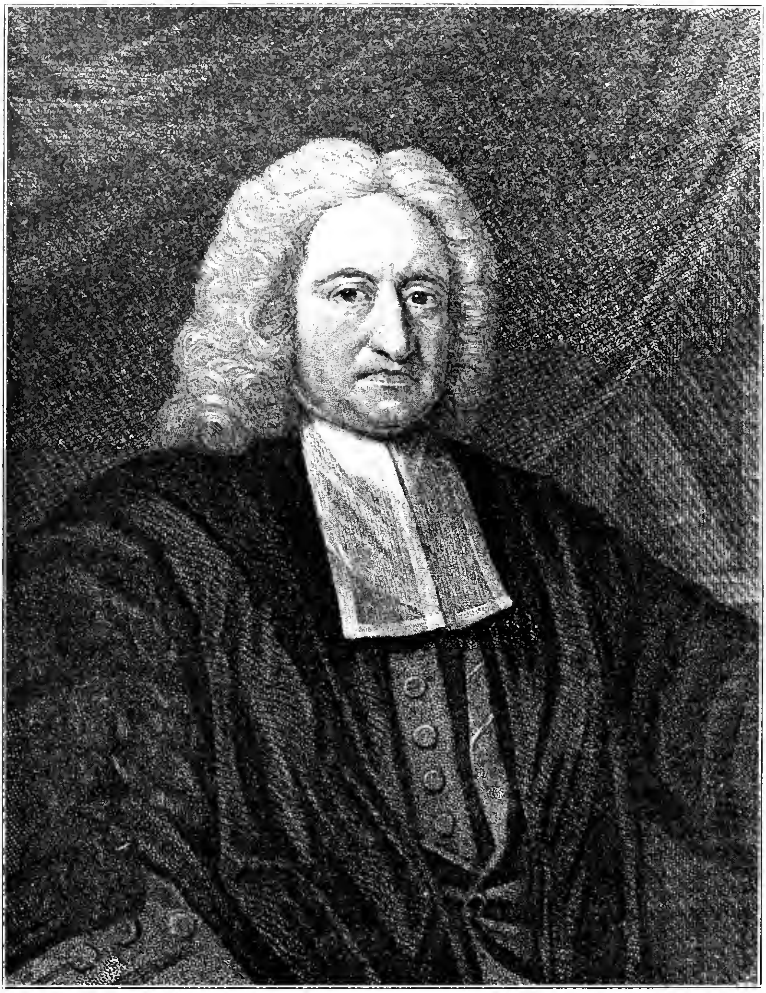
HALLEY'S COMET

BY PROFESSOR C. L. DOOLITTLE
THE FLOWER ASTRONOMICAL OBSERVATORY

IN what will be said in this connection respecting comets in general and Halley's comet in particular, it will not be necessary to occupy much space in repetition of the well-known series of ancient views respecting the physical nature of these bodies or the superstitious dread with which they were regarded. With reference to the latter phase of the subject it may be said in passing, that it was not altogether an unfortunate matter, as without this incentive, probably even such fragmentary and unsatisfactory records of comets as have come down to us would not have existed.

These accounts are very seldom of much service from a scientific point of view. Very few seem ever to have thought it worth while to measure the position of a comet, or to record anything that would help us to-day in the determination of its orbit, or in identifying it with earlier or later appearances. It was believed that they were meteoric in character, occurring like the aurora borealis only a few miles perhaps above the earth's surface, and subject to no uniform laws like the heavenly bodies. This applies to the western nations simply. We shall see that the Chinese were at least a little more rational in their methods, though little as to their ideas on this branch of astronomy is known.

There are, however, among the ancient writers, two whose utterances regarding comets are worthy of some attention, Diodorus Siculus and Seneca. The former wrote a voluminous universal history in which matters of authentic history are indiscriminately jumbled with myth and fiction, all apparently being considered of equal value. Among these, this statement occurs. "The ancient Egyptians and Chaldeans derived from long series of observations, methods for predicting the appearance of comets." As earthquakes and hurricanes were also occurrences which they were said to be able to predict, it seems to be the usual custom to dismiss the entire matter as belonging to the realm of astrology or myth, especially as nothing is said regarding the system employed. This would seem, however, to be a somewhat arbitrary procedure in view of what we know of their methods and results in other problems. It is well known that by comparison of long series of eclipses, these ancient people were able to predict their occurrence by



EDMUND HALLEY.

means of the cycle of 6,585 and one third days, or 18 years 11 and one third, or 10 and one third days, depending on whether the particular cycle included four or five leap years. It appears also, from comparatively recent investigation, that the same methods were employed in the planetary motions, and with success. It seems, then, a very natural method of procedure to attempt to find similar cycles for other natural phenomena.

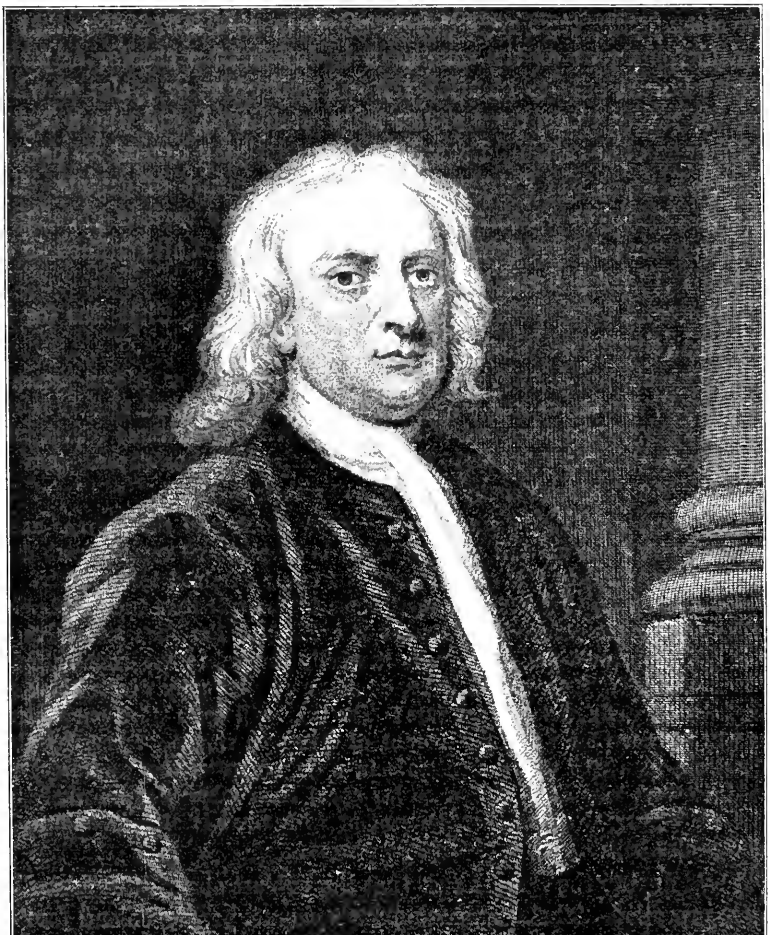
In view of the apparent facility with which the cycles, real or imaginary, can be discovered by those who have a taste for such investigations, we can readily believe that the occurrences referred to were thought to fall into line, and that predictions for the future may have been attempted. It is well to remember, in this connection, that no inconsiderable part of the science of to-day is in a similar empirical status. I need only to mention the sun-spot cycle, or cycles of which there are two or three, more or less fully established, and which depend wholly upon observation. Regarding the underlying causes, we perhaps know as little as the Babylonians did of the nature of comets. The numerous attempts which are still made to fit the various phenomena of the weather into some such orderly scheme are not all confined to the ranks of the ignorant and mentally unbalanced.

The second writer alluded to, viz., Seneca, makes, what was for his time, this remarkable statement:

> Why should we be surprised that comets, phenomena so seldom presented to the world, are for us not yet submitted to fixed laws, and that it is still unknown from whence come and where remain these bodies whose return takes place only at immense intervals? Fifteen centuries have not elapsed since
>
> Greece counted the stars by their names.
>
> How many people at the present day know nothing of the heavens except their aspect, and can not tell why the moon is eclipsed and covered with darkness! We ourselves in this matter have but lately attained to certainty. An age will come when that which is mysterious for us will have been made clear by time and by the accumulated studies of centuries. For such researches the life of one man would not suffice were it wholly devoted to the examination of the heavens. How then should it be, when we so unequally divide these few years between study and vile pleasure? The time will come when our descendants will wonder that we were ignorant of things so simple. Some day there will arise a man who will demonstrate in what region of the heavens comets take their way; why they journey so far apart from other planets, what their size, their nature. Let us, then, be content with what is already known; let posterity also have its share of truth to discover.

It was during the middle ages that the wildest absurdities regarding comets prevailed. Their connection with plague, pestilence and famine, with battle and murder and sudden death seems to have been called in question by no one. With the dawn of the renaissance, more rational notions began to appear. At first slowly, as we might expect.

One of the first to take hold of the problem in something approaching a scientific fashion, was the renowned Tycho Brahe, 1546–1601. From observations of his own he proved that comets were heavenly bodies, certainly as distant as the moon, instead of mere atmospheric phenomena, as was commonly supposed. With regard to their orbits, however, he was far from the truth in supposing them circular. Kepler was not so fortunate here as in his planetary investigations, supposing as he did that they moved in straight lines. Finally Dörfel, a clergyman of Plauen, upper Saxony, eighty years after the death of Tycho, proved by a graphic process that the orbit was parabolic. He knew nothing, however, of the physical causes underlying this motion, but shortly after this appeared the immortal "Principia" of Sir Isaac



Sir Isaac Newton.

Newton with his remarkable demonstration relating to the motion of bodies under the action of gravity, viz., that the orbit may be an ellipse, parabola or hyperbola. Thus comets took their true place as orderly members of the system, and the last reason, if any such ever existed, for the superstitious dread of previous times disappeared. Errors, however, die hard, and this particular form manifested the usual vitality, in fact, it has not even now entirely disappeared.

The "Principia" appeared in 1687. So far as the conclusions there reached apply to the subject before us, the labor of adapting the theoretical results to numerical form and applying them to the practical problem of orbit computation, fell to Edmund Halley.

Halley, a contemporary and friend of Newton, occupies a very prominent place in the history of astronomical and physical science. Among other important discoveries and researches, may be mentioned the long inequality of Jupiter and Saturn, the proper motions of the stars, the secular acceleration of the moon's motion, method of determining the solar parallax by observations of transits of Venus, researches on terrestrial magnetism, and his epoch-making work on the motions of comets.

HALLEY'S COMET.

No.	Observed Perihelion.		Authority.	Calculated Perihelion.	Authority.
(1)	11 B. C. Oct. 9,	Jul	Hind		—
(2)	66 Jan. 26	"	"	—	—
(3)	141 March 29	"	"	—	—
(4)	218 April 6	"	"	—	—
(5)	295 April	"	"	—	—
(6)	373 Beg. Nov. ?	"	"		
7	451 July 3	"	Laugier	—	—
(8)	530 Beg. Nov.?	"	Hind	—	
(9)	608 End Oct. ?	"	"	—	—
(10)	684 Oct.	"	"	—	—
11	760 June 11	"	Laugier	June 15	Crommelin-Cowell
12	837 March 1	"	Pingré	Feb. 25	" "
(13)	912 Beg. April	"	Hind	July 19	" "
14	989 Sept. 12	"	Burckhard	Oct. 9	" "
15	1066 April 1	"	Hind	March 27	" "
16	1145 April 19	"	"	April 6	" "
17	1222 Aug. 22	"	Crommelin-Cowell	Sept. 10	" "
18	1301 Oct. 23	"	Hind	Oct. 26	" "
19	1378 Nov. 9	"	Laugier	—	—
20	1456 June 8	"	Pingré-Celoria	—	—
21	1531 Aug. 26	"	Halley	—	—
22	1607 Oct. 27	Greg.	"	Oct. 27	Lehmann
23	1682 Sept. 14	"	"	Sept. 15	"
24	1759 March 13	"	Various	March 13	Rosenberger
25	1835 Nov. 16	"	"	Nov. 15	Pontécoulant
26	1910			April 8	Crommelin-Cowell

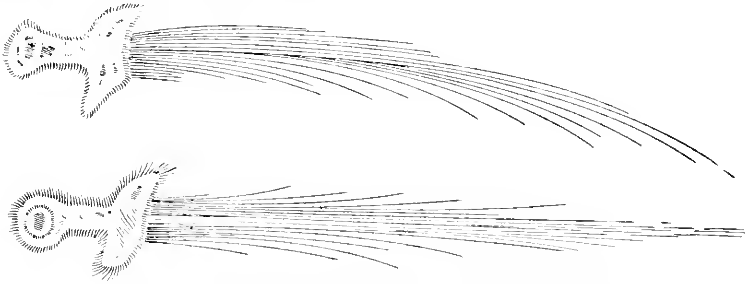
But perhaps Halley's most important work was the part which he took in the publication of the "Principia." It was largely through Halley's influence that Newton was persuaded to prepare this great work for publication, and entirely at his expense that the printing was finally done.

Among the contemporaries of Halley, we find many astronomers whose names have survived in history. We need only mention Flamsteed, the first astronomer royal, Cassini, Hevelius, Roemer and Huyghens. In his sixty-fourth year, Halley succeeded Flamsteed as astronomer royal and, at once, boldly set about the task of observing the moon through a complete revolution of the nodes, viz., a period of

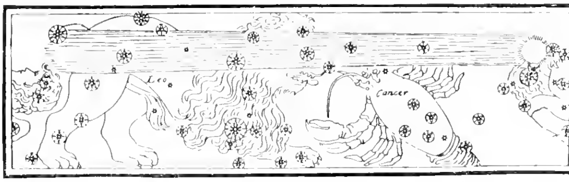
HALLEY'S COMET IN 1066 ON THE BAYEUX TAPESTRY.

eighteen years, for the purpose of improving the lunar theory, a problem which had long occupied much of his attention. He had the satisfaction of completing this eighteen-year task before his death, which occurred in 1742, his age being eighty-five.

Soon after the development of Newton's method, Halley set to work with the application to comets' orbits. Certain terms were tabulated in order to facilitate the application, but even with this aid Halley himself, who delighted in large undertakings, seems to have been greatly impressed with the magnitude of this one. The undertaking consisted in computing the parabolic orbits of all comets where sufficient data existed for this purpose, but, although the appearance of some four hundred of these bodies had been noted during historic times, only twelve had been sufficiently observed to give much hope of success. To this first twelve were afterwards added twelve more. The final results of this long investigation were not published until 1749, when it appeared with the title, " Synopsis Astronomiæ Cometæ." In these days, with improved methods of attacking the problem, such a task



REPRESENTATIONS OF COMETS AS FLAMING SWORDS.



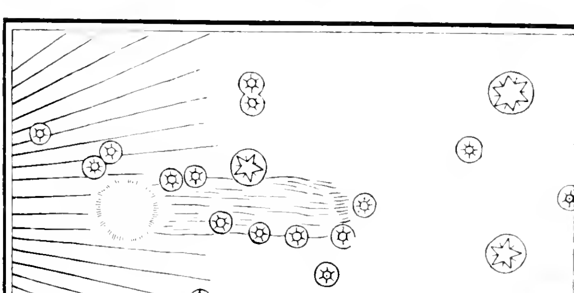
HALLEY'S COMET IN 1456 (according to Lubieniecki, Theatrum Cometicum).

would be very promptly disposed of. Of course, all computers are not like the late Professor Safford, who used to compute such an orbit in one hour, but we should probably not find it necessary to search long for one who would undertake to do the work in ten or twelve days. But the method developed by Newton seems now very cumbersome and its application laborious. It was, moreover, so far from comple-

TAILLESS COMET OF 684 (Halley?) in the Pleiades (according to Lubieniecki, Theatrum Cometicum).

tion that no means were found for computing the elliptic elements of a periodic comet unless it had been observed at a second return. The identification, therefore, depended on the similarity of the elements, a very uncertain criterion, as we shall see.

It is not at all improbable that if Halley had known more of the chances of failure which beset this method of identification he would hardly have ventured to predict another return of his comet. The step,



HALLEY'S COMET IN 1066, after its emergence from the Sun's Rays (according to Lubieniecki, Theatrum Cometicum).

in any case, was a bold one but, fortunately for Halley's reputation and for science, the result fully justified it.

The same process has been tried in many cases besides this one, but this seems to be the only instance where the prediction has been verified by success. Gibbon gives us a very interesting instance of this method of identification.[1] After referring to the remarks of Seneca, already quoted, he continues:

> Time and science have justified the conjectures and predictions of the Roman sage: the telescope has opened new worlds to the eyes of astronomers; and, in the narrow space of history and fable, one and the same comet is already found to have revisited the earth in seven equal revolutions of 575 years. The first, which ascends beyond the Christian era 1767 years, is coeval with Ogyges, the father of Grecian antiquity. And this appearance explains the tradition which Varro has preserved, that under his reign the planet Venus changed her color, size, figure and course; a prodigy without example either in past or succeeding ages. The second visit, in the year 1193, is darkly implied in the fable of Electra, the seventh of the Pleids, who have been reduced to six since the time of the Trojan war. That nymph, the wife of Dardanus was unable to support the ruin of her country: she abandoned the dances of her sister orbs, fled from the zodiac to the north pole, and obtained, from her dishevelled locks, the name of comet. The third period expires in the year 618, a date that exactly agrees with the tremendous comet of the Sibyl, and perhaps of Pliny, which arose in the west two generations before the reign of Cyrus. The fourth apparition, 44 years before the birth of Christ, is of all others the most splendid and important. After the death of Cæsar, a long-haired star was conspicuous to Rome and to the nations, during the games which were exhibited by young Octavian in honor of Venus and his uncle. The vulgar opinion that it conveyed to heaven the divine soul of the dictator, was cherished and consecrated by the piety of a statesman; while his secret superstition referred the comet to the glory of his own times. The fifth visit has already been ascribed to the fifth year of Justinian, which coincides with the 531st of the Christian era. And it may deserve notice that in this, as in the preceding instance, the comet was followed, though at a longer interval, by a remarkable paleness of the sun. The sixth return, in the year 1106, is recorded by the chronicles of Europe and China: and in the first fervor of the crusades, the Christians and Mahometans might surmise, with equal reason, that it portended the destruction of the infidels. The seventh phenomenon, of 1680, was presented to the eye of an enlightened age. The philosophy of Bayle dispelled a prejudice which Milton's muse had so recently adorned, that the comet from its "horrid hair shakes pestilence and war." Its road in the heaven was observed with exquisite skill by Flamsteed and Cassini: and the mathematical science of Bernoulli, Newton and Halley, investigated the laws of its revolutions. At the eighth period, in the year 2355, their calculations may perhaps be verified by the astronomers of some future capital in the Siberian or American wilderness.

In more recent times we have the remarkable group of bodies of which the comets of 1668, 1843, 1882 are members; there are others, the total number being probably very large. All of these bodies move in orbits almost identical, almost grazing the surface of the sun at the time of perihelion passage, and passing through millions of miles of the

[1] "Decline and Fall of the Roman Empire," Vol. IV., p. 289.

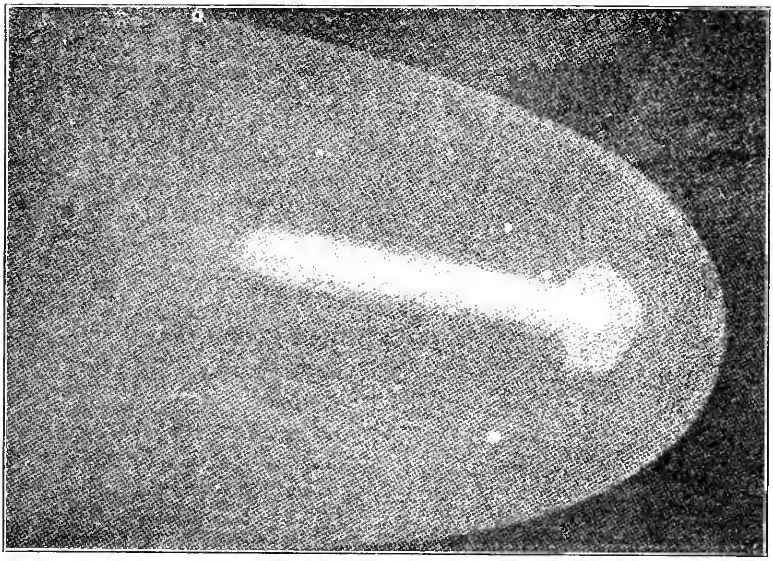
sun's corona. At the appearance of the 1882 member, it was fully believed by some prominent astronomers to be the same comet which had appeared in 1843, which was being rapidly drawn into the sun by the resistance encountered at perihelion passage. It appeared, however, that the orbit, derived exclusively from observations after that event, indicated a period of six hundred or seven hundred years, at least thus disposing of the question of identity. The behavior of the body itself was, however, very suggestive as to the true condition of things. After the close approach to the sun with its tremendous tidal strain, the nucleus was found to be broken up into a number of pieces. These parts, instead of approaching each other, separated more and more as long as the body could be kept in sight. At the next return, after some six hundred or seven hundred years, there will, no doubt, be four or five separate comets, following each other at intervals of perhaps a number of years.

HALLEY'S COMET IN THE YEAR 1682.

HALLEY'S COMET IN THE YEAR 1759.

Halley confidently predicted the return of his comet in 1759. He also identified it as having been seen in 1305, 1380 and 1456. The difference of period, which amounted to one year and three months, was somewhat disturbing, but Halley assigned this to the true cause, namely, the perturbations produced by Jupiter and Saturn. He remarked that the period of the planet Saturn might vary as much as a month from the action of Jupiter. He says:

> How much more liable to derangement, then, is a comet, whose excursion into space is four times greater than that of Saturn, and whose orbit is so eccentric that if the velocity be increased the 1/120th of its value, the ellipse described the comet would be changed into a parabola.



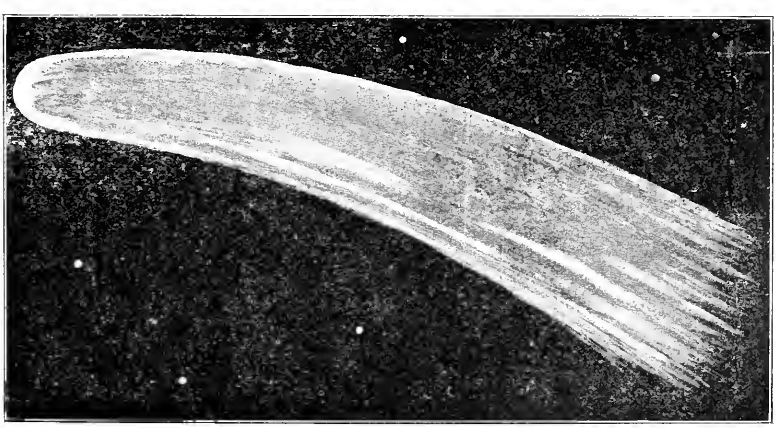
Halley's Comet in 1835 (by Sir John Herschel).

As no method existed at that time for precise determinations of the perturbations, there was considerable uncertainty as to when to look for the next return, but Halley estimated that the general result would be a retardation, and that it would not be visible much before the beginning of 1759. This, as we shall see, proved to be a very fortunate guess.

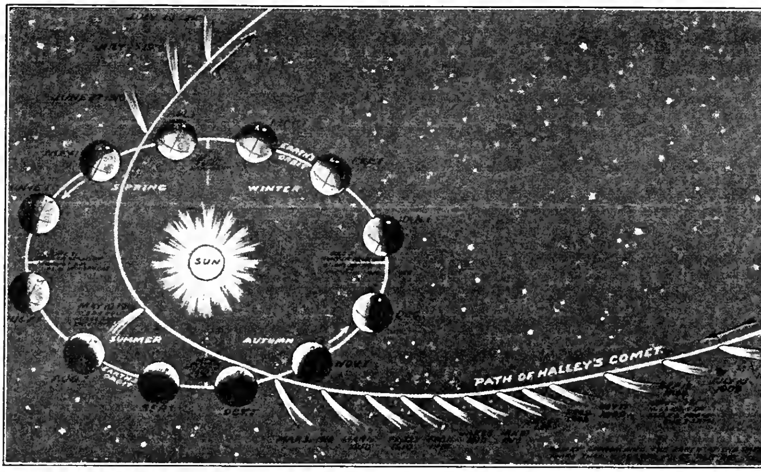
Naturally, the old chronicles were now diligently searched for records of earlier appearances. Beginning with 240 B.C., a continuous series of supposed appearances is found at an average interval of 76.8 years, but with the very considerable range of a little more than five years between the longest and shortest of these periods. With such a range, naturally, the period alone furnishes a very slight foundation for establishing identity, and, unfortunately, in many cases, the accounts given are so meager and unsatisfactory as to leave the matter in grave doubt. In a number of instances, where the comet has been connected with natural events, such as conjunctions of planets, eclipses, earthquakes and the like, or with important matters of history, the accounts may contain, in connection with much rubbish, sufficient material of value to leave no doubt as to identity. It has been thought by many that this is the comet mentioned by Josephus in connection with the destruction of Jerusalem. This would, perhaps, not be impossible, though a considerable stretching of the period would be required. The appearance in A.D. 451 is the first record which seems open to no doubt on the score of identity. In the autumn of that year the Huns, under Attila, were defeated by the Roman armies. Numerous historians and chroniclers of that day agree that this event was announced by a comet, which proves to have been this one of Halley. To eclipses of the moon, April the second and September the twenty-sixth of this year, assist in fixing the date securely. The second of these eclipses is charged to the account of the comet itself. The return in 1066 has received much attention on account of its supposed connection with invasion of England by William, the Norman, and with the overthrow of Harold at Hastings.

By 1456 something more like scientific activity had begun. It was indeed nearly one hundred years before the publication of the immortal work of Copernicus, and astronomical observers were few and far between, particularly in Europe. In recent times a series of observations has been brought to light, made by Toscanelli in Florence. The discovery was made by Celoria, in 1885, and, as may be supposed, it is a most welcome addition to our data for fixing the exact circumstances of this appearance. Perhaps never before or after has a comet caused so much consternation as upon this occasion. Three years before, the Turks under Mahomet the second had taken Constantinople and their armies were pushing their conquests to the west. Many were apprehensive of the complete subjugation of Europe. Then a brilliant comet appeared, the precursor, as was supposed, of further calamities, and a universal panic seems to have taken possession of high and low alike. Who wonders if the pope ordered the church bells to be rung everywhere at noon, and that all should then engage in prayer for the protection against the Turks and the comet?

1531 is one of the dates used Halley in fixing the character of the orbit, the other two being 1607 and 1682. This appearance is known as the comet of Apian, that is, Petrus Apianus, alias Peter Bienewitz, court astronomer of Charles V., and of Ferdinand I. His observa-



HALLEY'S COMET (by Struve).



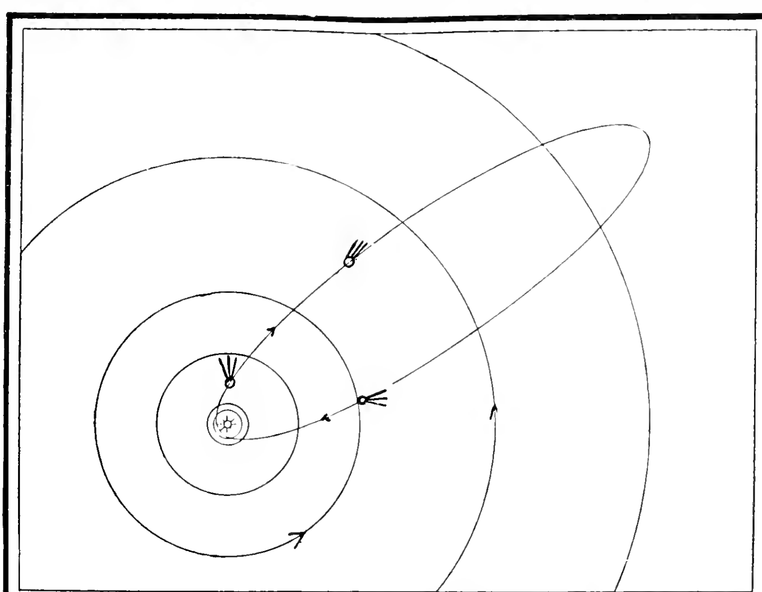
Path of Halley's Comet.

tions extended for three or four weeks, and were made at Ingolstadt. Apian first established the fact that the comet's tail is constantly directed away from the sun. This was the first substantial item of evidence towards showing that comets, instead of being simply terrestrial phenomena, are in some way connected with the cosmic universe. The system of Copernicus had not then appeared, so the true solution of the problem could not be expected, though here at least was a beginning. Earthquakes, showers of blood and fiery appearances in the heavens are charged to this comet, but from now on, we have less and less of these matters. The next appearance, 1607, was detected by Kepler, though it had been seen a few days before by a monk in Swabia. Kepler furnishes a series of observations from September 26 to October 26, but he was less fortunate in his speculations regarding its nature and movements than had been his lot in his planetary researches.

The year 1682 brings us again to Halley. In these attempts to identify the early appearances, the Chinese annals have been of great assistance. In some cases all of the substantial evidence which we possess comes from this source. These records were kept in a much more systematic manner than the chronicles of the western people. The times when the comet was first and last seen are carefully recorded. The path, observed among the stars, is often given, not, of course, with extreme accuracy, but sufficiently so as to admit of the determination of an approximate orbit, and thus furnish valuable data for identification. The Chinese appear not to have been disturbed by the superstitious dread of comets which pervaded Europe. Their accounts of the physical characteristics are unsatisfactory, the length of tail and similar matters being given, not in angular, but in linear, measure, which, of course, means nothing.

Much was done, between 1682 and 1759, in the way of advancing the principles and methods of celestial mechanics. It was now possible, as it was not seventy-five years earlier, to determine the effect of the planetary perturbations and thus reduce to narrow limits the uncertainty as to the time of appearance. The matter does not seem to have been taken up seriously, however, until 1757, when Clairaut, who had already proved himself a brilliant mathematician, attacked the problem. Elaborate discussions of the problem of three bodies had already been developed, but they were not adapted to this case, on account of the great eccentricity of the orbit. This made it necessary to attack the problem in a very different manner from that employed in the case of the moon and the planets. Clairaut, however, proved himself equal to the task, though the practical application involved an immense amount of numerical work, and the time remaining was short. He was ably assisted, however, by Lalande, then a youth of seventeen, and a lady, Madame Lepaute.

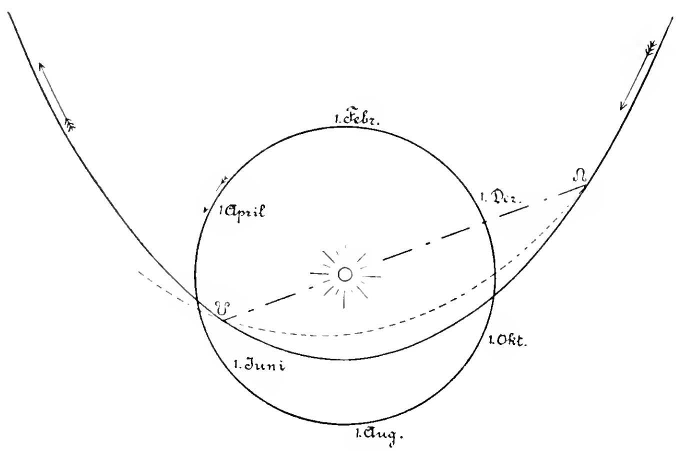
The final result indicates a retardation of 618 days, 518 being due to the action of Jupiter, 100 to Saturn. The time of perihelion passage was fixed at April 13, 1769, but, as it had been necessary for want of time to abridge the work, by omitting some small terms, Clairaut stated that the true time might differ from this by as much as a month. He states further that a body passing into regions so remote, and which is hidden from our view during such long periods, might be exposed to the action of forces, totally unknown, such as the



ORBITS OF THE PLANETS AND THE COMET (the smallest Circle is the Earth's Orbit).

attraction of other comets or even of some planet, too far removed from the sun to be even perceived. It should be remembered that nothing was known at this time of Uranus and Neptune. The actual time of perihelion passage was March 13, just within the limit.

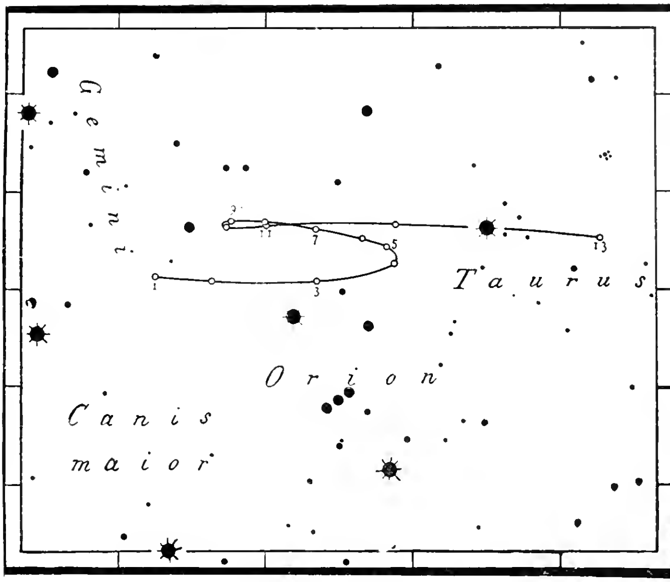
The history of its discovery is interesting. Though astronomers everywhere were looking forward with great interest to the event, the most elaborate attack was made at Paris. This was planned by De Lisle, but the work of searching for the body fell to Messier, whose name is familiar to astronomers everywhere in connection with the discovery of numerous comets, nebulæ and clusters. He had a genuine



THE PATH OF HALLEY'S COMET AND ITS CONJUNCTION WITH THE EARTH'S ORBIT.

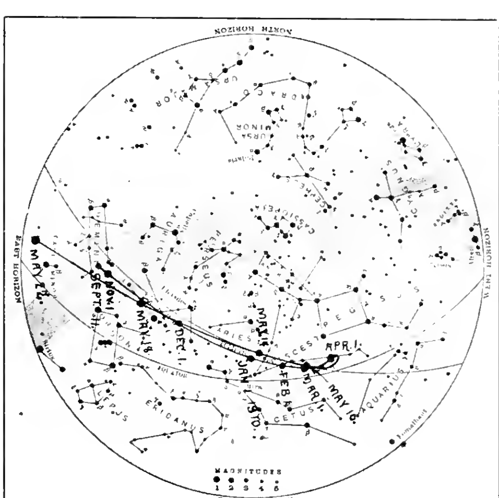
passion for this class of work, but no taste whatever for theoretical research. At this time he was living in the house of De Lisle, who seemed to think that he had a property right in Messier's observations, which Delambre tells us he hoarded as a miser does his wealth, neither using them himself nor allowing any one else to do so.

De Lisle planned a systematic siege of the stronghold. Assuming limits which he believed wide enough for the purpose, he prepared charts on which lines were drawn for convenient dates, the supposition being that the comet would be found somewhere on the line. Night after night for eighteen months, Messier carried on the siege until, finally, on January 21, 1759, he was rewarded with his first sight of the comet. It was doubtless humiliating to all concerned to learn that on Christmas eve, previous, the comet had been seen by a peasant named Palitzsch. Delambre states that he saw it with the naked eye, without previous knowledge of its existence, but this is not the true history. The account given by Palitzsch is quite different. He states that he was engaged in observing the variable star, Omicron Ceti, with his nine-foot tube, and that he found between Delta and Epsilon Ceti a nebu-



Apparent Orbit of Halley's Comet from October 2, 1908, to December 7, 1909. 1908 (1) Oct. 2, (2) Nov. 25. 1909 (3) Jan. 15, (4) March 3, (5) April 15, (6) May 25, (7) June 31, (8) Aug. 3, (9) Sept. 3, (10) Sept. 30, (11) Oct. 26, (12) Nov. 17, (13) Dec. 7.

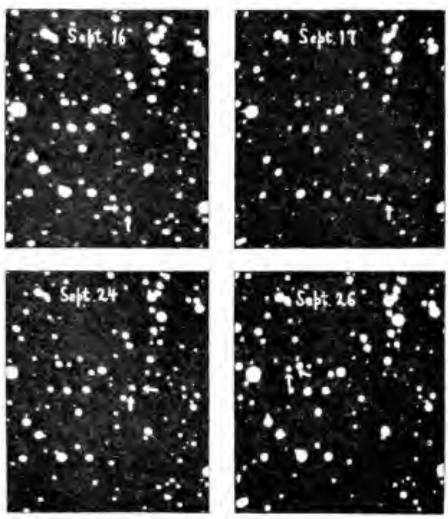
lous star which proved to be the comet. There were not wanting skeptics who doubted whether the comet would be found, but its return put an end forever to the old notions, and left no foothold for the opponents of Newton's theory of universal gravitation.



The Constellation at 9 p.m., December 1, 1899.

The prediction for the next return was taken in hand, in due time, by no less than four distinguished mathematicians—Damoiseau, Pontécoulant, Lehmann and Rosenberger. These found, respectively, for the time of perhelion passage, 1835, November 4, 13–15, 26 and 12. This time the perturbations due to Uranus and the earth were included as well as those of Jupiter and Saturn. The actual time proved to be November 16.

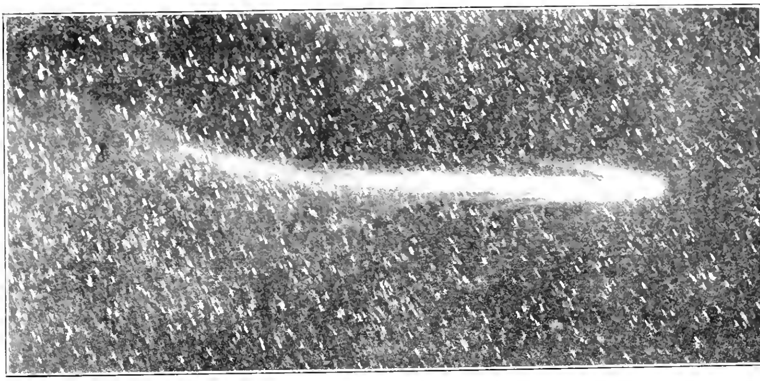
Search for the comet began, on the part of numerous comet seekers, as early as January, 1835, but the first sight of it was obtained August 5, by Dumorchel, at Rome, very near the predicted place. About the middle of September, two months before perihelion, it became visible to the naked eye. The greatest brilliancy occurred about the middle of



HALLEY'S COMET AS PHOTOGRAPHED WITH THE TWO-FOOT REFLECTOR OF THE YERKES OBSERVATORY.

October. The public had been expecting something very striking, but, unfortunately, cloudy weather interfered to a great extent. It practically disappeared from the northern hemisphere with perihelion passage, but was followed for some time longer by Sir John Herschel at the Cape of Good Hope.

As regards the present appearance, the comet is already with us. The preliminary searching on this occasion has been greatly facilitated by photography, a resource not available on previous occasions. More than a year ago, as soon as this region of the sky had fairly emerged from the sun's rays, the campaign began at a number of observatories, in this country and Europe. The results were negative. Dr. Wolf, of Heidelberg has the honor of being the first to detect the comet on one



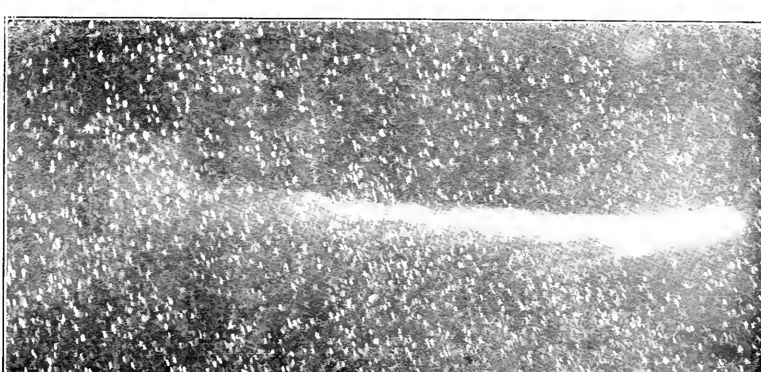
COMET MOREHOUSE, photographed at Lick Observatory, November 15, 1908.

of his plates, and is apparently the first who succeeded in photographing it. The first plate to show it was taken August 28, but he did not venture to announce it until September 11. At Greenwich two plates were taken September 9. At first nothing unusual was detected, but, after hearing of Dr. Wolf's discovery, a reexamination showed faint images on both plates. It has since been photographed and observed visually at several places. On the seventeenth the first view was obtained of it at the Flower Observatory.

The observed place differs from the computed one in right ascension 24^s, and $4'$ in declination, bringing the time of perihelion passage to April 20.0. Another result gives the time of perihelion, April 18.63.

The nearest approach to the earth will be in May 19, the distance about 14,000,000 miles. On May 18.14, Greenwich mean time, the earth and comet will be in heliocentric conjunction. It is not unlikely that on this date the earth will pass through the tail.

At the meeting of the Astronomical Society, 1908, a committee on comets was appointed, with the understanding that special attention



COMET MOREHOUSE, photographed at Lick Observatory, November 18, 1908.

should be given to this one. The plan which this committee hopes to carry out involves a constant watch of the comet, to be undertaken by a series of observers, so situated in latitude and longitude that the comet will never be lost sight of, except, of course, when it is in conjunction with the sun. A continuous series of photographs, taken in this way, on practically a uniform plan, will go far, it is hoped, toward the solution of some of the puzzling questions in connection with the physical behavior of these bodies, particularly with the rapid and peculiar change of the tail. The committee reports that good progress is being made towards carrying out their program. For the purpose of bridging the long interval between the Pacific coast and eastern Asia, Mr. Ellerman, of the Mount Wilson Observatory, expects to go to Honolulu early next spring.

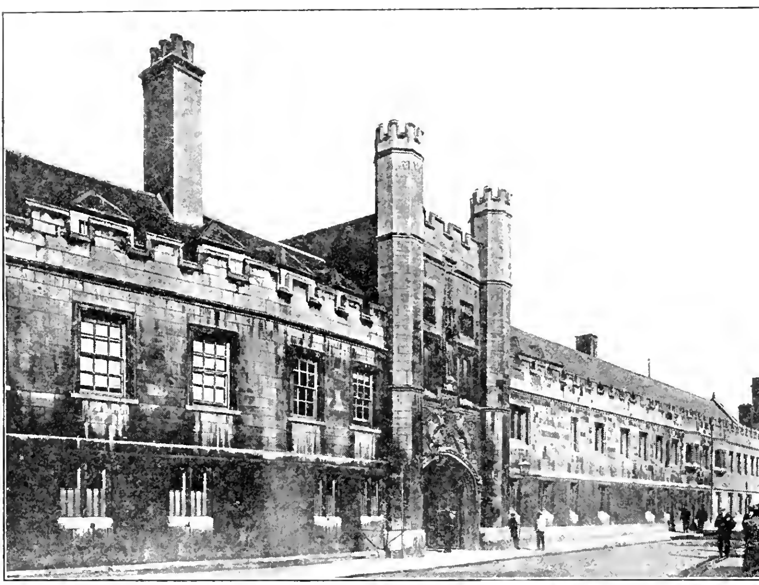
THE DARWIN CELEBRATION AT CAMBRIDGE

By Professor T. D. A. COCKERELL
UNIVERSITY OF COLORADO

THE Darwin Celebration, held by the University of Cambridge in June, was in every way a great success. So much has been printed concerning it that it hardly seems necessary in this place to go into many details; yet a brief account may be sufficiently interesting. The university did its part in the most magnificent way; indeed, so much entertainment was crowded into three days that the writer, who is not used to this sort of thing, was left rather bewildered. To see and meet some hundreds of people, any one of whom, encountered separately, would have furnished enough interest for the day, was like arriving in a strange country, where the fauna is all new and the pursuit of each rare object is interrupted by the sight of two or three others. This, however, was inevitable, and in spite of the complexity of the whole affair, there was apparently no serious hitch anywhere.

The delegates were both numerous and distinguished. According to the final list, which is understood to include only those actually present, there were twenty-five from the United States, not counting a couple of guests. Some of these were not biologists, but the list included many prominent workers, such as J. Mark Baldwin, J. Loeb, C. B. Davenport, E. L. Mark, E. B. Wilson, H. F. Osborn, W. B. Scott, C. D. Walcott, L. O. Howard, etc. Philadelphia did not send a single delegate of its own, though Professor Osborn, of New York, represented the American Philosophical Society. Harvard University and the Boston Society of Natural History had only one delegate between them. In general, however, the response from this country was highly creditable, considering the difficulty and expense involved, and the later, though in a certain sense rival, meeting at Winnipeg. Practically every country which makes any pretense to do biological work was represented, but some much better than others. Sweden sent eight delegates, including Nathorst and Arrhenius; Switzerland five, Holland six; but Norway only one, while Spain and Greece were represented solely by Englishmen. Germany, France and Austria had of course numerous and distinguished representatives. At the great reception by the chancellor of the university in the Fitzwilliam Museum, and again at the presentation of addresses, we marveled to see the splendor of the various academic gowns and hats, the men on these occasions really outshining the other sex in the conspicuousness, if not the beauty, of their attire. Two nations only, the Swiss and the Japanese, wore plain black clothes. Chancellors of English universities are usually noblemen of no particular distinction intellectually; but most fortunately and appropriately, the present official head of the University of Cambridge is Lord Rayleigh, himself a scientific worker of the highest rank. In this, and also in the person of Professor A. C. Seward, who was the official more immediately in contact with the delegates, Cambridge was happy in being represented by scientific eminence no less than academic distinction.

At Christ's College, where Darwin was in residence some eighty years ago, there was an exhibition of objects connected with his life.



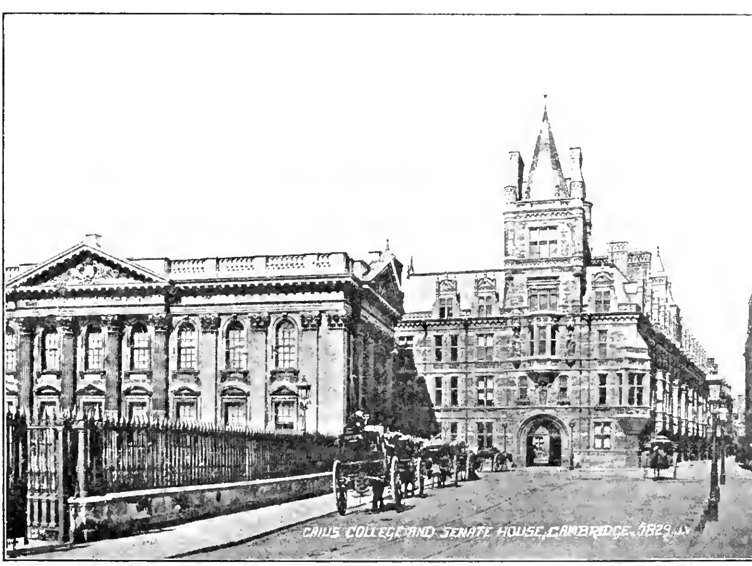
CHRIST'S COLLEGE, where Darwin attended from 1828 to 1831.

This included many manuscripts, the apparatus he used upon the voyage of the "Beagle," specimens he collected, numerous portraits, etc. There was even a series of contemporary caricatures, some good-natured, some otherwise. One represented a monkey with a face more or less like that of Darwin, sitting in a tree, reading the "Origin of Species." "Here," ran the legend, "but for natural selection and the survival of the fittest, sits Charles Darwin."

As we were looking at these things, Dr. Francis Darwin came in, leading an old man. My heart stood still for a moment to realize that this was Sir Joseph Hooker, the great botanist who was Darwin's friend and adviser more than fifty years ago. I had never expected to look upon his face, but there he was, ninety-two years old, yet quite able to enjoy the proceedings and converse with those who were presented to

FITZWILLIAM MUSEUM, where the Chancellor's reception was held.

him. In the few words I had with him, he recalled with pleasure his botanical trip to Colorado with Asa Gray. Old as he is, he has by no means given up botanical work; a paper describing new Asiatic species of *Impatiens* appeared only the other day.



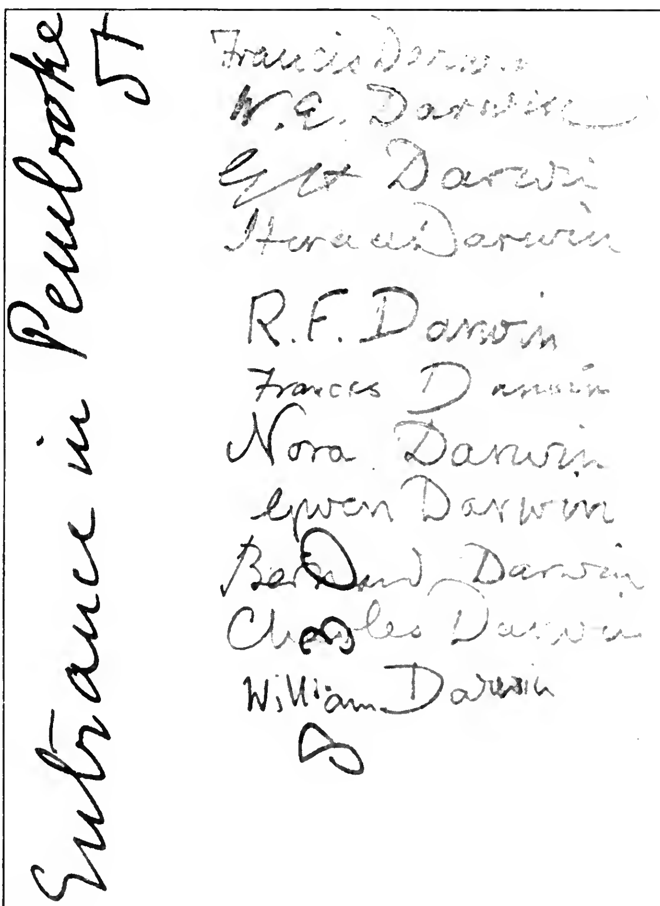
SENATE HOUSE (to the left of picture), where the addresses were presented and the honorary degrees conferred.

On the morning of June 23, in the Senate House, was the ceremony of presenting addresses. These were of course not read, but were handed to the chancellor as the names of the delegates were announced. Some, perhaps expecting to make a short speech, had no document to offer, but others had quite large books, elaborately bound and ornamented. The Japanese offerings looked particularly bulky and interesting: one could not help feeling curious as to their contents.

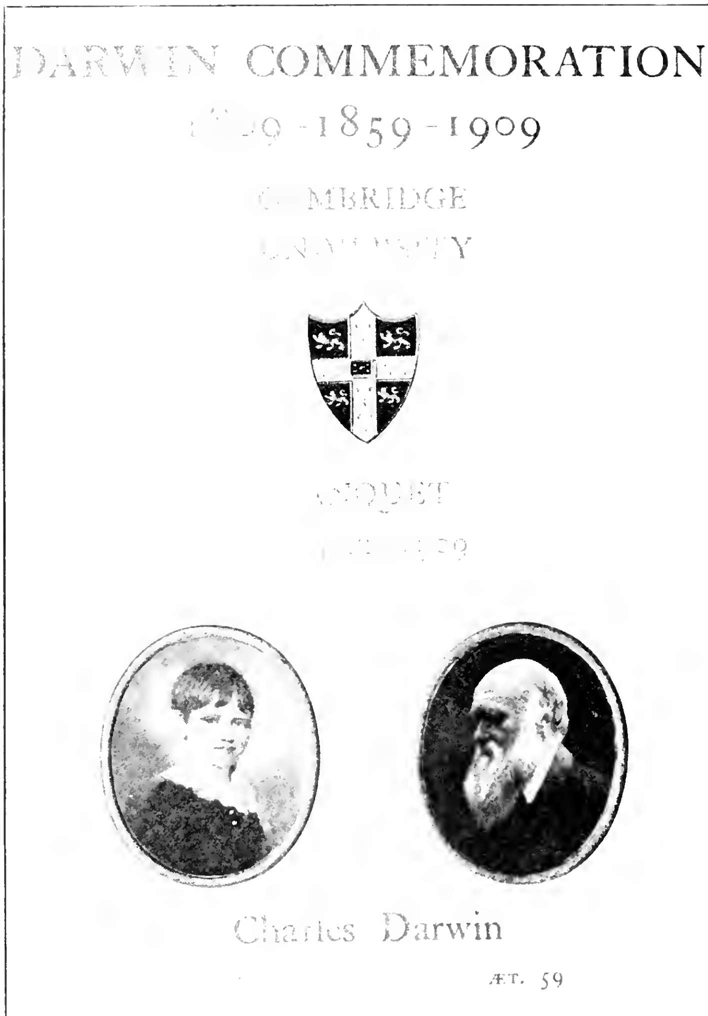
DR. FRANCIS DARWIN.

Although it was impossible to read the addresses, short speeches were made by representatives of Germany, France, the United States and Great Britain, these being Professor Oscar Hertwig, Professor Metchnikoff, Professor Osborn and Sir E. Ray Lankester respectively. The last speaker took somewhat controversial ground, maintaining the validity of the theory of the natural selection of minute and ubiquitous variations, and stating that certain views advanced by modern naturalists had been duly considered by Darwin, and for sufficient reasons set on one side. It could not be doubted, he said, that Darwin would have been deeply interested in Mendel's results, but these, although throwing light on the mechanisms concerned in hereditary transmission, were not in any way opposed to Darwin's great theoretical structure.

In the evening of the same day there was a great banquet in the new examination hall, 538 men sitting down. A few wives and daughters, as the custom is, were permitted to observe the feast from a gallery. We were furnished with printed lists, showing where everybody sat; so it was equally easy to find one's own place, and to learn the names of all one's neighbors. The menu was printed in a little booklet, on the outside of which were portraits of Darwin at the ages of seven and fifty-nine. There were blank pages, and so the books circulated round the tables, and came back full of pencilled signatures. The tables were



Signatures of members of the Darwin family present at the garden party given by them to those in attendance at the meeting. The first four are sons of Charles Darwin. The others are grandchildren. (The other writing on the card is that of Francis Darwin.)



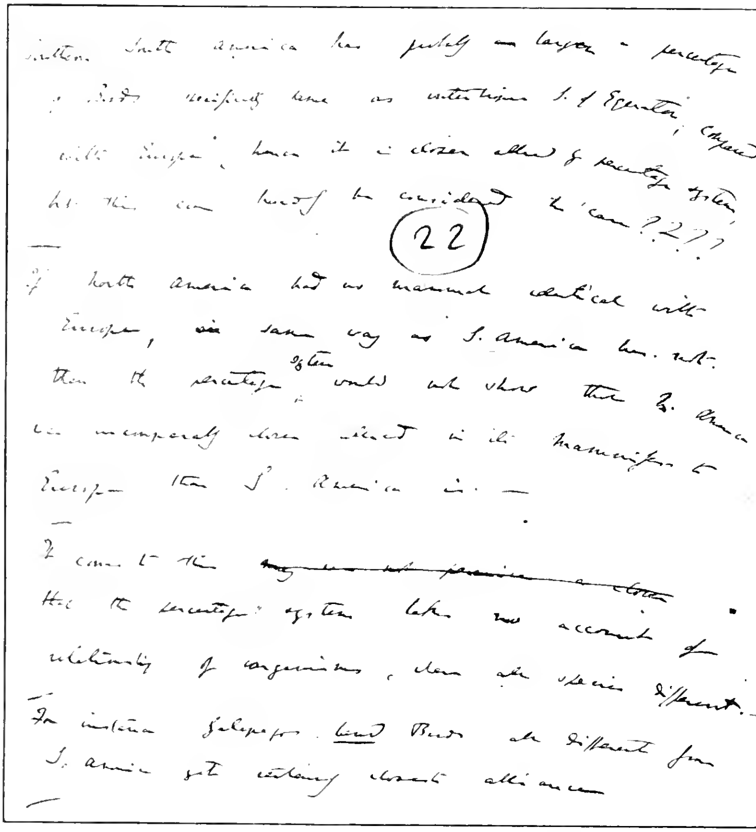
Cover of Menu Card at the Banquet.

decorated with flowers, one of which, chosen I believe at Professor Bateson's suggestion, was the Myrtaceous *Darwinia hookeriana*. As we left the table several of us took specimens to preserve in remembrance of the occasion. The speeches at the banquet were made by the Right Hon. A. J. Balfour, Mr. William Erasmus Darwin (Charles Darwin's oldest son), Dr. Arrhenius and Professor Poulton. The most interesting was naturally that of Mr. Darwin, who gave his recollections of his father. He said that in trying to think out his father's characteristics, the one which came most prominently before his mind was his abhorrence of anything approaching oppression or cruelty, and especially of slavery. Almost the only occasion when he had known him to be angry was when a subject of this sort was brought before him. He also spoke of the way in which Darwin treated his children, playing with them when they were young, and later treating them with entire trust and freedom. "It was rather touching to remember the tone of admiration and gratitude with which he acknowledged any help which they could give him." Mr. Darwin also referred to his father's modesty, and could imagine him saying, with a note of deprecation in his voice, that if there was to be a celebration, there could be no more fitting place for it than Cambridge.

At the close of the banquet the vice-chancellor got up, and spoke of the regret which all felt at the absence of Dr. Alfred Russel Wallace. It was proposed to send a telegram to him as follows: "The naturalists assembled at Cambridge for the Darwin celebration, can not forget your share in the great work which they are commemorating, and regret your inability to be present." This was endorsed by the most tremendous and unanimous applause: the vice-chancellor, speaking for himself, said he only regretted the word naturalists, as this might seem to exclude from participation such persons as himself, who, though engaged in other than biological work, were strongly in accord with the sentiment of the telegram.

Although Dr. Wallace could not prudently have endured the stress of the celebration, in which he would have been a central figure, I may be permitted to report that his health has much improved recently, and when I visited him in August he was as active minded and ready to discuss the celebration and other matters as one could have expected had he been thirty years younger. His garden is as beautiful and full of rare and interesting plants as ever, and he is collecting materials for a new book.

On the following day, June 24, the official proceedings closed with a session in the senate house, at which honorary degrees were conferred on a number of delegates, and the Rede Lecture, dealing with Darwin's contributions to geology, was delivered by Sir Archibald Geikie. On this occasion a venerable lady was observed occupying a chair, con-



PAGE OF DARWIN'S WRITING, taken from one of his note books, believed to be prior to 1859. Given to Mr. Cockerell by Dr. Francis Darwin.

"Southern South America has probably a larger percentage of birds, specifically same, as intertropic S. of equator, compared with Europe; hence it is closer allied by percentage system, but this can hardly be considered the case ? ? ? ?

"If North America had no mammal identical with Europe, same way as S. America has not, then the percentage system would not show that N. America was incomparably closer allied in its mammifers to Europe than S. America is.

"It comes to this, that the percentage system takes no account of relationship of organisms, when all species different.

"For instance Galapagos *land* birds all different from S. American. Yet certainly closest alliance."

[This is a very good example of his manner of criticizing his own methods, or methods presented to him, and considering the matters involved from every point of view.]

trary to all custom, on the floor of the senate house. It was Mrs. Huxley; to whom else could the unique distinction have been offered?

Degrees were conferred on twenty-one delegates, nearly all of them men whose names are familiar to every biologist.

Three Americans received degrees, Wilson, Loeb and Walcott. It is not customary for the university to confer degrees upon its own members, but an appropriate exception was made in favor of Francis Darwin, who, when he came forward, was received with deafening applause. With this exception, we thought de Vries was the most heartily received. The public orator, Dr. Sandys, made an appropriate speech to each one in Latin: here and there the resources of that language were somewhat taxed to find the means of describing the recipient's attainments. Was it justifiable, for example, to tell de Vries that he had worked on the *Primula vespertina?* We waited with curiosity to hear the Latin for Dr. Walcott's middle name, but it was discreetly skipped. The Rede Lecture was so appropriate and correct as to be somewhat dull, and had the misfortune to come when every one was tired out.

In the afternoon there was a garden party at Trinity College, given by the members of the Darwin family. Here were four sons and two daughters of Charles Darwin, seven grandchildren and one great-grandchild. The last mentioned, Ursula Darwin, aged ten months, daughter of Bernard Darwin, seemed to realize the dignity of her position. The high ability shown by Darwin's children is at least in some degree possessed by the third generation, as Charles Darwin, son of Sir George Darwin, was this year fourth wrangler.

After the Cambridge celebration was over, a large part of the Darwin exhibit was moved to the Natural History Museum at South Kensington, and to this was added a large collection of specimens of all sorts illustrating Darwin's theories and observations.

Some important literature was published at Cambridge in connection with the celebration. The most interesting was a small book entitled "The Foundations of the Origin of Species," being Darwin's original outline written in 1842, showing that his theory was far developed even at this early date. This work, edited by Francis Darwin, was issued in a special edition, a copy of which was presented to each of the delegates and guests.

"Darwin and Modern Science," edited by Professor Seward, is a large volume containing twenty-nine essays by prominent evolutionists. This will be familiar to students in America, and so need not be described. *Christ's College Magazine* issued a very interesting centenary number; while the "Order of Proceedings," given to each delegate, contains a sketch of Darwin's life, with admirable portraits of Darwin, Mrs. Darwin, Henslow and Hooker. There are also catalogues of the exhibits, both at Cambridge and South Kensington, both containing a quantity of interesting information.

DARWIN'S PROBABLE PLACE IN FUTURE BIOLOGY

By Professor WILLIAM E. RITTER
MARINE BIOLOGICAL STATION OF SAN DIEGO, CALIFORNIA

THIS centenary of Darwin's birth and semi-centenary of the publication of "The Origin of Species" will stimulate greater interest than ever in the illustrious naturalist's life and work. It may be hoped that the retrospective mood and generous spirit wont to pervade commemorative periods may contribute to better understanding and juster estimate of his achievements.

A strong current in biological thought is now running counter to belief in natural selection as an adequate explanation of evolution. One not at home in the biological literature of the day has but to read such general books as Morgan's "Evolution and Adaptation" and Kellogg's "Darwinism To-day," to feel the force of this current. That it is destined to wax stronger appears certain. Until its meaning is rightly seen it can but work injuriously to Darwin's fame.

Such productions as Dennert's "At the Deathbed of Darwinism" are symptomatic, though peevish, irreverent and false. They indicate disease somewhere in the body of evolutional doctrine. According to my diagnosis, the disease is seated near the vitals of the body and the name by which it is known is neo-Darwinism. It is a morbific growth and only its removal can restore the patient to health.

For a full generation, trade-marked expounders of evolution have insisted that only natural selection is true Darwinism. Powerful voices among these have said that natural selection is the full explanation of evolution, and on this basis are known as neo-Darwinians. By general assent natural selection becomes Darwinism, and by high authority Darwinism becomes neo-Darwinism. Consequently, now that neo-Darwinism has had time to come near its perdition, it not unnaturally seems to the little discerning to be dragging all evolution with it.

What did Darwin really do? Let us ask the question during this first centennial year of his birth, as though expecting the answer from the second centennial of his natal day.

To begin with, he gave us one of the noblest examples of a life devoted to search for truth that the modern world has seen. Splendid as are his works, more splendid still was the man. Every human life —every life—viewed from the standpoint of the larger, truer biology, must be seen to be greater than any of its works, for its works are but parts of the whole, and in biology, as elsewhere, a part is less than the whole. Viewed from the eminence of his own example, we shall see where he fell short and was led into error with as even an eye as we shall see what he did that must endure as long as science itself shall endure.

Directing our question to the works themselves, this is the answer that comes prompt and clear: Darwin convinced everybody competent to judge the case on its merits that new kinds of plants and animals originate naturally, not miraculously. He not only convinced experts of this truth, but he gained for it a secure place in the great, irresistible tide of common thought and life. Such was his supreme achievement. Many of his ardent disciples have not been content to accept this, for them, too modest appraisement of his work. They have said his true greatness lies not in his having established the "mere fact of evolution," but that he explained that fact—that he discovered the *how* and *why* of evolution.

The verdict of inexorable time will refuse to Darwin the glory of having really explained the origin of new species of organisms. It will allow that he did much in this direction, but not greatly more than others past and future have done and will do. Fame's recompense so far as this is concerned, Darwin will have to take share and share alike with many a fellow workman.

The question we have to consider is: Was establishing the truth of evolution an achievement of such magnitude as to enroll its accomplisher among those who belong beyond peradventure to all the ages? My answer is, yes. The reason for the answer, reduced to smallest compass, is that in doing this Darwin brought into the fold of observation and rational thought the latest and greatest ingredient of reliance on the order of nature, of belief in the infinite whole of things, of faith in the dignity and destiny of man. We here approach one of those vast realms of truth and human concern, the earliest visions of which are always gained by those geniuses known to us as prophets and poets. "Faith is the substance of things not seen," said in essence the philosopher disciple.

> O Faith, that meets ten thousand cheats
> Yet drops no jot of Faith!
> Devil and brute Thou dost transmute
> To higher, lordlier show,
> Who art in sooth that lovely Truth
> The careless angels know!

So speaks England's foremost living poet.

Darwin, more perhaps than any other single man of science, contributed to the incarnation of the truth presented here as vision; and only in so far as it is incarnated does it become daily bread for common men. Through such incarnations alone are men convinced that no lawlessness exists or ever has existed anywhere in nature, that nothing ever happens or ever has happened of such character as to wholly thwart and put to confusion the perfectly sober, the truly devout mind of man. When in the future laborious science shall have made itself and common humanity more fully and securely possessed of this truth, then will Darwin's labors stand revealed in their true grandeur.

Biologists are wont to say that evolution is now universally accepted. To see how far this is from true in a thoroughgoing sense, one has but to recall that Alfred Russel Wallace, the co-discoverer with Darwin of natural selection, denies evolution for part of man; and that an untutored, unbalanced woman, Mrs. Eddy, founds a religious cult, one cornerstone of which is an implied denial of universal evolution, which cult gets in a generation a larger following than any other started in recent times.

It is impossible to argue out the full case of the universality of organic evolution here. To do so would lead into the lowermost subtleties of technical science and logical process. A few of its surface strata must suffice for now.

Go to history to learn about the development of great ideas in physical science and you will see how, over and over again, this development has run much the same course. Three distinctly characterized stages are seen in these developments. The first is that of intuitive perception; of spontaneous, vague, fragmentary statement; of badly jumbled observation and fancy, thoughtfulness and vagary, truth and error. During this time scientific proof in the strict sense hardly appears at all.

Then comes the stage of what might be called discursive demonstration. The advance of this beyond the first is enormous in both essentials and consequences. Its greatest significance lies in the fact that the mind's ability to distinguish between *demonstrated* truth and *possible* truth has now found itself. The difference between generalizations and theories about nature that rest on objective experience, and such as may possibly be true, though they have no experiential basis, now begins to be clearly seen.

Finally comes the third stage, fundamentally differentiated from the second by the fact that the mind has at last grasped the vital meaning of quantitative values in demonstration. Evidence is now no longer *primarily* discursive and *incidentally* mathematical, but is *essentially* quantitative as well as qualitative. This quantitative stage biology is now barely on the threshold of.

It was Darwin more than any other biologist who carried the idea of evolution into the second of these three stages. Failure to grasp the full significance of this forward step must mean failure to assign to him his true place in the history of thought.

It has been pointed out time and time again that the evolutionary interpretation of living nature did not originate with Darwin; that in fact it is as old as Greek philosophy at least. And because, so the view has run, he was not a discoverer in this but only a promoter, there was not sufficient ground upon which to build a truly immortal fame. Such fame, so it has been maintained, could be reached only through a supreme original discovery. Such a discovery was natural selection, the greatness of which consisted in its being the chief if not the sole explanation of evolution. Now, however, we are coming to see that Darwin erred, and that some of his followers have erred more, as to the power of natural selection in species transformation.[1]

[1] Since the manuscript of this essay went to the publisher, the celebrations of Darwin's birth have been held at Cambridge University. On one of the occasions Sir E. Ray Lankester is reported (*Nature*, July 1) to have said:

"I think that the one thing about Charles Darwin which the large majority of British naturalists would wish to be to-day proclaimed, in the first place—with no doubtful or qualifying phrase—is that, in their judgment, after these fifty years of examination and testing, his 'theory of the origin of species by means of natural selection or the preservation of favored races in the struggle for life' remains whole and sound and convincing in spite of every attempt to upset it."

Also in the meantime the paper by Drs. Raymond Pearl and Frank M. Surface, entitled "A Biometrical Study of Egg Production in the Domestic Fowl" (Bull. 110, part 1, Bureau of Animal Industry, U. S. Dept. of Agricul.) has reached me.

From the mathematical treatment of the data collected through eight years of rigid selective breeding aimed at the improvement of egg production in chickens, the authors say: "It is shown that during the period covered by the statistics (1899–1907), which covers practically the whole period of the breeding experiment, there has been, apart from fluctuations up and down in individual years, a small but steady decrease in the mean or average annual egg production."

"The percentage of extremely high layers (producing more than 195 eggs in the pullet year) in the flock decreased during the period from 1899 to 1907. The percentage of exceptionally poor layers (producing less than 45 eggs in the pullet year) in the flock increased during the same period."

And concluding, the authors say: "It is shown that the intensity or stringency of selection became relatively greater during the progress of the experiment, though the absolute standard of selection remained the same. It is further shown that there is no evidence that the selective breeding practiced has improved the strain in respect to egg production. On the contrary, the data show that (*a*) the mean egg production has diminished during the experiment; (*b*) the variability in egg production has remained unchanged, and (*c*) in the last years of the experiment relatively slight environmental changes caused very marked changes in the flock productiveness. This is obviously inconsistent with the view that any particular type of egg production has in any way been fixed in a strain by breeding."

Reading Lankester's statement in the light of this work at the Maine Agricultural Experiment Station, and of several other late researches of like import but less demonstrative value, I am, after the manner of Abraham Lincoln, reminded of a story: A Jersey farmer on his first visit to a menagerie came upon the dromedary. After scrutinizing for a long time in amazed silence

It will require some generations yet to find out even approximately what rôle the wonderful process of struggle and selection plays in species-making. But it is becoming clear in part wherein and why Darwin and, following him, all the rest of us, have gone so wide of the mark concerning it. The subject is too vast to touch more than summarily here.

It is the very essence of the human mind to inquire after the causes of whatever happens in this world of ours. It is the essence of science to hold that these causes are natural, not supernatural. Darwin became convinced that species arise naturally while yet the philosophy of living things in which he had been nurtured contained practically nothing concerning any natural cause that could be assigned to species production. Special or supernatural causation was held as a dogma rather in default of evidence of natural causes than from proof of supernatural ones. So religious superstition and dogmatism had a free field here. Darwin's naturalist instincts said: "Since species arise naturally, natural causes sufficient therefor must exist. If they are natural they are ascertainable. I will search for them." So he set about the task with the result that all the world knows. He discovered the process called by him natural selection, and saw it to be a real cause in the generation of species.

Now comes the greatly important point. I have said Darwin carried the evolution idea into the second of three stages through which interpretations of the world usually run; the stage, namely, of qualitative, discursive demonstration. Not having yet reached the third stage, that of quantitative demonstration, he had no way of *measuring* in a mathematical sense the efficiency of natural selection. He could establish no quantitative relation between cause and effect. In fact he did not look at the problem from the quantitative standpoint in the proper sense at all. So it was almost inevitable that he should exaggerate the power of the cause he had discovered. And see the essential nature of this exaggeration: Before Darwin supernatural causes were held to account for the origin of species. But supernatural causes are always adequate, final. Supernaturalist doctrines are always absolutist doctrines. Therefore effort to make natural selection supplant supernatural causation is effort to make it, too, adequate, final. Attempt to make natural selection the sole, the complete cause of evolution, and you become a finalist, an absolutist. In a word you retain the essence of supernaturalism. Absolutist natural selectionism is only a disguised

the misshapen legs, cloven feet, pendulous lips, and curiously mounded back of the sleepy beast, the old man turned away with the remark "there ain't no such animal!"

I may be wrong as my sources of knowledge are limited, but I believe a considerable number of British naturalists will refuse to let Sir E. Ray take them with him into the class with the Jersey farmer.

form of supernaturalism. It is failure to recognize that by its essential nature physical science can deal with causation only piecemeal; that it can only grasp causes one by one and can never get them all. Absolutism is supernaturalism, and under whatever disguise is the seemingly everlasting and implacable foe, not merely of inductive science, but of rational conduct. Would that somebody might set forth this truth in words so hot that they should burn themselves ineffacably into the philosophy, the science and the daily round of common life of our and of all future generations of men! With what serenity some of our best accredited men of science are themselves striving, and advising the neophytes in science to strive, for the solution of ultimate problems! So long as this is so there is necessity for, and will surely always be, theosophy, christian science and the whole retinue of psychic absolutisms. The one brand of finality is but the counterpoise of the other.

Though still in the second stage of idea-development as regards natural selection, a few important truths about the process are being revealed to us that Darwin overlooked, or did not sufficiently emphasize. In the first place, while he soon saw that natural selection could not be the sole cause of evolution, and while he recognized it to be a cause of a general nature, he never grasped in its full meaning the truth that there are not one, nor a few, nor even many, but literally an infinite number of causes at work in the production of species.

It is curious, once one comes to think of it, that Darwin and the rest of us should have talked so long and so absorbedly about one or a few "factors" of evolution when the demands of rigorous science are that there shall be at least as many causes as there are species. Were this not so the same cause would produce different effects, and that would make biology a hocus-pocus indeed. Supernatural causes would be quite as amenable to science as such natural ones. Trouble has befallen us here from not having listened with due attention to what David Hume has told us about causes. His definition of a cause as "*an object followed by another, where, if the first had not been, the second never had existed,*" has not sunk deeply enough into our minds.

The course by which we have seemed to keep out of this limbo has been exactly one element in our discomfiture. We have said "Why, to be sure natural selection always takes variation and heredity for granted. Darwin made that clear enough." But when we make the causes of evolution our problem, why not face the music squarely? Why not make sure of the causes first and classify and name them afterwards? That is the way we proceed in systematic botany and zoology.

The truth is, natural selection itself is a great bundle of causes some of which are different in each particular case to which the bundle applies, so must be separately investigated for each particular species.

Does any *Allmacht* natural selectionist believe in his heart of hearts that even an approximate consensus of opinion among biologists will ever issue from such general discussion of the "natural selection factor" as has been carried on during the last half century? I do not think so. The most that can be said for such views is that they stimulate research. But there is an aphorism in hygiene about over stimulation that ought not to be forgotten even in science, when stimulants are advocated.

What more prophetic utterance of Darwin's can be found than that made to Wallace after he had thought over natural selection for twenty years? "My work," he said, "will not fix or settle anything."

Another important matter that Darwin never laid hold upon with sufficient grip is the great significance of struggle aside from its rôle in species production. The numberless things that struggle may accomplish short of killing somebody, did not greatly attract his attention. From his standpoint struggle short of life and death struggle seems not to have counted for much. So in his writings struggle almost always appears as "struggle for existence."

Nature is exactly a vast system of parts, each part having a nature of its own, but at the same time being dependent upon innumerable other parts.

"Natural selection" (the expression has for the most part been restricted to the living world, but there is no essential reason why it should be. It would be quite as explanatory of the process of origination, applied in the inorganic, as in the organic, realm) is that complex of operations by which natural bodies get so located that the capabilities of portions of nature for doing their part toward the sustentation of other portions are utilized to the best advantage. Otherwise stated, it is the method by which organisms become arranged in nature according to their special needs and merits. In this operation, inconvenience, injury and destruction often result. But such results are *among others,* rather than the end and aim, the total result of the process. In many cases, though by no means in all, it must play a large part in determining the characteristics, especially in late life, of individual organisms. In a word, natural selection is probably one *vera causa* in species formation. In what instances it has been thus influential, and how far this influence has gone, are matters to be ascertained, as far as possible, *in each particular case.* If Greenland has the wherewithal to support men, in however meager and cheerless a way, it is at least as reasonable to conceive Mother Nature (if one is to personify nature) as congratulating herself that she has some men able to accept such bounty and like it, as to conceive her as fiendishly gloating, or filled with impotent grief, as the case may be, over having crowded a few of her mortal beings off into so hard a quarter. Darwin did not view the process in this light very much.

Again, a phenomenon of organisms that Darwin appealed to in elaborating his hypothesis is their prodigality in generation. He almost always looked at this from the standpoint of the inevitable crowding and struggle, carnage, famine and death, that result.

But there is another direction from which this prodigality must be viewed, namely, from that of the absolute interdependence, the reciprocal relationships that prevail among organisms. Though always consumers, organisms are likewise always producers, and are producers in *larger measure than is necessary for their own perpetuity and best interests.* "Every species is its own worst enemy." There is consequently, on the whole, a surplusage of product as regards both the individual and the kind. So it comes about that the consumption that is going on is in part a consumption of surplus. Do not understand me to say that this is *the* correct view of the matter while the other is incorrect. Both views are true, and hence exclusive or unbalanced attention to either is inadequate.

Our conclusion amounts to this: Darwin's fame will grow in luster parsi passu with growing recognition that he did not discover *the* cause of evolution. This paradoxical statement ought to be viewed askance, as all paradoxes should be. But see its justification. We biologists will be able to approach the important truth of struggle in animate nature with minds open for evidence of every sort as to its meaning when we shall have broken up the habit—for habit it has surely become —of attributing to it powers and capabilities beyond those it actually has.

We turn again to the greater side of Darwin's work. Transform yourself in imagination to a state of mind that holds all the natural kinds of plants and animals by which you are daily surrounded, to be each an independent miraculous creation, to be objects, that is, concerning the origin of which no human being shall ever gain the slightest real knowledge. Thus transform yourself, and then, and only then, may you grasp the momentous significance of the extension of the domain of law in the physical world wrought by the establishment of the "mere fact" of evolution.

Since my position makes so much of the distinction between establishing the truth of evolution and discovering the adequate cause of evolution I must justify myself more fully. Let us ask how sharply Darwin himself made this distinction, and how he appraised his own work from this standpoint.

That Darwin was convinced of the *fact* of descent with modification before he had any working hypothesis as to its *cause,* in other words, that he was an evolutionist before he was a natural selectionist has not been given due weight, though perhaps is well enough known. Let us look briefly at the evidence for this statement.

The aid of Francis Darwin, his son is important here. The chief sources of information are the two editions of the "Journal of Researches," and his early notes and queries printed after his death. The first edition of the "Journal" was finished in 1838, though not published till the following year. It was in October, 1838, that he read Malthus's "Essay on Population," the incident that started him on the road to natural selection. The first edition of the "Journal" was, consequently, practically uninfluenced by his famous causal hypothesis.

Discussing this early period of his father's ideas, the son writes:

> After reading the second edition of the "Journal" (published in 1845) we find a strong sense of surprise at how far developed were his views in 1837.[2]

It will be observed that 1837 was the year before the Malthus essay was read. But the evidence from posthumous notes is more to the point. The son remarks:

> We are enabled to form an opinion on this point from the note-books in which he wrote down detached thoughts and queries.

From these I quote a few.

> Propagation explains why modern animals same type as extinct, which is law, almost proved.
>
> If we choose to let conjecture run wild, then animals, our fellow brethren in pain, disease, death, suffering and famine—our slaves in the most laborious works, our companions in our amusements—they partake (of) our origin in one common ancestor—we all may be melted together.
>
> It is a wonderful fact, horse, elephant, and mastodon, dying out about same time in such different quarters.
>
> They die, without they change, like golden pippins; it is a *generation of species* like generation of indivduals.
>
> . . . so with useless wings under elytra of beetles—born from beetles with wings, and modified; if simple creation merely, would have been without them.

So much for evidence that Darwin was an evolutionist before he was a natural selectionist or had any other causal hypothesis. As to the relative value set by him on his part in establishing the "mere fact" of evolution, and his effort to explanation of that fact, the son's testimony is again important. He writes:

> It comes out very clearly that . . . my father did not rejoice over the success of his special view of evolution, viz., that modification is mainly due to natural selection; on the contrary, he felt strongly that the really important point was that the doctrine of Descent should be accepted.[3]

Any one who knows Darwin's life-work in spirit as well as in letter will accept this statement unhesitatingly. Utterances of like import by Darwin himself are numerous. For brevity's sake I give but one. Writing to Asa Gray in 1863, he said:

> I have sometimes almost wished that Lyell had pronounced against me. When I say "me," I only mean *change of species by descent*. That seems to me the turning-point. Personally, of course, I care much about natural selec-

[2] "Letters," I., p. 367.

[3] "Letters," II., p. 163.

tion; but that seems to me utterly unimportant, compared to the question of Creation *or* Modification.[4]

How vitally it concerns both justice to Darwin and sound views of life generally that technical biology and lay understanding alike should face right in this matter!

But if natural selection is really unimportant as contrasted with evolution, how has it come to occupy so large a part of the stage? How is it that accredited expounders of evolution the world over have insisted that natural selection is the only genuine brand of Darwinism, and must be the corner-stone of Darwin's greatness?

The elements entering into the answer are manifold. Three have been indicated already. These may be summarized thus:

1. Undue weight has been attached to the fact that the idea of evolution did not *originate* with Darwin but is "old as thought itself." Absence of adequate experiential evidence for the truth of this vague idea until Darwin produced it, has not been given enough importance.

2. With the passage of time and our familiarization with the idea of evolution there has been a tendency to minimize the importance of the grip in which miraculous creation held men's minds up to the Darwinian era.

3. A wholly unwarranted importance has been attached to the part played by the natural selection hypothesis in *promoting belief* in the truth of evolution. Darwin became an evolutionist before he was a natural selectionist, and there is good reason for supposing the rest of us would have gone with him had he never thought of natural selection.

Other elements in the answer to our query must now be taken up. In the first place, Darwin himself placed a heavier burden of causal efficiency on his hypothesis than it is able to bear. This he at length acknowledged in his usual open, honest way. Perhaps his most positive statement to this effect is in "The Descent of Man."[5] It has often been quoted, though hardly enough heeded. He says:

> I now admit, after reading the essay by Nägeli on plants, and the remarks of various authors with respect to animals, more especially those recently made by Professor Broca, that in the earlier editions of my "Origin of Species" I probably attributed too much to the action of Natural Selection or the survival of the fittest. I have altered the fifth edition of the Origin so as to confine my remarks to adaptive changes in structure. I had not formerly sufficiently considered the existence of many structures which appear to be, as far as we can judge, neither beneficial nor injurious; and this I believe to be one of the greatest oversights as yet detected in my work.

But the mischief had been done, and Darwin's inability to remedy it troubled him not a little.

Let us see if there is anything either in his argument itself, or in his

[4] "Letters," II., p. 163.

[5] I., p. 146.

mode of handling it, that set the tide of his influence wrong beyond his power of righting.

For one thing, Darwin was unfortunate in the title chosen for his foundation book. "The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life" is the title in full. A little reflection discovers ambiguity in this. Is the author concerned primarily with the *origin of species* or with *a particular way* of accounting for their origin? One piece of internal evidence of a general character is to the effect that the second alternative is the true one. The explanatory hypothesis is treated first and occupies fully half the work, while the observed proofs of origin by natural modification are given second place. Why did not Darwin present his proofs of evolution first and his hypothesis second, thus making his title and order of treatment correspond? The fact is he wavered as to where the emphasis should be laid touching the relative importance of the two objects he tells us he had in view in writing the "Origin." This wavering he never to the end of his life was able to fully correct.

We can point out specifically how this equivocal meaning of the title has operated to make Darwin a natural selectionist in a sense that he himself resisted. One biologist, a particularly strong pro-natural selectionist, has written:

> This title is of interest, as has been pointed out by Professor E. Ray Lankester, in relation to the controversy upon the exact meaning of the word "Darwinism." Some writers have argued that the term "Darwinism" includes the whole of the causes of evolution accepted by Darwin—the supposed inherited effects of use and disuse and the direct influence of environment, which find a subordinate place in the "Origin," as well as natural selection, *which is the real subject of the book and which is fully defined in the title.* It would seem appropriate to use the term "Darwinism" as Wallace uses it, to indicate the causes of evolution which were suggested by Darwin himself, excluding those supposed causes which had been previously brought forward by earlier writers, and especially by Lamarck.[6] (Italics mine.)

The large conception that "Darwinism" might be "evolutionism" has no place in this author's mind, so it would seem from this statement. Darwinism according to such a view must have sole reference to certain specified causes of evolution instead of evolution itself through any and all causes that may be behind it. The power of mental bias to lead men unconsciously wrong is not often more strikingly illustrated than in this; for here it goes to the extent of making professed followers and admirers of Darwin do him grave injustice. What meaning can Darwinians who thus circumscribe "Darwinism" put into such of their prophet's language as this?

> I may be permitted to say, as some excuse, that I had two distinct objects in view, firstly, to show that species had not been separately created, and secondly, that natural selection had been the chief agent of change, though

[6] Poulton, "Charles Darwin," p. 99.

largely aided by the inherited effects of habit, and slightly by the direct action of the surrounding conditions. . . . Some of those who admit the principle of evolution, but reject natural selection, seem to forget . . . that I had the above two objects in view; hence if I have erred in *giving natural selection great power, which I am far from admitting*, or in having exaggerated its power, which is in itself probable, I have at least, as I hope, done good service in aiding to overthrow the dogma of separate creations.[7] (Italics mine.)

The kernel of the bias that has done so much harm is not difficult to find. Pursuit of the question as to which one of several supposed causes of evolution is the *whole cause*, has been so ardent that the extremists among the upholders of the particular cause discovered by Darwin, have been blinded to what he himself has declared to have been the first of two objects in writing the "Origin of Species."

The question of what "Darwinism proper" shall be is relatively insignificant. If one's linguistic taste favors making Darwinism apply to the particular causal principle discovered by Darwin, well and good. Then Darwinism is of no great moment, relatively. On the other hand, if one's taste is more catholic, he will prefer to have Darwinism apply to the really great thing that Darwin did, and the term will mean organic evolution, the unfailing reign of law in the origination of living beings, one of the greatest truths of nature, when its establishment shall be complete, that the mind of man has yet possessed itself of.

While Darwin himself was not without responsibility for this narrowing, withering view of what "Darwinism really is," by far the greater responsibility rests upon two other men, namely, Alfred Russel Wallace and August Weismann. These two, each truly eminent in his own right, have been looked upon by a too little-discerning biological period as those upon whom the "mantle of Darwin" has fallen. Let us away once and for all with this false and flimsy notion about any man's mantle falling upon some other man! Every man's mantle, be he great or small, is his own alone, and goes to his grave with him, or ought to be allowed to. What kind of self-esteem is that which wants the distinction of wearing another's clothes? Mr. Wallace has certain interesting biological ideas and so has Professor Weismann. The ideas of both have much in common with ideas held by Darwin. Both men have worked out their ideas as best they could, greatly influenced no doubt by the methods and writings of Darwin. But Mr. Wallace's ideas are his, Professor Weismann's are his and Mr. Darwin's were, and shall be, his. Let us take them all and estimate them on this basis. In so far as all three or any two sets are alike, let us recognize the resemblance; but in so far as they differ, let us see the differences also.

The relation of Weismann's doctrines to Darwin's I merely touch upon here. It should be recalled that Weismann is a neo-Darwinian

[7] "Descent," I., p. 147.

of the Neodarwinians so far as natural selection goes. By far the most important nexus between Darwin and Weismann, when it comes to the deeper reaches of biological theory, is through Darwin's pangenesis hypothesis and Weismann's germ-plasm-determinant doctrine. This I treat at length elsewhere. It may be left to one side here because of its relative unimportance as touching Darwin's work proper, though of fundamental importance to an exhaustive discussion of the present status of biological philosophy.

Mr. Wallace's ungrudging recognition of Darwin's towering genius as compared with his own is one of the particularly bright and inspiriting examples of what personal relationship between men may be. And to Mr. Wallace is the greater honor because his was the lesser intellectual endowment and achievement.

Turning from Mr. Wallace's beautifully deferential attitude toward his friend, to the facts upon which he based this, what do we find?

We have already seen that Darwin had convinced himself of the truth of descent with modification before he thought of natural selection, and that it was the essay of Malthus on population that gave him the idea of struggle and survival. On December 22, 1857, he said in a letter to Mr. Wallace:

> My work at which I have now been at work more or less for twenty years, *will not fix or settle anything;* but I hope it will aid by giving a large collection of facts, with one definite end.[8] (Italics mine.)

It should be remembered that Malthus's essay was read in 1837.

The circumstances under which Mr. Wallace became the co-propounder of evolution and co-discoverer of natural selection are told by himself. He says:

> After writing the preceding paper (On the Law which has Regulated the Introduction of New Species) the question of *how* changes in species could have been brought about was rarely out of my mind, but no satisfactory conclusion was reached till February, 1858. At that time I was suffering from a rather severe attack of intermittent fever at Ternate in the Moluccas, and one day, while lying on my bed during the cold fit, wrapped in blankets, though the thermometer was 88° Fahrenheit, the problem again presented itself to me, and something led me to think of the "positive checks" described by Malthus in his "Essay on Population," a work I had read several years before, and which had made a deep and permanent impression on my mind. These checks—war, disease, famine and the like—must, it occurred to me, act on animals as well as man. Then I thought of the enormously rapid multiplication of animals, causing these checks to be much more effective in them than in the case of man; and while pondering vaguely upon this fact there suddenly flashed upon me the *idea* of the survival of the fittest—that the individuals removed by these checks must be on the whole inferior to those that survived. In the two hours that elapsed before my ague fit was over, I had thought out almost the whole of the theory, and the same evening I sketched the draft of my paper, and in the two succeeding evenings wrote it out in full, and sent it by the next post to Mr. Darwin.

[8] "Letters," I., p. 467.

Then Mr. Wallace goes on to speak of the letter from Mr. Darwin containing the quotation given above, and says:

> The words I have italicised (the same italicized in my quotation) and the whole tone of his letters, led me to conclude that he had arrived at no definite view as to the origin of species, and I fully anticipated that my theory would be new to him, because it seemed to me to settle a great deal.[9]

There you have the difference between the two men's minds, at least in their attitude toward survival of the fittest, put in a nut-shell by Wallace himself. What seemed to him from two days' reflection able "to settle a great deal," seemed to Darwin after twenty years' reflection, not able to "fix or settle anything."

Another highly instructive exemplification of this difference is furnished by a discussion between the two on natural selection and sterility. This is given us in "More Letters of Charles Darwin," letters 209–216, the correspondence having been carried on in 1868. Wallace presents (letter 211) "what appears to me a demonstration on your own principles, that natural selection could produce sterility of hybrids." Darwin's general position on the point is well indicated in letter 213. He says:

> I have been considering the terrible problem. Let me first say that no man could have more earnestly wished for the success of Natural Selection in regard to sterility than I did, and when I considered a general statement (as in your last note) I always felt sure it could be worked out, but always failed in detail. The cause being, as I believe, that Natural Selection can not effect what is not good for the individual, including in this term a social community.

Although Darwin was sure there was something wrong in Wallace's argument, and was not budged an inch by it, he seems not to have recognized its logical preposterousness. He did not explicitly point out to Mr. Wallace that since over-productivity, or geometrical increase, is one of the fundamental presuppositions of natural selection, to suppose natural selection could produce sterility would make it capable of negativing one of its own presuppositions. Stating the matter figuratively, Darwin saw no logical difficulty in the supposition that natural selection might commit suicide. With him it was merely a question of whether it does this or not, and he could not make out from the evidence that it does. But he did not see that Wallace's argument carried out consistently would not only enable natural selection to commit suicide, but in reality would make it able to prevent itself from coming into existence.

The scope and balance of Darwin's mind are seen nowhere to better advantage than in his efforts to prevent his own causal hypothesis from going beyond bounds. Nevertheless the true inwardness of the difference between himself and those who later were to produce the so-called neo-Darwinian school, the school founded on the omnipotence of

[9] Poulton, "Darwinism," p. 88.

natural selection, is nowhere better seen than in his position relative to the application of natural selection to man. While one of Darwin's greatest achievements was his proximate demonstration that man is not a being wholly cut off by his origin from the rest of nature, and while he saw prophetically rather than rigorously, that the final test and goal of all science, evolutional biology with the rest, must be its ability to help man to understand and guide himself in the full scope of his nature, he did not see, at any rate clearly, what must be the inevitable outcome of trying to make struggle and selection explain fully the evolutionary process.

He failed to see the deeper meaning of the circumstance that it must work toward making the brightness and beauty of the living world appear as though seen through a somber-colored distorting-surfaced, glass screen.

He did not see that it must foster a sort of egoism that would make the golden rule as dead on the statute books of human relationship as a mastodon in a Siberian ice-bed.[10]

The golden rule in its ethical significance does not now concern me. It is as a biological phenomenon that I am looking at it. *Living* organisms, and each one in its *totality* or so much of its totality as I can reach, are my biological data. Should I study the honey bee or the American beaver I should be adjudged an unsound biologist were I to draw sweeping conclusions about them, in which little or no cognizance should be taken of some of their most prominent traits, as for instance, of their community habits. Or still more should I be adjudged unsound were I to enter upon the study with already-fixed conceptions about instincts, let us say, that would lead me to overlook, or have to explain away, certain prominent traits.

The golden-rule trait is one that man actually presents no less surely than is the iron-rule trait. There it is, written into his history and stamped upon his behavior almost everywhere.

It is exactly the office of biology as it undertakes the study of man to frame its explanatory theories large enough to take in whatever it finds characteristic of him. If man really is a part of nature, as an unflinching evolution seems to say he is; and if natural causation really can be relied upon throughout the world, then there must be something wrong with a causal theory of evolution that not only makes no provision for, but actually negates, some of the most fundamental qualities that man's nature presents. Let us not fail to see that Huxley's trouble over the conflict between the cosmic and ethical processes involves not merely natural selection, but goes to the vitals of evolution and natural law itself. This is a mighty question.

He did not perceive that it would enable pride, avarice, cruelty and injustice to draw the sacred mantle of science about them.

Read the encyclopædias of biography from A to Z and you will find portrayed there no warmer hearted, more genuine, generous souled, open minded man than was Charles Darwin. But when you read his life for aid in understanding his work, do not fail to read the whole of

[10] My point here could hardly be misunderstood were it possible to read these statements properly set in the general discussion to which they belong.

it. He was a nature-loving, country-dwelling English gentleman of the best type—not a gentleman in the political and social sense, but in the manly sense. Further, he was to the very marrow of his bones an English naturalist as well as an English gentleman. He inherited the instincts of the naturalist and likewise the worldly wherewithal that enabled him to follow his bent without let or hindrance. So it was that the naturalist's standpoint was literally both first and second nature to him. Rarely is it the fortune of a scientific career to run through from beginning to end so strictly along the lines of instinctive choice and least resistance, as Darwin's ran. It is not too much to say that Darwin knew nothing of that sort of discipline that comes from compelling one's self to do things which initially he does not like. It is well known that even in biology, the realm of science to which by nature he so clearly belonged, he as a youth dodged those of its disciplines that he did not like, however basal they might be. For example, when trying himself out as a medical student, he did not like anatomy, so anatomy he did not study in any serious way.

Comprehensive and well balanced as became his scientific efforts and knowledge, these were always so within the bounds of predilection rather than of logical and philosophical compulsion. This I believe to be the weightiest of several reasons why Darwin saw so imperfectly the direction in which the struggle-selection principle must lead those who misunderstand and exaggerate it.

Had he grounded himself in mathematics, psychology and ethics, not necessarily as fully but as sympathetically as he did in natural history, he might have anticipated, at least in outline, what has actually happened. He might have foreseen the fate of his friend Huxley, who found himself driven to attempt the rehabilitation under an altered nomenclature of the old, old conception of the world as a battle ground, with man the chief prize, where an infinite, beneficent God is field-marshal on one side, and an infinite, malevolent devil leads the hosts on the other; and of his friend Wallace who landed finally in the shadow-realms of disembodied spirits and ghosts; and of such strong-timbered, though loosely-framed minds as that of Friedrich Nietzsche,[11] for whom

[11] This does not necessarily mean that I take sides in the controversy as to the extent of Darwin's direct influence on Nietzsche. From my standpoint it matters little, if it be true, that Nietzsche never understood natural selection. The case has to be viewed in a much broader way. Nietzsche's ethics is one precipitate, so to speak, out of the same solution that Darwin's famous hypothesis came from. This solution filled the atmosphere of the whole western world for at least a half century before these two precipitates were thrown down. The essence of this solution was not so much an exaggerated individualism as it was an individualism *waging its warfare within itself, i. e.,* with no supreme outside judge and power to guide and check, to approve fair fighting and punish unfair, and to direct the whole to some glorious end. Whatever Nietzsche's

the way of a self-annihilating individualism and utilitarianism, could hardly be other than the way to the mad-house; and finally of numberless mediumly endowed souls in whom such doctrines could not fail to beget a pusillanimous indifferentism toward all human weal excepting such as can be seen to be directly advantageous to one's own weal.

We may be sure that the volumes of social and ethical doctrine that have been written from, not the Darwinian, but the neo-Darwinian, standpoint, and the still larger volumes of unethical practise that have consciously and unconsciously been instigated and justified from the same standpoint, would have brought inexpressible anguish to the noble spirit of Charles Darwin, could he but have seen them in full flower and fruit.

My conclusion then as to Darwin's probable place in future biology may be summed up thus: Darwin has been frequently called the Newton of Biology. Not so! Newton discovered a great mathematical, that is, exactly expressible law of nature. Darwin found no such law. For its real Newton, biology will probably have to wait another fifty years at least. When he appears he will be a mathematical biologist.

If the counterpart of Darwin in inorganic science is to be sought, Copernicus rather than Newton would be the man. The revolution in men's attitude toward nature wrought by each of these was much the same, both in kind and magnitude, and both men's names will grow brighter on the pages of history so long as mortals are stirred by the beauty of orderliness and law, and by what is lovely in form and color and motion; so long as they have feelings of gratitude and obligation for what has gone to the making of themselves and the things they enjoy, what they are; and so long as their faith in the Infinite Whole of Things abides and waxes stronger.

"Super-man" may be, this much is certain: It, or he, is man-, not God-conceived, and is to be man-, not God-created.

Nietzsche's enterprise made it necessary for him to kill God thoroughly. While even the suggestion of such a thing was abhorrent to Darwin, it is nevertheless true that among the most trusted weapons used by Nietzsche in his killing, were the very ones of individualism and conflict used by Darwin, and it matters not so far as my main point is concerned, whether Nietzsche got his instruments from Darwin or from the same factory that Darwin's came from.

THE EVOLUTION OF MAN AND ITS CONTROL[1]

By ROSWELL H. JOHNSON

An Introduction to Eugenics

THERE are two very different ways in which the progress of man may take place, and great error and confusion have arisen from the failure to discriminate them. The one consists of a change in the intrinsic qualities of men as they are born from generation to generation. This is biological progress or evolution. The other process, to some extent independent of the individual, is a change in the things men have, know, and do, and may be called social progress. If, we compare the best tribal stocks of the present with those of two thousand years ago, we find but little innate gain, but the social progress in that time has been astounding.

The comparative slowness of biological progress as contrasted with that of civilization is to be expected when we consider the power of the latter to accumulate and hand down the results of every advance, while in biological evolution there is a constant intervention of heredity on the conservative side. Although the greatest human progress thus far has consequently been wrought in the social rather than the biological field, there have always, since as early as Plato, been patriots and philosophers who aimed to uplift not only the environment of the race, but its inborn character as well. The question is—is it possible to secure for the new-born babies of the future an innate moral, mental and physical nature superior to that of the present generation?

It is as an answer to this question that the new science of eugenics is being mapped out, its field being the study of the biological factors affecting human evolution, with their application to the breeding of a better race of men. Though it deals chiefly with the laws of heredity it must consider also problems of environment and nurture, as will be seen later on.

The chief reason for the impracticability of most plans of race improvement until recent times has been that their advocates failed to regard the complex relations which social and biological progress must always bear to one another. Plato, for example, in his anxiety to allow none but superior children to be born into his Republic, was willing to give up such a valuable institution for social progress as the family. We must aim, therefore, to bring into harmony, as far as possible, the

[1] The author is indebted to Miss Jessie Wallace Hughan for assistance in preparing this manuscript for the press.

two great modes of progress, choosing such methods of biological improvement as may help rather than hinder civilization, and, where this can not be done, judging carefully in any specific case between social and biological values.

That the modern preachers of eugenics are quick to recognize their unity of interest with the workers for social and institutional progress is shown by Dr. Francis Galton:

> Eugenic belief extends the function of philanthropy to future generations. It renders its actions more prevailing than hitherto by dealing with families and societies in their entirety, and it enforces the importance of the marriage covenant by directing serious attention to the probable quality of future offspring. It strongly forbids all forms of sentimental charity that are harmful to the race, while it greatly seeks opportunity for acts of personal kindness as some equivalent to the loss of what it forbids. It brings the tie of kinship into prominence and strongly encourages love in family and race. In brief, eugenics is a virile creed, full of hope, and appealing to many of the noblest feelings of our nature.

Chapter I. *The Method of Evolution*

Before coming to a decision upon radical schemes for race improvement, it is of vital necessity that we consider first the factors of human evolution, and second the possibility and means of their control, with the relations of these means to progress that is social rather than biological. We must ascertain from biology those factors which are actively producing change in other organisms, and then determine to what extent they are potent in human beings as well.

Natural selection, though a dominating factor, is not the sole one in evolution, *determinate variation* and the *direct influence of environment* being also of great importance. Of these two the former is non-controllable, and affects eugenics only in so far as its presence may make our work easier or more difficult; so we may confine our interest at present to natural selection and the direct influence of environment.

The latter factor brings us at once to the time-honored controversy over the "inheritance of acquired characteristics." The dispute seems to have ended in a drawn battle, one party having established its claim that modifications of the body are not inherited in kind, while the other has proved that the environment is able to originate certain inheritable characteristics, provided only the action in question is able to penetrate to the germ cells themselves. This modification of the germ cells caused by environment is called *blastophthory* by Forel, and is thus described (p. 35, "The Sexual Question"):

> I mean by blastophthory or deterioration of the germ that which can also be called false heredity, that is, the consequence of every direct pathogenic or disturbing action, in particular, of certain intoxicants, upon the germ-cells, of which the hereditary determinants are also changed.

An illustration of this direct influence is afforded by the experiments of Professor Wm. Tower, at the University of Chicago. It was found that potato beetles subjected to hot, dry conditions were made lighter in color and that part of their progeny raised under normal environment retained this characteristic.

Mere modifications of muscle or brain, accordingly, as in the trained mind of a savant or the brawny arms of a blacksmith, are not inheritable, but such is not necessarily the case with a quality like smallness of stature due to under-feeding, an influence affecting the mechanism of inheritance itself.

By far the best known of the factors working upon the lower animals is natural selection; that evolution which takes place when, without conscious selective action, one generation has been contributed by a part of the previous one differing from the non-contributing portion, as when wild deer of one generation are descended only from those previously existing deer who have been able to live to maturity because of their superior swiftness. Variations are thus seized upon by natural selection and perpetuated by heredity. The evidence of such a selection in the case of man has been tangibly presented by Sir Francis Galton, Karl Pearson and others working with them.

Natural selection stands opposed to artificial selection, that which is accomplished by conscious effort, such as Burbank's famous work in the production of improved varieties of fruit. It consists of two main processes, each containing several subdivisions, and a common error has been to confine the term *natural selection* to the first of these main processes, which may be called lethal selection. The case of the deer mentioned above is an instance of lethal selection—that which results from the *death* of some individuals before reproduction is completed.

The second process of natural selection, of perhaps even more importance at present in man, is *reproductive selection,* the result, not of premature death, but of a differential number of progeny. This may sometimes counterbalance lethal selection, as in the survival of some of the lower species of animals, whose marvelous reproductive ability preserves them in the face of a very high death rate.

When the cause of the absence of progeny is a failure in the individual to mate at the proper time, it is called *sexual selection,* but if, for other causes than success in mating, the number of offspring varies among individuals, *fecundal selection* results.

Sustentative selection, the type of natural selection most commonly recognized, comes from a pressure upon the means of subsistence by proportionately excessive numbers, such as that which sent the successive waves of Aryan migration over Europe. A *non-sustentative* form of natural selection takes place from the destruction of the individual by some adverse feature of the environment, such as excessive cold, bacteria or some bodily deficiency, and is independent of mere food-supply. As Plymouth Harbor, for example, kept growing gradually muddier, the broad crabs were subjected to a heavier death rate, so that the general type of crab in the harbor became comparatively narrow. Selection of this sort may depend on some physical advantage, or sometimes on differences in mentality, as in the survival of races of mankind intelligent enough to overcome a hostile environment—to escape cold by the use of fire or smallpox by the invention of vaccination.

The classification of the modes of natural selection is shown by the following diagram:

Natural selection	Lethal	Sustentative
		Non-sustentative
	Reproductive	Sexual
		Fecundal

An indirect form of sustentative selection may be said to exist when malnutrition has the effect of destroying resistance to an adverse environment, as in the case of tuberculosis. Both modes of lethal selection, moreover, may act upon groups, as well as upon single individuals. Though group selection is best typified by a war between two tribes, such cases as the decline of the Alaskan aborigines illustrate its occurrence without combat.

Chapter II. *Artificial Selection*

Throughout the measureless ages before man natural selection worked without let or hindrance.

At last, however, the life of the tree-dwellers evolved that ape-like ancestor of ours, the tailless arboreal mammal with four hands. The hand, originally an adaptation for the purpose of grasping limbs, gradually became fitted for grasping other things than limbs, that is, for "handling" tools. Naturally such an organ made slight variations of brain structure of great advantage, for a better way of handling objects in hunting and fighting might lead to survival, not only of the individual, but also of the tribe. The resulting complexity of brain development brought with it the capacity to think, to hand on thoughts from generation to generation by oral and written tradition, and thus to formulate ideas into science.

Here, however, came a marvelous change in the methods of evolution. Although our primitive ancestors had been, up to this time, like the lower animals, a mere bagatelle under the influences of environment and heredity, thinking man now acquired the power of reflection, and even of discovering and criticizing the laws of evolution themselves. In certain cases we are able to register our dissatisfaction with the course which nature is leading us, and to make definite attempts at turning this course from the merely fittest to our notions of the best. We have learned that the forces at work changing our species are themselves partially under our control, and that, if, like the powers of the physical world, they may at last be harnessed to the service of reasonable man, the future is largely in our hands.

Man early utilized the forces of heredity in the culture of plants and animals, and his achievements in this direction, from the prehistoric domestication of animals to the great successes of our modern breeders, have been amazing. It is natural, therefore, that philosophers should have begun their eugenic activity by recommending the direct control of heredity by thoroughgoing artificial selection, and from Plato onward we have had various projects for the deliberate improving of the human stock. Such modifications admit of accomplishment in two ways, by the prevention of breeding from the worst and by very extensive breeding from the best.

Little can be hoped from this latter method in connection with making superior women the ancestresses of the race, for at best a mother can bear and do justice to but few children. Accordingly, some polygynous device must needs be resorted to in order to utilize fully the men of best type as fathers. Such suggestions vary from free love or crude polygamy, involving as it does greater parenthood for the economically successful, to Noyes's "stirpiculture," as practised in the Oneida community, whereby a few picked men were the authorized fathers of all the children, or to G. Bernard Shaw's licensing of supermen for extra-matrimonial relations. The directness and sensational character of these projects has given them, to be sure, great notoriety, and it is perhaps to be regretted that the Oneida experiment, at least, was not allowed to work itself out as an attempt at artificial selection for the light it would have thrown on the subject.

Here, however, we must bear in mind that we are seeking social, as well as biological progress. No wholesale plan can ever prevail which denies to the majority the right of parenthood, and the family, notwithstanding the aspersions of Mr. Shaw and others, has proved too valuable a social institution to be lightly discarded. Moreover, from the viewpoint of heredity alone, any of these schemes might tend to perpetuate instincts generally considered undesirable, by breeding most extensively from those who voluntarily embraced polygynous relations.

We must have far more light from investigation and experiment before such plans as the foregoing can be profitably adjudged, and, as they are obviously out of immediate consideration, their discussion does little more than arouse prejudice and postpone real progress.

We reach solid ground for the first time when we consider the prevention of breeding from the very worst. A definite beginning of such prevention has already been made in our prisons and institutions of public charity, and the only difference of opinion can be as to just what class of inferior men and women should be cut off altogether from parenthood, and as to what methods can be employed that will not endanger social progress.

Although the limits of this class must always vary with the advance of criminology and pathology, we can almost all agree as to the inclusion of certain individuals. Among the mentally unfit for parentage may be counted the insane, the feeble-minded, and the epileptic, leaving to the future the question of "backward" children. While the criminal classes mark roughly the boundaries of the morally unfit, political offenders must of course be excluded from the category, and we must not forget that many of our criminals are made, not born, and may represent valuable variations from type. Our laws in general would better follow the tendency seen in Ferri's positive school of criminology, and determine the treatment from the nature of the criminal rather than of the crime. Those malefactors who show no improvement under reformatory influences or the indeterminate sentence may surely be included, as also all those whose record displays an excessively anti-social nature, from the murderer to the habitual drunkard.

Any attempt to weed out the physically unfit must proceed still more carefully, for we are not yet competent to point out just who come under this classification. We may be tolerably sure as to those afflicted with syphilis and with congenital defects of the senses, among the latter being reckoned many cases of deafness. Schuster's[2] investigations give the high rate of .54 for parental and .73 for fraternal inheritance in deafmutism, and other statistics give the percentage of deaf among the children of deaf parents as eight per cent. as compared with one tenth per cent. in the population as a whole. As to all others action should be very conservative, since natural selection may be trusted to take care of mere weakness and susceptibility to special bacterial diseases. In any case, it is a long and tedious process to weed out a disease susceptibility from man. A certain consumptive stock, for example, may happen to be of high social value, and there is better prospect of conquering tuberculosis by medical means than by the severe processes of artificial selection.

The prohibition of marriage within certain degrees of consanguinity would doubtless assist these preventive measures materially and here a beginning was made many ages ago. As far back as the Mosaic law, we see certain degrees of consanguinity proscribed under severe penalties, and this eugenic regulation forms a part of every civilized code.

As the list of unfit must vary considerably with scientific advance, it is best for the present to agree on the obvious defectives just mentioned, to study human heredity with redoubled vigor, and to consider carefully the means by which this prevention of parenthood may be brought about.

[2] K. Pearson, "Scope and Importance to the State of the Science of National Eugenics," p. 28.

The choice of methods must be governed by considerations of social welfare and individual happiness, and means must always vary with persons and circumstances.

The most radical remedy of all is proposed by McKim in his scheme of a lethal chamber. Since our one relic of the death penalty, however, in the case of murderers, is falling into disuse on excellent grounds, it is undesirable to suggest any such violent method of assisting evolution. Public opinion would be equally opposed to Plato's scheme of surreptitiously disposing of babies that failed to come up to specifications. Respect for human life as such has been established by society at too much sacrifice to admit of its being recklessly imperilled.

Castration is too severe a penalty for general application, though perhaps advisable in cases of rape, but Rentoul's operation, a simple process by which sexuality is retained but sterility produced, has much in its favor. In Indiana such a method has been enacted, but in general it could not fail to meet with great opposition among voters and legislators.

The most practical method under present conditions seems to be compulsory segregation, already followed in prisons and reformatories and needing only to be extended and modified. Since the confinement of the proscribed classes ought to be made terminable only by old age or voluntary sterilization, humanity dictates that in many cases celibate isolation be substituted for imprisonment. It is advisable that islands be used for one-sex colonies, thus interfering less with the happiness and health of the defective persons, allowing some degree of self-support, and making it possible for ability in special directions to manifest itself. The great advantage of this method is that, while combining effective eugenics with far greater humanity than the present prison system, it would remove the more powerful influences for evil permanently from the environment of the next generation, thus accelerating social progress to a marvelous extent.

In the case of certain congenital defectives such as the deaf, it might be sufficient to prohibit marriage with blood-relations or with other similarly afflicted persons. Some of the congenitally blind, deaf and epileptic might even be allowed their liberty under parole to refrain from reproduction or under a suspended sentence of celibate isolation.

Chapter III. *The Direct Action of the Environment*

Our review of the projects of artificial selection has shown that deliberate breeding from the best is for the present impossible, as well as opposed to ethical and social progress, but that the prevention of breeding from the worst is both practicable and in accordance with the best present interest of society.

The direct action of the environment has been mentioned as, aside from natural selection and the non-controllable determinate variation, the most important factor in evolution. Since characteristics resulting from outside forces can be inherited in cases where the germ plasm itself is affected, it follows that much can be accomplished eugenically by public action with a view to environmental improvement. It is quite probable, for example, that exposure to cold, underfeeding and impure air may cause inheritable defects, judging from the before-mentioned experiments of Professor Tower on potato-beetles and the observations of Bezzola.

The seriousness of the environmental influence, furthermore, arises largely from the fact that it is not confined to one generation, but may, after once becoming established in the germ plasm of an individual, be transmitted to many generations by the ordinary processes of heredity.

As it is precisely upon combating such evils as these causes of germ deterioration that the *social* reformers place their emphasis, we have here an opportunity for the eugenicist to lend his support to those who would improve the race by modifying its environment for the better. While we can not trace accurately the germinal effects of the windowless tenement, the unventilated street-car and the factory where women work all day in poisonous fumes, yet the indications are sufficient to range the eugenicist on the side of those who demand pure air by building and factory laws.

Excessive fatigue as a probable cause of defective offspring brings us again into the domain of labor legislation, for children stunting themselves in factories and railroad men compelled to run their trains for an excessive number of hours are merely glaring instances of what may prove a most spendthrift drain upon the future in the interest of our breathless industrialism.

Since scurvy and rickets by improper food, and gout, rheumatism and Bright's disease brought on by unbalanced indulgence, might both pass on a taint to the offspring, education in hygiene assumes special importance. Our recent pure food legislation, furthermore, is an indication of what enlightened public opinion can do to protect the careless and the ignorant against the evils of malnutrition and improper feeding.

There is definite work for special legislation against certain diseases, such as syphilis, the toxin of which is known to affect the offspring, and the same may be said with regard to the excessive use of opium, cocaine and especially alcohol.

Forel gives startling facts as to the action of alcoholic poison (p. 294, *op. cit.*):

> But what is more important is the fact that acute or chronic alcoholic intoxication causes a high degree of deterioration in the germ plasm of the parents. The recent researches of Bezzola seem, moreover, to prove that the old belief in the poor quality of infants conceived during drunkenness is not without foundation. From the Swiss census of 1900, in which figure 9,000

idiots, and after a careful examination of the bulletins concerning them, this author has proved that there exist two annual maximum points for the conception of idiots (calculated by going back nine months before the day of birth). These are the seasons of the carnival and the vintage, in which there is the most drinking. Now, in the wine-growing cantons, the maximum formed by the season of the vintage is enormous and stands almost alone, while it scarcely appears in the others. Furthermore, these two maxima fall precisely at the annual period when the curve of conception for the rest of the population is at its minimum. The maximum of normal conceptions is in the beginning of the summer.

The bearing of these facts upon the regulation of intoxicating liquors need not be pointed out.

Though spread of knowledge and ethical training must be the ultimate reliance in dealing with these deleterious influences in the environment, yet they work but slowly, and legislative methods must be resorted to where feasible. In the whole great field of environmental betterment, eugenics is at one with social reform. The time has gone by when the cry of "paternalism" could block the path of protective legislation, for, even though the individualist may still claim the right to destroy himself, society must restrain him from dragging with him unborn generations to suffering and degeneracy.

Chapter IV. *The Action of Lethal Selection*

As natural selection is most often represented as a struggle for existence, or war between individuals or races, lethal selection of the direct group variety, by which a weaker tribe is exterminated or subjugated by a stronger, has been made much of by historians.

War, however, is losing its place as a factor in group selection, as has been graphically shown by David Starr Jordan, in "The Human Harvest." In former days, every able-bodied man was a soldier, victory depended upon personal prowess and generalship, and thus the tribe of inferior warriors was not unfrequently exterminated. At present the army is not the whole tribe, but merely a professional class, so that its personal might is no necessary criterion of the fitness of the nation. A modern victory depends on such a complex of circumstances, commerce, finances, organization and alliances, that any fitness indicated by military survival, while perhaps a very important attribute of the social organism as such, has no direct relation to the inheritable qualities of the race. Even when defeated, moreover, a modern tribe stands little chance of extermination, and may even lose fewer men than its conqueror.

When we consider selection within the race, on the other hand, war becomes a definite influence toward degeneration. The modern military system involves a selection among the adult males as to who shall be the soldiers and thus be subjected to a high death rate from disease as well as battle. Those selected as marks for bullets and fever are always, to some extent, superior, being compelled, even in our army, to reach a good standard of physique, and in the case of officers of mentality as well. In vital struggles such as our own civil war, that appeal rightly or wrongly to principle or idealistic feeling, the ethical selection within the group, is appalling. The stagnation from which the southern states are now only just awakening after so many years is but the natural consequence of the wholesale destruction of superior men in the last generation, and much of the governmental progress of the Australasian colonies is probably due to their freedom from war under British allegiance.

Since war now means, therefore, the destruction of the young, the strong and often the mentally superior, and the survival for reproduction of those whom war can not use, it has clearly lost whatever eugenic value it once possessed, becoming on the contrary a dangerous agent of deterioration. Since to this biological cost must be added also the terrible social waste that war entails, the setting back of the hands of progress in ethics, economics and social organization, the present movement toward universal peace by arbitration must be counted as a factor tending to accelerate, rather than retard, the course of human evolution.

The old necessity for physical conflict will doubtless soon disappear as a declining birth rate removes the old cause for the seizing of territory. Indirect selection, moreover, is taking the place of war in eliminating many of the inferior peoples through an unequal struggle with disease, unfriendly nature or the complexities of civilization. Resulting largely from the superior hygienic and medical status of an economically successful people, it is now a factor of preeminent importance in the replacement of inferior races, as in North America and Australia. As advancing ethics does away with the military factor, it would be well for us to take full advantage of this indirect mode of selection, by the discouragement of miscegenation between markedly unequal races such as our whites and the negroes; it may even be desirable to prohibit, as far as possible, such marriage and cohabitation. It appears that the Aryan blood of India has been preserved effectually by the caste system, though here the racial advantage may have been outweighed by the social cost of such interference with the individual.

Immigration offers a wide and legitimate field for the application of eugenic principles. As every one knows, the old migration to our shores of such kindred stocks as the Irish, Germans and Scandinavians has gradually given way to an influx of inferior peoples from southern and central Europe, and more recently to the great stream of Asiatic and eastern European folk that are now beating, some of them ineffectually, at our doors. Shall we continue and extend the policy already inaugurated of excluding undesirable stocks? Shall illiteracy be made the test of suitability, or some deeper qualification? Or, on the contrary, shall we hospitably ignore all race distinctions in the interest of the American employer and impose upon our public school system the superhuman task of assimilating to our own standard this polyglot avalanche? An artificial element has here been introduced into group selection, which, as wholly under man's control, deserves careful study.

Sustentative selection, in the sense in which it depends upon a supply of food and shelter insufficient for the population, has been considerably overvalued as an evolutionary factor. Very few species are affected directly by it, as is shown by the rarity of starvation among the lower animals, and in man it has practically disappeared, unless it be in India, Siam or a few savage and barbarous tribes. The advance in the sciences and arts which has so wonderfully extended our supply of wealth has abolished any necessity for sustentative selection in the civilized world, except through the artificial scarcity often maintained by the ability of some individuals to divert to their own use, or even disuse, the possible subsistence of a multitude.

Even under these conditions, our growing sense of sympathy has tempered the severity of the struggle, and among the western nations men do not starve with the conscious consent of the community. Nevertheless, in spite of charity and the poorhouse, an indirect sustentative selection is shown clearly enough by the statistical correlation between poverty and the death rate, resulting probably from improper clothing and care, or in the case of infants, from a sort of semi-starvation due to lack of suitable food. Mortality among the poorer school-children results quite as often from lack of rubbers or medical attendance as from literal under-feeding, and the deaths from tuberculosis and drunkenness, so often the result of poverty, are not put down under the head of starvation.

Spencer, among others, has urged that charity be abandoned, in order that sustentative selection be again allowed full scope, but, aside from the terrible expense in human suffering that this method would entail, we can not afford thus to imperil *social* progress by allowing poverty to work its havoc unchecked. The moral and physical diseases originating in the submerged classes do not stop at the boundaries of the slums, and may corrupt both the fit and the unfit in their progress.

In deciding as to the eleemosynary projects, however, it is desirable that legislators and philanthropists should give the preference, other things being equal, to those institutions which save people with good inheritable qualities, running all others, as far as possible, on a celibate basis. The hospice for the goitrous in Aosta described by President Jordan, in which crétin mates with crétin, is a horrible perversion of charity to the service of degeneration.

Though civilization demands that lethal selection be reduced as far as possible within the group, the possible rate of this reduction has been much exaggerated. In spite of all our charities 45 per cent. of the present generation die before the average age of marriage, indicating a great penalization of ignorance and immorality in the broad sense. As this selection is especially active among the physically unfit, these need not give so much concern to the eugenicist as the mentally and morally deficient. While we have no assurance that the children of the criminal and the imbecile will not live to hand down the curse, the weak and diseased are more likely to die out unless vitalized with fresh blood. The one exception is in the case of defectives in special senses, the deaf and blind, for example, being quite capable of perpetuating their defects through generations.

On the whole, lethal selection is attended with too much suffering and social sacrifice to be deliberately retained, but can never wholly disappear. We may always rely upon it to some extent as a weeder of the physically unfit, but the mentally and morally infirm are left to be dealt with chiefly by the projects of artificial selection previously mentioned.

Chapter V. *Sexual Selection*

While lethal selection shows a gradually decreasing action as we rise in the scale of evolution, and works by means generally opposed to civilization, the second great form of natural selection, that which acts not by premature death but by differential success in leaving progeny, reaches its greatest importance in man. Its first mode, sexual selection, has always been valuable in developing human aspects which lethal selection is powerless to invoke, including many of the esthetic and moral characteristics. Since it is not, like lethal selection, inextricably bound up with human suffering, it can be looked to whole-heartedly for progress. However, as this is a factor lying wholly outside the province of social control and within the bounds nearly universally left sacred to the individual, little has hitherto been attempted in the way of utilizing it in human evolution.

The influence of sexual selection is often belittled on the grounds that almost any man can marry and that love is often aroused by trivialities rather than worthiness. However badly it may work, however, its existence is proved by the fact that there are many people precluded from marriage by some obvious defects. Another very large group of inferiors, the criminals, tramps, paupers and prostitutes, largely substitute promiscuity for marriage, which leads to few births because of the consequent frequency of sterility and abortion. Those who marry are usually conscious of having made a selection from several, in spite of the fatalistic impression current in this field and finding voice in the proverbs "Marriage is a lottery" and "Love is blind."

Sexual selection, then, is an active force. The question is, Does this selection work to insure the marriage of the fittest according to our best moral, mental and physical standards?

In the absence of any Bradstreet's of marriageability, we should be able to take our college graduates as a picked class, probably for all three ratings, and the indications here are not encouraging. According to the *Yale Alumni Weekly*, the percentage of married men in twenty classes, twenty years after leaving college, is estimated at only 61 per cent., less than two thirds. The annual report of the president of Harvard College (1901–2) gives for the classes of 1872–7, twenty-five to thirty years after graduation, 28 per cent. still unmarried, and Dr. G. Stanley Hall estimates that, while three fourths of the men graduates of colleges remain single for twenty-five years after graduation, one half of the women graduates are still unmarried after ten years.

Since, then, the marriage rate of men and women of education and achievement is below the average of the population, the eugenicist is at one with the advocate of social progress who seeks definite means to raise the choosing of a mate to a higher plane than at present. The aims are two—first to induce all the suitable to embrace matrimony, and second to make the choice as discriminative as possible of the characteristics most socially desirable.

Legislation is here out of the question, and the only hope is in a gradual modification of public opinion in regard to personal evaluations. That this is not a forlorn hope is shown by the changes that have already come about in sexual desirability, in response to social and esthetic progress. Women no longer require proofs of personal prowess in their mates, and masculine beauty possesses on the whole less attractiveness in our times than achievement. The criterion of feminine excellence has varied from the physical perfection of ancient times to the spirituelle attenuation of our grandmothers, and now fortunately back to a standard into which physique again frankly enters. We have some justification also in saying that the moral standard for masculine and the mental for feminine excellence have risen since the days of "Tom Jones" and "The Vicar of Wakefield."

While it is undeniable that love when once established defies rational considerations, yet we must remember that sexual selection proceeds usually through two stages, the first being one of mere mutual attraction and interest. It is in this stage that the will and the reason are still operative, and here alone that any considerable elevation of standard may be effective. There is in this book, therefore, no suggestion of substituting the planned marriage for the romantic, but merely of bringing the preliminary psychological stage of the latter under the control of reason rather than chance.

It is worth while, accordingly, to indicate some directions in which the public opinion of the twentieth century may well be modified.

Beauty of face still carries far too much weight as a desideratum for matrimony, but this quality is not without some eugenic value. Far more serious is the modern tendency to substitute for mere beauty another characteristic which, for want of a better name, we may term flashiness. In our sober moments we all recognize the flashy man or woman as *per se* inferior, but it is undeniable that, other things being equal, the matrimonial chances of this class are above, rather than below the average. There is hope in the consideration that this demand is largely artificial, stimulated by the press, the popular magazine, and, above all, the stage. A moment's recollection of the standard of sexual desirability displayed in the ordinary farce will illustrate forcibly the disparity between the artificial qualities there emphasized and the characteristics really desired by the general public in wife or husband.

Along with a shifting of values from this false emphasis there is needed the general cultivation of conscious selection, this again depending largely upon the attitude of the press and the stage. While a large percentage of our current witticisms inculcate the cynical, and many of our novels and plays, the fatalistic view of marriage, it is not to be wondered at that sexual selection still falls far short of the ideal.

Although an elevation of standard is of preeminent value not only for eugenic, but for social progress, it is obvious that too rigid a criterion might have the effect of leaving many desirables unmated. We must balance this tendency, therefore, by doing away with certain obstacles to free sexual selection which have hitherto worked to produce celibacy in superior men and women.

Social caste lines, for example, if closely drawn, tend to leave unmarried many individuals who, though unable to find mates in their own class, might easily do so in another: the diplomat's daughter whom propriety forbids to fall in love with her father's secretary, and the butler's daughter to whom exceptional endowment has made distasteful the suitors of her own walk of life, are alike the victims of convention, their line being extinguished in this way as effectively as if they were undesirables.

Extreme inequality of wealth has an even more unfortunate effect, as confining choice within limits much more arbitrary than those of hereditary class, and thus keeping possible mates in widely distant spheres. Such luxuries as the parlor car, the country estate and the many-barriered ocean steamer have fixed a gulf between the millionaire and the lower middle class that is seldom traversed matrimonially except through the medium of the stage.

While the legislative interests of the eugenicist and the social reformer here again coincide in their common opposition to extreme inequalities of wealth and rank, something may be accomplished even under the present economic disadvantage by the mere enlargement of circles of acquaintance. All social functions that are not merely formal, but give opportunity for real acquaintanceship should be encouraged, in order that young people of both sexes may meet under favorable circumstances and frequently enough to admit of knowledge of and friendship with many individuals. Intelligent opposition to such functions is largely because of their restriction to narrow circles and their excesses in late hours, dress, food and decorations, none of these being essential accompaniments of social intercourse. The churches have hitherto done excellent work in this direction of social mingling, and the same may be said of the various organizations in which young men and women meet together for definite purposes.

That social intercourse is definitely recognized by the public as a means for rational sexual selection is shown in the series of letters to the New York *Times* through October, 1908, resulting in the proposed formation of the Lonely Club.

Since the college at its best is one of the last bulwarks of social and economic democracy, and affords our nearest approach to an environment unspoiled by convention, where individuals are given opportunity to display their true moral, mental and physical mettle, much may be expected from coeducation in the selection of the future. In the west, where coeducation is comparatively wide-spread, there is apparent a higher marriage rate among educated women than in the east, and a thorough investigation of such rates in educational institutions of both classes is needed to bring the attention of educators to this important matter.

The character of the college courses desirable for women is another point that must soon be considered in the educational world. It is quite possible that their too academic nature at present is partly responsible for the low marriage rate of women graduates, and that training more adapted to the needs of wives and mothers than to those of scholars and teachers should be adopted. The preponderance of women teachers in girls' colleges may be another contributing cause, in its setting up of ideals other than domestic.

Clerical celibacy in former times, continuing at present in the Roman Catholic Church, though instituted in the interest of the spiritual, has worked rather to the weeding-out of the gentle, the spiritual and the intellectual. Much of the decline in modern Spain and Italy may be ascribed to this custom, together with the prevalence in the past of religious persecution. It may not be wholly useless for the eugenicist to lift up his voice against this suicidal institution, for, soon some progressive pope, seeing that the practise is clearly detrimental to the interests of his institution, will set himself against it.

To the degenerating effect of modern warfare already mentioned should be added the interference with sexual selection brought about by a standing army and navy, through which a large proportion of picked men are, for the best period of their lives, placed in an environment where immorality thrives and marriage is discouraged, if not absolutely excluded. The movement toward universal disarmament thus comes into eugenic favor, and, even at present, some reform might be effected by the abandonment of the practise of isolation of troops and the permission of soldiers to reside out of barracks, responding to roll-call at definite hours.

Among the many evils that follow in the train of sexual immorality may be mentioned the hindrance to sexual selection of the highest sort brought about by the corruption of the emotional nature, by which a man's choice when he eventually marries is likely to be far inferior to that which otherwise might have been possible for him. Here, once more, therefore, eugenics gives its hearty support to all movements for the raising of public morality.

A change in social values as to reputability and honor is greatly needed for the better working of sexual selection. The conspicuous waste and leisure that Veblen points out as our chief criterion of reputability have no necessary connection with mental or moral qualities, and, in the present somewhat illogical inequality of distribution, do not always bear a direct ratio even to the traits that make for genuine economic progress. On the other hand, the fact that the insignia of success are too often awarded to trickery, callousness and luck does not argue the abolishing of these signs altogether in favor of a "dead level" of egalitarianism. Distinctions, if rightly awarded, are an aid, rather than a hindrance, to selection, and effort should be directed no less to the proper recognition of true superiority than to the moderation of our excessive social differences.

Galton has devised a definite, if matter-of-fact method of establishing a better standard of social esteem. This is a plan of issuing certificates to such young persons as would voluntarily present themselves for examination and decimal evaluation, those reaching a higher standard to form a social elite naturally sought after as desirable husbands or wives. Though this scheme would be far from infallible, owing to the elusive nature of many characteristics, the difficulty of allowance for growth, and our ignorance of the exact laws of heredity, such a true aristocracy, would certainly possess great advantages over the present classifications of The Four Hundred, Daughters of the Revolution, hereditary nobility and social cliques. Even its somewhat humorous deficiency in romanticism arises largely from its novelty, since idyllic love seems to have survived the equally unpoetic institutions of the dowry, the license and the divorce regulations.

Valuable as are these suggestions, however, no mere device can ever wholly take the place of a lofty and rational idea of marriage, to be brought about by an uplifting of public opinion. It is difficult to bring under the control of the mind a province that has for so long been left almost superstitiously to caprice, but much can be done, in an age of growing social responsibility, to produce a genuine respect and desire for marriage as a necessity to the complete life. More and more we see an appreciation of the immortality achieved by the training up of children to the betterment of the world.

CHAPTER VI. *The Distribution of Births*

Even if it were possible to attain the ideal working of sexual selection the task of eugenics is not completed.

Fecundal selection, or the principle of descent from those leaving the most numerous offspring, seems to be the most powerful influence in the contemporary evolution of mankind. Throughout the western civilization we find, between 1870 and 1880, the beginning of a marked decline in the birth rate, which, while affecting the backward races least of all, shows no signs of abating at present.

Among the causes of this decrease may be mentioned the more expensive standard of living in civilized countries, the competition of other than domestic activities, greater ambition for the child coupled with greater fluidity of social classes, and, last and most important, a greater knowledge of the physiology of reproduction and the prevention of conception.

Though this general decline in the birth rate gives in itself no special cause for alarm, the serious consideration is that this decline is distributed very unevenly through the social classes. Pearson brings out this point very clearly, the differential character being shown by the fact that in Copenhagen 25 per cent. of one generation is producing from 50 to 60 per cent. of the next. The personnel of this 25 per cent. is not encouraging. The analysis of Pearson, Heron and others for London shows that the decrease in birth rate is greatest among families of the highest income and social position, while Passy gives the birth rate for rich Paris as 1.9, of poor Paris as 2.8. Figures for the United States show that the decline affects American blood far more heavily than that of the immigrants, the Massachusetts birth rate in 1890 being only 2.4 for the native as against 4.3 for the foreign population. The old Puritan families are gradually disappearing—that of John Alden, for instance, will in the next generation be extinct in the male line—while the Finns, Portuguese and French Canadians are spreading over New England. College-bred men and women are apparently failing even to replace themselves, the married members of the Harvard classes above referred to, themselves but a small proportion, having an average of but two surviving children twenty-five years after graduation.

A glance at the causes as given above will explain this disproportion in the decline of the rate. It is the more individuated who feel the greatest interest in those activities which compete with child-raising, and the better informed who know the efficient methods of preventing the unwelcome child. The majority of large families at present are the result not so much of deliberation as of ignorance. As with the increase of knowledge and the complexity of civilization the situation is likely to become more pronounced, it is a pressing problem to ascertain by what means we may increase the birth rate of the superior stocks, and keep down at least proportionately the children of inferior blood.

There is need for a direct appeal to make child production a matter of religion and ethics rather than of mere whim, though too much must not be expected from it. A plea such as Roosevelt's, however, for indiscriminate large families is certainly uncalled-for, and "race progress" rather than "race suicide" should be the cry. If the decline in the rate were evenly distributed, it might not even be regrettable, for the old rate could not have been maintained indefinitely without undue pressure on the productivity of the earth. The only logical excuse for the Roosevelt attitude is the military one, but the favorable geographical position and commercial supremacy of the United States may save us from anxiety on this score, and the disadvantage of a rapidly growing population in greater poverty, poorer education and a slower rate of social progress is a far more important consideration for us at present.

The appeal for large families is of use only when directed especially to persons of superior ability, as from the innately inferior the fewer children the better. The average parents should replace themselves by bringing at least two children to maturity and marriage, four births in general being required for this result.

A most desirable means for limiting the families of the inferior, as falling in with the noblest efforts for social progress, would be the abolition of child labor. While every additional child in the lowest stratum of society may be made a means of profit within ten or fifteen years, we must expect the lazy and the incapable to multiply at the expense of those to whom the child is an object of care and sacrifice.

Another definite advantage in the redistribution of the birth rate would be gained by ceasing to treat as illegal the knowledge of the prevention of conception. Thus the ignorant would no longer be favored in fecundity, and a more reasonable proportion would result. Though it is true that the rate might in this way be brought somewhat below the point of maximum advantage, yet we should then, granting selected immigration, be placed in a position to build up the population by an increase of membership from the best stocks.

The divorce laws also might be made of beneficial effect. The eugenic value of divorce at present is that it removes from the parental possibilities of marriage certain individuals who are inferior in one way or another, and that it permits a remarriage of some superior persons to better partners. In order to increase this action it might be advisable to extend the recognized grounds for divorce. Such defects as epilepsy, feeble-mindedness, extreme cruelty, moral perversity, repeated conviction for crime, or habitual drunkenness should be made of equal weight with unfaithfulness and desertion, as indicating innate inferiority rather than an "occasional crime."

Venereal disease, in so far as it causes infecundity among the vicious, may be regarded as a eugenic agent. In view of its great cost to society, however, the eugenicist should encourage every effort to stamp it out by education, medical control and the enforcement of social morality. While the vicious would, at best, only gradually become exempt, the innocent should at once be protected and society freed from the evil which now causes the sterility of 45 per cent. of its childless women.

The measures just mentioned, though important, do not effect the deplorable decline of the desire for children among the best men and women that is menacing the future. The work of Sir Francis Galton and Karl Pearson in England illustrates the efforts that should be brought to bear upon the enlightened classes to recognize the rearing of children as a duty to the race. Men and women should be made to realize the feeling of nothingness that is the portion of the childless in old age and the gratification that lies in living youth over again in one's children. The surest immortality, as well as the noblest fulfilment of life, is to be found in marriage and parenthood.

The strongest single influence in the voluntary limitation of the family is the complexity of modern life, with its abnormally high standard of expenditure. Not only does the selfishness of parents forbid any curtailing of personal extravagance for the sake of children, but parental love itself causes a restriction of the family to one or two, lest it be impossible to lavish upon a larger number all the care and luxury demanded by present-day standards. Dress, education and launching into life are all to be considered, and as a result we have the family too small to replace the parents and a stock that quickly dies out before the prolific immigrant peasant.

Both from the eugenic point of view and from that of the social reformer, there is need of an ethics of expenditure. As Professor Ross points out, a high valuation placed upon the things money can buy has as its reverse side, a low valuation of the things money can not buy—the integrity of the politician, the virtue of the woman and the ideal of the artist—and there is something alarming in the standard of "conspicuous expenditure" which sacrifices to itself both the souls of the present and the lives of the next generation.

A further result of the too extravagant standard is the postponement of marriage until the young people can begin life upon the same plane as their parents, too often resulting in an abandonment of marriage altogether, and almost always in a limitation of the family. Why can not young men and women return to the simpler ideals of "love in a cottage" and leave ostentation, if it be necessary at all, to their elders? The French and Chinese custom of giving financial assistance to children during the first years of marriage is commendable as tending to perpetuate families of ability, but the method of bestowing dots has the counterbalancing disadvantage of reacting unfavorably upon the parents, by a restriction of the number of children in a zeal to enlarge the dowry.

Unfortunately those youths who are destined for the more exacting professions are now obliged to spend a long unproductive period in education. While the past generation of A.B.'s, after leaving college at about twenty, found immediately open to them some field of professional usefulness, the young man of the present is compelled more and more to supplement his bachelor's degree by some definite technical training, or, if he seeks livelihood in the academic world, he must usually add to his previous study years of advanced research. Marriage is thus unduly delayed among the young men of greatest social value. Our universities, in granting many fellowships too small for the support of a wife, are increasing this tendency. A practise far more favorable eugenically would be the bestowal of the same income upon fewer men and in amounts large enough to insure a living, increasing the sum with marriage and the birth of children.

The marriage of the finest young women, on the other hand, is often delayed and sometimes even prevented by an exaltation of the "career" at the expense of wifehood and motherhood. This striving, probably propagated more in radical feminist circles than in the colleges themselves, leads some women of the highest ability and character to remain celibate, or if married to be content with but one or two children. The various movements for the higher education of women, with all their furthering of social progress, are doubtless partly responsible by their emphasis on "culture" and neglect of the training for the work of wife and mother. The large proportion of women professors and instructors in the women's colleges has the unfortunate effect of exalting "careers" for women.

While due care must be observed not to lose sight of the qualitative principle in sexual selection, by an encouragement of too early marriages, yet it is clear that fecundal selection can work satisfactorily only when the superior men and women marry in time to more than replace themselves by their children.

The whole factor of reproductive selection, both sexual and fecundal, is, to sum up, a greater power in modern life than lethal, often called natural, selection. Sexual selection, though operating somewhat more beneficially as civilization progresses, is still far from ideal, and needs to be placed upon a basis of ethics and judgment rather than caprice and convention. Fecundal selection is in a still more unsatisfactory condition owing to the steady diminishing of families among the better stocks and the consequent propagation of the race by inferiors. Though certain social devices would be of some advantage, our main hope again must be in raising the ethical standard, by placing child production as a goal of manhood and womanhood.

CHAPTER VII. *The Mission of Eugenics*

It has been shown that, while improvement of the race in innate quality is almost a *sine qua non* for permanent social advancement, the factors which make for it frequently fail to coincide with the influences tending toward social progress. Pearson says:

> Consciously or unconsciously, we have suspended the racial purgation maintained in less developed communities by natural selection. We return our criminals after penance, our insane and tuberculous after "recovery" to their old lives, and we leave the mentally defective flotsam on the flood tide of primordial passions. We disregard on every side these two great principles: (*a*) the inheritance of variations, and (*b*) the correlation in heredity of unlike imperfections.

The eugenicist urges, therefore, scientific investigation as preliminary to action. He proposes, first, that the registration laws of both federal and state governments be so amended as to make vital statistics reliable and comprehensive, and, second, that the students of biological and sociological laboratories be encouraged to wider and more accurate study of the laws of human heredity according to the methods of Galton and Pearson.

Like all contributions to the sum of social ideas, eugenics must work by the successive steps of invention, generalization and tradition, corresponding to the biological processes of variation, survival of the fittest and heredity. Invention, or discovery of the laws of eugenics, is here the part of the laboratory specialist, and should loom high in the attention of the sociologists of this generation.

We must not wait, however, for full knowledge before proceeding to the next step, for full knowledge can never be attained. The exact concontribution of the parents or degree of inheritableness need not be ascertained before we begin work, for we know already a certain number of characteristics possessing a high degree of inheritability. Though cattle breeders know little quantitatively of the inheritance of milk production, they have acted upon this little for many years with marvelous results; if, on the contrary, they had waited for elaborate statistical investigation and experimentation, we should now be using goats for milk instead of cows.

Not until tradition has played its part, however, can the schemes for eugenic reform become actual. As Professor Kellar reminds us, the folkways and customs of the race must be deeply affected before mere education and legislation can exercise an appreciable influence upon action, and such a change at best is slow, though permanent.

The immediate mission of eugenics becomes, then, the advocacy of all measures tending to race improvement and not involving heavy social cost, the examination of all proposed reforms from both the biological and the social points of view, and, perhaps most important of all, the creation of a new standard of ethics with regard to marriage and the family. It is time for American men and women to leave the vital subject of race progress no longer to social iconoclasm on the one hand and fatalist superstition on the other, but to consider it seriously and religiously, aided by the best resources of modern science, and then to give their support to such measures as may seem to them best, freed alike from flippancy, conventionality and sensationalism.

COLLEGE DIVERSIONS

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THE phase assumed by discussions respecting athletics must bring great comfort to coaches and others who derive profit or glory from intercollegiate contests. They are to be congratulated upon the success attending their efforts to divert attention from the serious matters at issue and in concentrating it upon wholly irrelevant inquiries as to the alleged brutality of football.

It may be said in passing that a game which, in the short season just closed, can boast of 30 killed, 20 others fatally wounded, as well as nearly 1,000 more or less seriously injured, may be regarded as fairly brutal; but this is merely incidental: if parents choose to permit their sons to play football, that is their concern. The main issue is vastly broader and the dust raised about football is merely an attempt to conceal it.

If a visitor from some outside region should read the college papers, which are encouraged because they give young men an "admirable preparation for journalistic work in after life," he would be convinced that American boys in college think of little aside from professional sport. Appeals to college spirit abound, urging the fellows to attend the games and to bring their friends—to prevent a deficit in the treasury; lamentations are prolonged, deploring the lack of college spirit shown by muscular men who fail to apply for places on the teams; there are doleful predictions because students do not pay up for support of the several crews and gloomy forecasts abound because the college is in danger of losing its high standing. If a team has gained a victory, the paper is hardly large enough to hold the story; the work done by the coaches is extolled as entitling them to the everlasting gratitude of the college, for whose advancement they have done so much. It is true that the college professors are not forgotten; there are frequent references to them in connection with the formulation of new rules abridging still further the personal liberty of students.

If the visitor pass into the college buildings he might be led to believe that the professors themselves respect intellectual prowess as little as the students do. The walls are often decorated with trophies won in intercollegiate contests; the names of college champions shine out on the roll adorning the gymnasium, but he finds no roll of honor-men in the class-rooms; silver cups and medals of gold, silver or bronze abound for athletes, but prizes for men who excel in study are few and insignificant; victory in the intellectual arena seems to count for little even with the professors; victory in contests requiring only such abilities as a savage possesses alone deserves permanent record in the shrine of learning. If this visitor go farther in examination of the college plant, he may find that great sums of money have been expended in acquiring athletic fields, in provision for comfortable seating of spectators; that buildings for physical culture often excel in equipment those for mental culture and that the coaches for teams in athletics are, as a rule, better paid for the time expended than are assistant professors or, in some cases, than even the professors. He will have little doubt that those who have control of college affairs think more highly of the extraneous courses than they do of the college curriculum.

Should this visitor turn to the great daily papers, he will discover that popular opinion coincides with that of students and college authorities. A page or even two pages may be devoted to description of a single football contest; for days beforehand, the betting odds are given and the police make due preparation to repress too great exuberance on the part of the visitors' sympathizers. But during the greater part of the year he will find little reference to any college work except that of intercollegiate contests. The pressure of interesting news prevents insertion of any but passing notes respecting the mental culture side—unless a professor make a statement, which, separated from the context, appears to conflict with some popularly accepted opinion concerning morals or social relations.

If this visitor should pursue his inquiries in detail, he would find that appearances do not belie the fact. He would discover that glee clubs give abundant concerts during the term time and that sometimes they even make tours; that the football season consumes two months or more at the opening of the college year, when men should be devoting their whole energy to study; that the baseball season is at its height during the closing weeks of the college year, when men are supposed to be grinding at the final reviews; and that the anxiety of young men to prevent too close absorption in study has led them to introduce basketball and hockey to fill the unfortunate gap which exists between the seasons of football and baseball. As if these were not enough, he would find careful provision for the needs of men indifferent to violent exercise; for them there are intercollegiate contests in chess and debating; there are "magazines," "newspapers," dramatic exhibitions—so many devices to entice men from their legitimate work that it seems impossible for any to escape the net.

If, after this investigation, the visitor should express the opinion that in a great proportion of American colleges intellectual development is subordinated to other matters, surely no one could censure him.

It is said that this is but a reaction from the conditions of former days, when colleges neglected the physical welfare of students and devoted their attention so strenuously to intellectual work as to endanger the health of those entrusted to their care. This is hardly exact, for there never was a time in this country when the curriculum was so severe as to endanger any man's health; in any event, the study of alumni catalogues shows that in pre-athletic days college students were, as they are now, a selected class, with tendency to long life and were, on the average, excellent risks for life insurance. But whether or not the statement be true that colleges in former days neglected the physical welfare of students, the fact remains that they are doing little better now.

The plea for funds with which to purchase athletic fields and erect gymnasiums was successful and vast sums have been expended, far out of proportion to any possible good that might result. But what has been gained by the expenditure? Some colleges have a brief compulsory course in the gymnasium; but the great equipment is utilized more and more each year for teams composed of men whose bodies need no such anxious care. The vast majority of students must gain their physical culture by proxy, by paying generously toward support of the college champions, just as they must secure much of their esthetic culture by supporting publications or teams in chess and debating and by purchasing tickets to glee club concerts—all for the advancement of the college. The chances for neglect of physical culture are greater than formerly, as the pocket money which enabled the boys of other days to have their little baseball and rowing clubs is now consumed in purchasing admission tickets to concerts, contests and the rest.

The method in which defenders of intercollegiate contests have conducted their side of the discussion does no credit either to their manliness or to their integrity. Those who oppose the waste of time and the diversion of funds have been stigmatized as men indifferent to the health of students, as effeminate, as desiring that young men become "mollycoddles"; sneers have taken the place of argument. But the statements and characterizations are false throughout. By far the great majority of those who criticize the present deplorable condition are warm defenders of physical culture; they would be gratified if the course in gymnastics were made more extensive and compulsory, for they recognize that young men who need such training have no desire for it; they not only maintain that physical exercise, singing, chess playing, debating and the rest are commendable, but they assert also that such diversions are necessary for they are firm believers in the old adage that "All work and no play makes Jack a dull boy, they say." But they denounce the present system which has relegated study to the background and has made the proper college work merely an annex to exhibitions. That which is only incidential has been made all-important.

Men from foreign universities are astonished to find that Harvard, Yale, Princeton and other great universities are known to the public generally only as football associations; that the newspapers so rarely make reference to the eminence of men composing the faculties of those universities, that such references as are made are too often in the shape of squibs ridiculing statements charged upon them by irresponsible reporters. Little is said now about sitting at "the feet of Gamaliel" and apparently Gamaliel's race has disappeared. It is no wonder that the callow graduate of a few years' standing announces to the gaping undergraduate that he never derived any advantage from the professors and that his present greatness is due wholly to himself.

The effect on the morale of our colleges is increasingly bad; alumni of less than fifteen years' standing seem to think that they can show their love for alma mater best by a gift for a grandstand, a stadium or something else to increase interest in team exhibitions; the athlete is the college hero, the mere student is a "dig" without college spirit; worse than all, the new generation of college instructors has grown up in this atmosphere and favors continuance of the condition; appeals of a highly-paid coach or of the team manager do not fall on deaf ears when addressed to such instructors, who are not likely to check the growing tendency to lower the standard in favor of efficient athletes.

It is impossible to ignore the fact that this tendency exists. The college curriculum was arranged so as to require much time for actual preparation outside of the class-room; yet men, who during a considerable part of the college year are unable to give serious attention to study, succeed in "catching up" so as to pass examinations and in obtaining their degrees. The usual reply to this argument is that so-and-so, who was very prominent in sports, graduated at the head of his class and did well afterward. Very true. And the writer knows a man who, throughout his college course, earned his livelihood as night watchman for the custom house on a New York pier, yet graduated at the head of his class and made his mark afterward in the world's affairs. But to offer such men as representing the average student is as absurd as would be the assertion that Aristotle typified the Greek intellect or that James J. Jeffries typifies American physique. The average student finds much study a weariness to the flesh; glee clubs, athletics and the rest increase the weariness; they absorb the chief interest and there remains only a petty fraction of the original interest to be devoted to study. Other men, loving study quite as little, spend their energy in "rooting" for the team and they too receive their degrees.

But the matter of good faith must not be neglected. This wild craze for outside courses is of comparatively recent origin. The great funds acquired by our colleges were given for the training of the mind, not for the training of the body; the money for gymnasiums and the rest was obtained originally on the plea that the student's body must be cared for that he may do better work with his mind. The colleges have not kept faith with the donors. The college is becoming an annex to the athletic field so rapidly that the absurdity of the relation affords the most fruitful source for newspaper jests; while the equipment for physical culture has been diverted from service for the great number to service for the few. Coaches are selected because of their well-known qualifications and are paid accordingly; college instructors are not always selected and paid on a similar basis.

Is the condition to continue and to grow worse? Certainly, unless those in control of our colleges change their conception of what a college should be. Denunciation of commercialism rings out in hoarsest tones from many a college rostrum and one might suppose that in our haunts of learning there is freedom from the coarse influence of the market. Yet nowhere is the so-called commercial idea more prevalent than in college management. The only conception of success seems to be growth in wealth and in number of students—quantity not quality. A great increase in the freshman class brings jubilation and a decrease leads to gloomy search for cause of the decay. This evil has brought about the present condition. Wandering glee clubs and successful teams gain much free advertising; the public reads the sporting pages and becomes aware that the college exists; boys in secondary schools learn which college has gained victories and they long to share in the glory. It "pays" to have coaches of high grade, well remunerated. But a faculty of men, competent and willing to give the best of teaching, would bring no advertising, would attract only a small class of students; the college would not become great during the lifetime of one man; it is not worth while to expend much on that which brings such small returns.

The present wretched condition will be changed when the control of college affairs has passed from the hands of men unacquainted with the actual needs and when it has been placed in the hands of those who know what teaching means and have respect for teachers.

THE THEORY OF STYLE

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ALTHOUGH signs of reaction are by no means wanting, the dominant form of criticism at the dawn of the twentieth century seems to be what is usually called literary impressionism. To keep his mind sensitized to all the influences his reading can bring to bear upon it, to disengage his impressions, and to set them forth in the choicest phraseology at command, are now recognized as constituting the supreme virtue of the critic. This attitude of impressionism towards literature is distinctly opposed to the literary dogmatism of the seventeenth and eighteenth centuries, and may be regarded as tending to supersede the subsequent phase, the so-called historical criticism, which traces calmly, if at times somewhat schematically, the evolution of poets and literatures, and even the more distinctly scientific criticism, which looks upon works of art as indices of the souls of artists and nations to be explained on the bases of esthetics, psychology and sociology. One remarks in all the more recent tendencies in literary criticism a certain degree of catholicity. Literature is no longer to be dogmatically approved or disapproved, but it is to be appreciated and *placed* according to recognized principles or a frankly individualistic point of view.

Of course impressionism is very far indeed from being democratic. Its high priest, the well-read, well-endowed, susceptible critic is still in some sense a public guide. He is a superior sort of camera, and a newly-acquired language may aid, like a new lens, to improve the quality of the impression. He starts, however, with no *a priori* principles of taste, and he may even be disdainful of esthetics. His desire for freedom from standards carries him perhaps too far in his contempt for theory. At any rate, it is not obvious that an emotionalistic esthetic which recognizes the conveyance and transmission of a mood as the essential of art is at variance with the spirit of genuine impressionism. In fact such an esthetic might ask, in view of the dearth of fixed principles, and the great stress laid in recent criticism on the mere ability to record impressions, whether literature about literature has not itself become art and renounced all claim to be called scientific. The difficult and tedious task of collecting and classifying impressions and striking averages and seeking bases of agreement from the broadest possible data is largely to be done before a science can be deduced from the mass of esthetic judgments.

Now, as a matter of fact, the great literary artists have possessed such a knowledge of the minds of their readers, such a skill in applying it to common human nature, as to at least ensure the popularity and in some cases the immortality of their works. The poet who feels that his verse will stand "to times in hope" speaks with a certainty that few formal doctrines can claim. Poets know by natural tact and through experiment the esthetic probability of achieving desired emotional effects by certain literary means. It is true that there are limitations to their success. Racine, Lamartine, La Fontaine, can never appeal to the English mind as to the French. Many well-equipped Germans will continue to find their translations of Shakespeare—for us grotesque—better—for them—than the original. The ultra-democrat and the moujik philosopher may be blind to the charm of Elizabethan art. Nevertheless, the greatest literary artists made their appeal not to the adventitious, but to the permanent in human nature, and a psychological study of their masterpieces should enable us to make explicit and doctrinal what with them was implicit and more or less intuitive.

Criticism itself has developed from a consideration of oratory. It was an attempt on the part of the rhetoricians to analyze the work of the orator with the intention of profiting by his successes and of taking warning from his failures. Some general theory of style is presupposed. The profundity to which this study was carried led to the clear recognition among the Greeks and Romans of the psychological significance involved in oratory and rhetoric. The orator is a philosopher with something added. The rhetorician must know the true and the false, he must understand the human mind even if his sole purpose be to deceive. The artist who ventures to play upon us must have a just appreciation of our tendencies and susceptibilities.

That recent rhetoricians take a less serious view of their vocation can be shown by a reference to their pages. One proclaims, for example, that "every piece of style may be said to impress readers in three ways—intellectually, emotionally, esthetically." This dictum forms the basis of a theory of style that cost its author ten years of study. A little further study along philosophical lines might have convinced him that a distinction between the emotional and the esthetic is not so radical as his classification implies. In fact, a glance at recent rhetorics might indicate that as far as the rhetoricians are concerned the same condition prevails now as Spencer complained of over half a century ago: No general theory of expression seems yet to have been enunciated. It was the desire to discover the psychological basis of the heterogeneous rules of the rhetoricians that led him to formulate his theory of the economy of mental energies and sensibilities. The little essay that sets forth his theory, refused by one magazine and dubbed by the editor of a second with the grandiose title Philosophy of Style, would hardly call for serious comment, only that it is still highly praised by American rhetoricians and that Spencer in his publications of 1902 reaffirmed his belief in the conclusions reached by him in 1853, though indeed he confessed that the question of style had never by him been made a real object of study.

Spencer maintains that the desideratum that underlies the specific rules of rhetoric is to so present ideas that they may be apprehended with the least possible mental effort, and he proceeds to inquire whether economy of the recipient's attention is not the secret of the effect sought in the choice of words, their collocation, the arrangement of clauses, figures of speech and the rhythmical sequence of syllables. The short, familiar, imitative, specific, Saxon words are more forcible because they economize the reader's powers. The English idiom which puts the adjective before the noun is better than the French, because on reading the expression *un cheval noir* one tends first to think of a bay horse and an effort must be made to repaint the image, so to speak, while on reading *a black horse* the idea suggested by the adjective, being abstract, is suspended in its application until the noun gives us the substance for our concrete picture. On the same principle the predicate, which presents the subject under a certain aspect, must come first. *Great is Diana of the Ephesians* is more impressive than what is sometimes called the natural order. This theory of style is at first glance very plausible. That one should not waste mental effort seems obvious. But the more closely one examines it the more paradoxical does Spencer's so-called philosophy of style become. One feels this when he proposes to call the *inverted* style the *direct*, and the *natural* order the *indirect*. The philosopher himself is forced to recognize that his theory has limitations. It is not always the shortest epithet that is the most effective; *It is grand* may be less impressive than *It is magnificent*. Moreover, he confesses that beyond a certain point more is lost than is gained by the inverted order; the effort to carry in suspense is greater than that needed to correct a series of misconceptions in approaching the complete statement. He goes so far as to say "A greater grasp of mind is required for the ready comprehension of thoughts expressed in the direct manner, where the sentences are anywise intricate." This style admittedly demands a "considerable power of concentration." That is, it calls for a high degree of attention. Spencer says further "even when addressing the most vigorous intellects the direct style is unfit for communicating thoughts of a complex or abstract character."

In fact, as we proceed we find that this theory of style becomes hopelessly involved because of the failure to distinguish between clearness and force, and, again, between clearness and simplicity, and to recognize that style must suit itself not merely to different capacities but to different purposes. The theory's defects become apparent when

Spencer comes to consider figurative language. The main object of figures of speech is to bring one "more easily to the desired conception," that is, they tend to simplicity and clearness rather than to impressiveness and stimulation of the feeling. The metaphor owes its superiority over the simile to the great economy it achieves. Whately, on the other hand, had maintained that "all men are more gratified at catching the resemblance for themselves, than in having it pointed out to them." Spencer opposed this view. He probably recognized that underlying it was a principle that could be formulated in direct antithesis to his theory of style, *not economy of mental energies and sensibilities, but the greatest possible stimulation. Not the minimum of effort, but the maximum of response!* Attention is correlative with interest and it must be aroused rather than economized. It is not mere clearness of exposition, but the *power to evoke*, that is the supreme virtue of style.

Later in his essay Spencer stumbles on the secret of his so-called direct manner. "Mental excitement spontaneously prompts the use of those forms of speech which have been pointed out as the most effective." In other words, the inverted order is the emotional order distinguished by force, while the natural order is the intellectual order distinguished by clearness. When one reads what the essay contains concerning the economy of the mental sensibilities, the paradoxical character of the whole theory is greatly emphasized. Climax is more fruitfully described as an exploitation of the mental sensibilities than as an economy of the same. It is the cumulative effect of a summation of stimuli. What is the value of saying that antithesis and variety economize the attention rather than that they arouse the attention? The greatest possible emotional effect is the main purpose aimed at in the employment of the various figures of speech.

When Spencer comes to speak of poetry and proclaims its superiority to prose, into which view his brief for the inverted order leads him, there become marked the inadequacy and lack of discrimination of his whole theory of style. The principles that explain a prose style fail to account for a poetic style inasmuch as their purposes are different. To adopt Spencer's phraseology for a moment, economy of the mental energies is frequently at variance with economy of the mental sensibilities. Or, as I very much prefer to say, the appeal to the understanding is not always consistent with the appeal to the emotions; and in poetry clearness of expression is very often sacrificed to force. This conflict is apparent if we consider the question of rhythm. According to Spencer rhythmical structure is an economy of the reader's or hearer's attention. The strain required by the total irregularity of prose is diminished. If Spencer implies here by the indefinite word *economy* that the recipient's intellectual powers are utilized to the utmost and the attention of the understanding is aroused to its fullest capability by the metrical form of poetry, I can not agree with him. Its very monotony tends to lull the discrimination to rest. If Spencer in explaining the value of rhythm means by economy of attention a failure to exercise the intellectual energies, he is inconsistent with himself. Yet in his account of the effects of rhythm I agree with him. In its soporific effect on the intellect, in its holding of the understanding in abeyance, lies the virtue of metrical language. Poetry is necessarily metrical because it is necessarily emotional. Spencer himself recognizes not merely, as previously stated, that emotion naturally chooses the bepraised *direct* order, but that the natural language of emotion is metrical if the emotion be not violent. "Whilst the matter embodied is idealized emotion, the vehicle is the idealized language of emotion," he says in speaking of poetry.

Before dismissing Spencer's theory of style let us make a further effort to render it plausible. In the first place the essay was written, not as a philosophy of style but as a study of the causes of force of expression. From this point of view it is comprehensible to proclaim the superiority of poetry to prose, to make much of rhythm, and to be a little transcendental in the application of the inverted order. Again, no one can gainsay the principle of economy clearly set forth and rightly applied. But it is misleading in the highest degree to use *economy* in a double sense, as *failure to exercise,* and as *exercising to the greatest possible advantage.*

Now, it is true that in both prose and poetry there must be the greatest possible economy of both the mental energies and the mental sensibilities. But in poetry economy of the sensibilities means their greatest possible utilization, and economy of the mental energies their comparative suspension and elimination. While, *vice versa,* the principle of economy as applied to prose demands economy of the mental sensibilities in the sense of their comparative suspension and economy of the mental energies in the sense of their utmost utilization. In other words in poetry clearness must at times be sacrificed to force, and in prose the emotional must yield to the intellectual impression. This opposition between clearness and force is based on the psychological fact that the emotions interfere with the judgment. Attention to the sensational aspect of an impression may blind us to the perception. The subjective mental attitude militates against the objective. When Spencer recommends the use of Saxon words—a recommendation which in 1902 he confesses not to have himself followed—and at the same time praises the use in prose of the inverted order, he is really regarding the subject from two points of view. The short, familiar Saxon word may bring us more readily to the idea, it may be perfectly clear and all the more so because not emotional. But "Great is Diana of the Ephesians" is poor in its intellectual content, while it voices in the Bible story the ignorant fury of the populace. In the consciousness of this double aspect of the question Aristotle describes perfection of style as being clear without being mean. Now Saxon words tend to meanness and may, even on account of their simplicity, fall short of clearness. It is very obscure to say that an object is *round,* because *round* may mean *circular, spherical, cylindrical, discoid,* etc. Similarly Saxon words may be simple at the expense of clearness and precision. It seems perfectly natural that Spencer should find the language of the twelfth century inadequate to the needs of the twentieth. But even when clear, the Saxon, perhaps on account of its very familiarity, lacks the distinction that Aristotle recognizes as a requisite of perfect style. Choice of words is largely a matter of context, but *magnificent* may be preferable to *grand* or to the Saxon *great* on many grounds, among which its emotional suggestiveness should not be neglected. At any rate the attempt to hold university men of the twentieth century to the vocabulary of the subjugated portion of the population of England in the twelfth and thirteenth centuries is an absurdity that no theory of style can sanction, whether it lays emphasis on clearness, force or elegance.

More important than the mere choice of words in lending elevation and distinction to language is the use of figurative expressions. In the words of Aristotle "the greatest thing by far is to have a command of metaphor. This alone can not be imparted by another; it is the mark of genius—for to make good metaphors implies an eye for resemblances." Spencer similarly recognized that genius naturally tends to produce that style of composition which on analysis proves the most effective. The kinds of sentence which are theoretically best are those generally employed by superior minds, and by inferior minds *when excitement has raised them.*

When we regard the theory of style from the standpoint of recent psychology, a whole series of problems are seen to be involved—the nature of literary genius, association by similarity and its relation to the feelings, and connected with all these—and offering, perhaps, the best point of attack for our present purpose—the functioning of the creative imagination.

One might expect some light on the workings of the imagination from those who approach psychology from a pragmatist position and especially from such as treat the genetic and functional phases of psychology, particularly in view of the part played by the imagination in shaping our conduct—a part so great that we may be said to rehearse in imagination our vices and virtues before putting them into practise. In fact, the justification of recent psychologists in retaining the classifications and subdivisions of faculty psychology would seem to be the hope of confirming popular convictions in reference to mental science and of showing how the memory, will, reason and imagination contribute in their functioning to the needs of the organism. Such expectations still lack something of fulfilment. Chapters on the imagination continue to give a large, perhaps undue, proportion of space to the discussion of imagery. Works on psychology that confess a disposition to make the functional their text are disappointing and inadequate in their treatment of the imagination. In this field we may confidently await fresh developments, as functional psychology, pushed far enough, should tend to bridge the chasm between a dry science of the states of consciousness as such and a vital knowledge of human nature.

A psychology genetic other than in name may enable us not merely to realize the part played by the imagination from the dawn of psychic life and its contribution to the physical and social adjustment of the individual, but also to trace the connection of this faculty—I venture to write the word without quotation marks—with the life-preserving and life-promoting emotions.

It would be rash to claim that *recognition* in the lower animals implies imagery and that consequently all progressive adjustments, such as form the criteria of intelligence, imply the exercise of imagination. In fact, the indefiniteness of our conception of our own images when we speak of gustatory and tactual imagery, and the increasingly impalpable nature of the conception as in comparative psychology we descend the animal scale, make apparent in this matter the futility of all dogmatism. But it seems certain that growth in intelligence is correlative with the breaking up of the total situation, to which the animal reacts, into disparate and independent images, which can be grouped and elaborated after the manner of, in judgments, the later concepts. This means the gradual displacement of association by contiguity through association by similarity, which culminates in the imaginative constructions of genius.

This development of the consciousness is naturally most marked where the need of adjustment is most imperative. At this point of vital interest the feelings also are naturally engaged, and consequently an intimate relation is to be expected between the imagination and the feelings. We need not pause now to consider the interdependence of the functioning of the imagination and the genesis of the emotions. If necessity is the mother of invention, fear, anger, sympathy, pride and love in their various guises bring it to birth. *The inner connection between the emotion and the imagination seems to lie in the kinesthetic image* or, as some might prefer to say, the kinesthetic sensation. Here the distinction between image and sensation is hard to make. Introspection reveals that all perception is accompanied by kinesthetic sensations from the eye, ear and other organs of sense. The corresponding visual, auditory and gustatory images have also a kinesthetic accompaniment. Needless to say, the kinesthetic image is similarly accompanied and an extraordinary power of introspection would be required to observe a distinction.

The close association between the motor sensation and the affective phases of consciousness betrays itself in the terms used to indicate the latter. The following may be cited: *émotion, Gemütsbewegung, commotion, répulsion, aversion, Abstossung, agitation, Unruhe, moving, stirring, aufregend, rührend, erschütterend* and *émouvant.* Even *touching* and *touchant* (duco) might be added, though in them as in *das Gefühl, le sentiment* and *feeling,* the tactual predominates over the kinesthetic as the fundamental idea. The fact, however, can not be ignored that *feel* and *toucher* mean *to pass the hand over* and have consequently an important motor implication.

It is not then surprising to hear it maintained that the kinesthetic (strain and relaxation) is a necessary ingredient, not certainly of feeling-tone, which, though it depends upon sensory and ideational activities, can not be analyzed into motor elements, but of the complex emotional state, of which the feeling tone, or affection, is the characteristic feature. Whether the physiological complex that gives an emotion its special value can be analyzed into merely three pairs of elements, strain and relaxation, exaltation and depression, the agreeable and the disagreeable, or whether other ingredients might be mentioned, as the secretions and excretions and the cerebral circulation, the part played by the first pair is undoubted. In fact from the genetic point of view it might have been anticipated that the sthenic emotions would be accompanied by muscle strain and the asthenic by a corresponding relaxation; so much of the physiology of both fear and anger can be explained in terms of preparedness for action.

The value of such a view for the present study is that it enables us to trace the relation of the emotions to the imagination. The kinesthetic element forms, on the one hand, part of that physiological complex which gives to emotion color and zest, while on the other hand it supplies material for imaginative elaboration and renders more vivid imagery from other sensory sources. *In fact it is solely the presence of this element of feeling that distinguishes the imagination from the understanding.* The image, the raw material of the one, differs from the concept, the raw material of the other, just in that vividness which an accompanying kinesthetic sensation is able to impart. Moreover, a critical examination of an imaginative masterpiece will reveal, that a poet is guided by his feeling in the choice of subject, in his selection and rejection of the aspects of the theme which are to receive emphasis, in his use of phraseology and epithets—in fact, in the employment of all the devices of poetic art. The conveyance of a mood is the substance of art. For this contribution to truth we stand indebted to an emotionalistic esthetic. Now it must be added that *this conveyance of a mood is just the function of the artistic imagination,* as can be illustrated by an investigation of a poetic treatment of historical material. All additions, all subtractions, character-groupings, emphasis, subordination, retardation and precipitation of the events of the plot, local color and diction—everything that makes the finished product a work of the imagination—is brought about through the selective power of the mood to be conveyed. Painting would furnish similar examples of the working of the imagination. The feeling of exuberant exultation interprets for me Böcklin's "Im Spiele der Wellen"—the grotesque forms, the color scheme, every tint and shade, the atmosphere, every detail. Again, the feeling of dauntless resolution is the key to Dürer's "Ritter, Tod und Teufel." From the point of view of the mood to be conveyed nothing in the picture seems superfluous or irrelevant. The feeling guides the imagination of artist and connoisseur.

The view here maintained of the interdependence of the artistic imagination, the feelings and the kinesthetic elements of consciousness finds further confirmation when we consider esthetic appreciation as accompanied by a sympathetic imputation of our states of consciousness to the object contemplated, whether this be a part of nature or a work of art. This ascription of our motor states lies at the basis of personification and dictates the terms of imaginative description. Columns and spires and mountains are felt to *rise* majestically, or the headland *frowns* with beetling brows, the landscape or the sea *smiles,* and the sun *laughs* a pitiless laugh. It is a commonplace of psychology that the imaginative use of terms like *sweet, bitter* and *sour* is explained by the similarity of the physiological concomitants of certain affective states and of certain gustatory sensations. Of these similar concomitants the kinesthetic element constitutes the important feature. A sudden grief that we would regret and cast from us is *bitter,* months of deferred hope and suspended activity the poet describes as *sour.* That this sympathetic imputation of our own states of consciousness to the object contemplated involves, not merely imaginative and kinesthetic elements, but also an emotional element, is best indicated perhaps by the German word *Einfühlung.* This term expresses far better than *imputation,* or *inner imitation,* or *illusion,* or *conscious self-deception,* the attitude of the mind at the moment of esthetic appreciation. I ascribe its superiority to its recognition of the feelings as the basis of artistic satisfaction.

The close relation between the poetic imagination and the feelings is also seen when we consider that conditions that reduce to a minimum the perceptions, and the activities of the critical understanding, arouse both the feelings and the imagination. In dreams, in reveries, in visions of the night, at twilight, upon vague, obscure, ambiguous, sensory stimuli, they are set in motion. Mists, echoes, clouds, moonlight, shadows and reflections play a great rôle in poetic art. A faint perfume or the sound of a distant bell may bring a scene before the imagination with almost hallucinatory vividness. A slight sensory hint like the song of a bird heard in the heart of London may have such reminiscent power as to kindle the feelings and imagination so as to transform the dust into mist, the street into a stream, and the buildings into hills and mountains. That poets are especially subject to these illusory influences the investigations of Professor Dilthey serve to demonstrate.

It is the vague and indefinite in nature that calls forth the feelings and affords scope for the exercise of the imagination. Similarly it is the suggestive power, the alluring ambiguity, of poetry that constitutes its great charm. *Not clearness, but obscurity, is the supreme virtue of the poetic style.* Our study, then, of the creative imagination confirms the view, arrived at in the first part of the discussion, that economy of the mental sensibilities is frequently at the expense of the economy of the mental energies. To get the greatest possible emotional and imaginative effect the understanding must in literature, as it is in music, be held largely in abeyance.

Besides this general question of the theory of style, which lies at the basis of literary criticism, many others of course call for psychological treatment. The psychiatrist already speaks with authority in reference to the portrayal of abnormal characters in literature—cases of congenital paresis, senile dementia or *folie du doute;* the psychologist should speak no less decisively in reference to types of normal character and their development. In fine, hardly a question raised by literary criticism would fail to be elucidated and advanced by expert psychological investigation. Certainly, if criticism is to be rescued from its present state of mere impressionism and placed on a scientific basis, the psychologist must share in the task.

THE TRANSMISSION OF DISEASE BY MONEY

By A. CRESSY MORRISON

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THE demonstration of a few of the avenues by which infection is transmitted is among the triumphs of modern experimental medicine. By its revelations cholera is now known to be mainly a water-borne disease; likewise it is recognized that typhoid is transmitted by those means by which the waste products of an infected individual are transferred either directly or in round-about ways to the food of another; malaria is no longer thought to be wafted by the night air, but is known to be directly carried to and introduced into the system by the mosquitoes; and, even a later triumph, yellow fever is seen to approach its human victim through the same hosts; while, finally, it has been determined that bubonic plague, the scourge of the tropical east, is carried by the rat flea. Notwithstanding these recognized avenues of transmission in specific instances, many other and more common infections continue to travel from one to another by paths that we do not know.

Before the knowledge of cholera transmission by water, it would have been considered a scientific contribution to the subject to have demonstrated the absence of cholera germs in twenty-four samples of water taken at random some of which perhaps were dirty; but to-day we know that the bacteriological study of water for evidence of cholera will usually demonstrate the avenue of infection only when and where cholera is prevalent. Similarly, it would be a matter of the greatest surprise if the examinations of twenty-four or many more samples of water or food for typhoid germs revealed their presence, even if the water or food was dirty and offensive. Likewise, the most diligent search of twenty-four or more mosquitoes for malaria or yellow fever would in all probability fail to show a single malarial plasmodium or yellow fever bacillus. In the same way, hundreds of rat fleas might be caught and made to bite guinea-pigs or rats without the production of bubonic plague in a single instance. Do any of these negative observations disprove or discredit in the least degree our present views on the origin of the various diseases whose avenues of infection we have mentioned?

By what privilege then does our scientific friend, Warren W. Hilditch, of the Sheffield Laboratory of Bacteriology and Hygiene, Yale University, claim in THE POPULAR SCIENCE MONTHLY of August, 1908, even the least knowledge of the transmission of disease by money from the bacteriological study of twenty-four bills, "the dirtiest I could obtain from various sources, such as railroad, trolley and theater ticket offices, banks, drug stores and individuals in different part of the state"? When the facts of the transmission of cholera and typhoid by drinking water were discovered it was not by the demonstration of the corresponding germs in water, dirty or otherwise, which was taken at random. Indeed, these demonstrations were the last and most difficult steps in the whole chain of evidence and were only successful directed to water known to have been closely associated with epidemic outbreaks of the disease. By what reasoning, then, may we expect any more ready demonstration of infected money and why should not the same outside evidence of the possibility of infection guide as in the selection of money samples to be examined? Likewise, the demonstration of malaria in mosquitoes and bubonic plague in fleas was the last, not the first step in the chain of evidence, proving the avenues of infection of these diseases. The possibility and even the probability to a high degree were previously established by other evidence so that the material examined was advantageously selected.

Precisely as with cholera and typhoid the examination of water casually selected offers practically no opportunity of proving the transmission of these diseases by the demonstration of their specific infective organisms in the samples; exactly as with malaria, yellow fever and bubonic plague the examination of mosquitoes and fleas selected at random offers no promise of proving the transmission of these diseases by these hosts; so the examination of 24, of 240 or even of 2,400 bills not selected with intelligent appreciation of the opportunity for infection will contribute nothing at all to the solution of the transmission of infection by dirty money.

Great saving of human suffering and even life has resulted from triumphs referred to; likewise, the closing of other avenues of infection will certainly act as a prophylactic measure in regard to other infections. It is particularly desirable to discover the transmitting media of the more common but no less fatal organisms, such as the germs that infect the respiratory passages, notably the germs of colds, grip, diphtheria, pneumonia and tuberculosis. It is probable that the avenues of transmission of these germs are limited as are those of the diseases already discovered. It is, therefore, much more difficult to demonstrate the exact part that any particular avenue plays in the transmission. That dirty money, which, according to Mr. Hilditch, of the Sheffield Laboratory, Dr. Park, of the Research Laboratory of the Board of Health of New York, found to be "similar to other paper and rags and capable of carrying living tubercle and diphtheria bacilli for some days or longer," plays an important and unfortunate part in such transmissions is not only highly probable but is rendered more so by the very conditions found by Mr. Hilditch on the twenty-four bills selected by him from various sources, none of which is known to have had any direct connection with infectious material.

Examinations of drinking water for the agents of cholera or typhoid infection is so laborious and negative results are of such uncertain value that bacteriologists do not ordinarily make use of the direct isolation and identification of the specific germs of the disease in determining the purity of a given water, but rather look for indirect evidence of pollution which may be determined with more certainty and which is accordingly of greater negative as well as positive value. This evidence ordinarily consists of the identification of the colon bacillus, the recognition of which is certain and the presence of which signifies the contamination of the drinking water with material in which the colon bacillus is a normal inhabitant, namely, with human or animal waste. The demonstration of colon bacilli, then, constitutes proof of pollution of the water in a way that makes the introduction of cholera and typhoid germs possible. Even if they are not present, the way is open for their introduction at any time and the water is accordingly unfit for consumption.

It is desirable, it seems to me, to apply precisely the same principles to money. Mr. Hilditch has demonstrated that the average number of bacteria in each of twenty-one bills was 142,000, while by far the most common forms present were the varieties of the pyogenic staphylococcus. These organisms were not in possession of their full virulence but merely produced a more or less local reaction, on guinea-pig injection, with swelling of the lymph glands of the groin. Their constant presence on money is certainly of greater significance than merely indicating the exposure to the bacterial contamination of the air; they clearly indicate that the money has been contaminated by handling and without regard to the virulence or the danger of infection to which these particular organisms themselves expose those who receive the money, they establish beyond question the most fundamental and significant fact for scientific demonstration, viz., that *money is a medium of bacterial communication from one individual to another.*

Upon the question of the communication of highly infectious organisms, scientific evidence should now be sought by competent examinations of money known to have been exposed to sources of such contamination. It is not enough to know that much of the money in circulation is merely dirty; it should be known whether it is or is not a medium of the transmission of disease where such disease exists to be transmitted. From the contributions of Mr. Hilditch it appears that the handling of money infects it; from the observations of Dr. Park it appears that the germs of diphtheria and tuberculosis may live on bills infected by these germs for several days or longer. It seems but a step, then, to the final demonstration of the actual transmission of these and similar diseases by money in circulation and to the prevention of such spread of disease by the proper measures to eradicate such possibilities.

HOW COULD AN EXPLORER FIND THE POLE?

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THE claim to have reached the north pole, a point sought for several hundred years by many intrepid explorers, must, of course, be substantiated by adequate proof; and it may interest readers of this magazine to know what kind of proof is possible and necessary, and what observations the explorer must make to determine his geographical position when he is in the neighborhood of the pole.

Let us say, in the first place, that neither photographs, which only show the condition of the ice, but do not indicate whether they were taken near the pole or several hundred miles from it, nor the testimony of human beings, gives any evidence whatever that an explorer has been to the pole. Persons who were not actually with the explorer can only express their confidence in his good faith, in his knowledge of the proper astronomical observations to be made, and in his ability to make them with sufficient accuracy. Persons who accompanied him could only vouch for the fact that he did not remain in camp at a comfortable distance from the pole and manufacture observations, but that he actually traveled in the general direction of the pole, that on a certain date he claimed he was there, and that he made frequent astronomical observations on the route.

The only evidence which can at all satisfactorily show that an explorer has been near the pole is that afforded by observations on the sun or stars, capable of determining his successive positions at the times they were taken. Other evidence might prove the negative; such as inconsistencies in the narrative, inadequate time or insufficient food for the distance traveled, the description of phenomena which could not have been seen at the place where the explorer thought he was; and so on. It is impossible to foresee the many discrepancies which might show that an explorer has not been to the pole; they will not be considered here, as this article is not controversial, but merely aims to set forth, as simply as possible, what kind of observations must decide the claim of having reached the pole.

Confining our attention for the moment to observations on the sun, for the sake of simplicity of statement, we may say that the determination of one's position anywhere on the earth depends upon measuring the altitude of the sun above the horizon at two times, the second being, preferably, after the direction of the sun has changed by 90°. This becomes clear if we consider Fig. 1. Let us suppose the sun is in the direction S and is immediately over the point A of the earth's surface. Its altitude there is 90°. As we pass along the earth's surface away from A, the direction of the horizon continually changes and the altitude of the sun continually diminishes until we reach the great circle, BC, which divides the light from the dark hemisphere, and there the sun is on the horizon and its altitude is zero degrees.

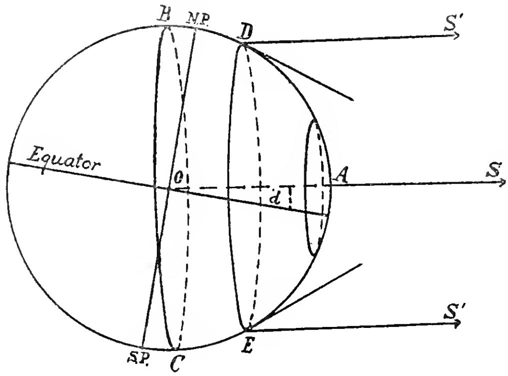


FIG. 1.

As the earth is spherical, and therefore symmetrical round the line OS, if we draw a circle DE on its surface, with its plane at right angles to this line, the altitude of the sun, as seen from all parts of this circle, will be the same; at the point D this altitude will be represented by h, the angle between the direction of the sun DS' and the horizon; for the sun is so distant from the earth, that its direction is the same from the center of the earth and from any point of the surface, to the degree of accuracy required by explorers. Every part of the circle DE is at right angles to the direction of the sun. The altitude of the sun changes with, and is determined by, the distance of the circle DE from A; and, *vice versa*, if the altitude is known, the distance of the circle from A is determined. The point A, itself, is fixed when we know Greenwich time and the angular height d of the sun above the equator; this latter is called the *declination;* it is continually changing, but its value at any time can be found in the "Nautical Almanac." An explorer would always take with him a copy of this work or an abbreviation of it; and he would also be supplied with chronometers keeping Greenwich time.

If an explorer has measured the altitude of the sun, and has at the same time observed the Greenwich time by his chronometer, he has merely determined that he is somewhere on a certain circle, whose position he could plot on his map; but other considerations, such as his last determined location, and the approximate distance he had traveled from it, would make known more or less roughly in what part of the circle he was; but he could not determine his position accurately. If, some time after his first measure of the sun's altitude, he should make a second similar measure, he would determine his position on a second circle; and the intersection of those two circles would determine his position completely. The determination, of course, would be more accurate if the circles cut each other at a high angle, and this could be insured by making the second set of observations on the sun after it had changed its direction (measured on the horizontal plane) by about 90°. Instead of making two sets of observations on the sun, we might, in the evening, observe two stars properly located with respect to each other, and we could then find two circles of position in a few minutes and completely determine our position.

If the sun is due north or south the part of the circle on which the observer is will coincide with his parallel of latitude, which is thus immediately determined; if the sun is due east or west, a part of the circle will correspond with the meridian and the longitude will be found. The old method of determining position at sea, and one still in use, was to observe the sun at noon for latitude, and to accept as local noon the poorly determined time when the sun reached its highest altitude; or to observe also in the morning or evening for time or longitude, guessing at the latitude to work out the observations. But the new method makes it possible to observe altitudes at any time and to get satisfactory results even if the sun were hidden for several hours during the middle of the day. And besides it makes clear just what information regarding our position is yielded by a single observation of the sun's altitude. This beautiful method was first used by Captain Thomas H. Sumner, of Boston, Mass., in 1837; the short parts of the circle which are drawn on the map in finding one's position are called *Sumner's lines.*

If an explorer were approaching the north pole, and had arrived, let us say within a degree of it, it would be necessary for him to determine his latitude in order to know his distance from the pole, and to determine the direction of the pole in order to know his course. It might be supposed that when approaching the pole he would, by means of his compass, be able to follow his meridian; but the difficulty of keeping a fixed direction when traveling over rough ice, and especially the shifting of his position by the unknown drift of the ice, would soon make a decided change in his longitude in a region where the meridians converge so rapidly.

In the neighborhood of the north pole the compass needle points approximately in the direction of the meridian 155° west of Greenwich, according to Neumayer, but the angle between the needle and the meridian changes considerably for comparatively small variations of position; especially as the distance from the pole becomes smaller.

The North Star, so closely associated in our minds with the pole, would be of no use to the explorer, for it is about a degree and a quarter from the pole, and, like the other stars, it would circle around the observer, and at times even be directly south of him. To determine its direction the explorer would have to know his own latitude and local time; moreover, it would be invisible if the sun were above the horizon.

By means of his chronometer, keeping Greenwich mean time, the explorer could determine the direction of any meridian, for the sun would be on the meridian of Greenwich at Greenwich noon, and would move 15 degrees in longitude for every hour thereafter; this knowledge would be very valuable to enable him to lay out his return course from the pole to his base of supplies, but it would not, in ignorance of his meridian, help him to find the pole; for the direction of the pole in relation to the direction of the sun, or of the compass needle, does not depend upon the general direction of the meridians, but upon the particular meridian on which he happens to be.

We have thus the apparent anomaly that the same observations would enable a person to set a satisfactory course away from the pole, but not toward it. But the anomaly is only apparent; for, suppose the base of supplies were on the 70th meridian and in latitude 83°; and suppose the explorer were near the pole and twenty miles from the 70th meridian, on one side or the other; he could lay a course parallel with the 70th meridian and this direction would only differ by about a third of a degree from the most direct line to his base of supplies; but if he kept this course accurately, he would miss his base by twenty miles. This, however, would be less important than missing the pole by the same distance.

The very simple method of determining latitude by the altitude of the sun when on the meridian would not be available to the explorer, for his meridian would not be known; and it would require a set of observations extending over several hours to learn when the sun was on his meridian. On the sixth of April the sun would circle around the horizon, at an average altitude of about $6\frac{1}{4}$ degrees, and would only be two degrees higher at midday than at midnight, as seen by an explorer one degree from the north pole, provided its declination were constant; this, however, is not so; but on the date mentioned we should find, superposed on the variation in altitude due to the rotation of the earth, a steady increase in altitude amounting to a little more than a third of a degree in a day. On April 21 the sun's altitude would be about $11\frac{3}{4}$ degrees above the horizon, and the variations in altitude during the day would be almost the same as on the earlier date.

To determine his position, and the direction of the pole, the explorer must fall back on the method of Sumner's lines, and fortunately they can be applied with special facility in the neighborhood of the pole.

Let us suppose then that an explorer is approaching the north pole in the neighborhood of meridian 120 degrees. (See Fig. 2, where the outer circle represents a circle one degree from the pole, and the radiating lines are the meridians, 0 degree being that of Greenwich.) He determines the altitude of the sun when by his chronometer, let us say, it is in longitude 30 degrees. He now works out his latitude on the supposition that he also is in longitude 30 degrees; suppose his results give an apparent altitude of 89 degrees 50 minutes. He lays off that latitude on the 30th meridian at *A*, and draws a straight line

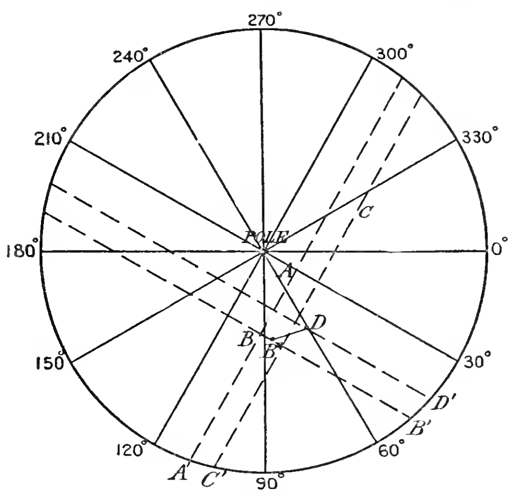


FIG. 2.

AA' at right angles to the latter; this line will practically coincide with a part of the circle at all of whose points the sun has the observed altitude at the time the observations were made; his position is therefore somewhere on this straight line, and, guessing about how far he has traveled from his last determined position, he can estimate roughly where he is; but if bad weather has prevented observations for several days, or the unknown drift of the ice has been strong, he might be many miles wrong.

If he should wait for six hours and make another similar observation of the sun's altitude when it is on the 120th meridian, he would determine a second line on which he would be; his true position would then be at the intersection of these two lines. If the second observation determined an apparent latitude of 89 degrees 40 minutes, he would lay off this latitude on the 120th meridian, draw a straight line, *BB'*, at right angles to the latter, and his true position would be at *B*;

this is about 22 minutes, or about 25 English miles, from the pole, and nearly on the 90th meridian. He now knows his position, and by the Greenwich time and the position of the sun he knows the direction of the 90th meridian, and therefore of the pole.

He then travels in the direction of the pole, keeping this direction by means of his compass or by the sun and his chronometer. Knowing about how fast he travels, he knows when he is in the immediate neighborhood of the pole, and he checks his position again by another pair of observations similar to the last.

Suppose, however, the drift of the ice has been quite strong; it may have carried him several miles from the line *AA′* during the six hours between his observations; at the time of the second observation he would, indeed, be on the line *BB′*, but he would no longer be on the line *AA′*. If he should wait another six hours and observe the sun when on the 210th meridian, he would then find himself, let us say, on the line *CC′;* and, assuming a uniform drift of the ice, his position at the time of the second observation would have been on the line *BB′* half way between the lines *AA′* and *CC′*—that is, at *B″*; but he has drifted away from the line *BB′* during the six hours since he determined his position on that line, and he does not know exactly where he is on the line *CC′*. If he waits six hours longer, and observes the sun when on the 300th meridian, and then finds himself on the line *DD′*, his true position at that time will be at *D*, and the drift of the ice during the twelve hours between his second and fourth observations will have been in the direction *B″D*, and it will have drifted a distance equal to the length of the line *B″D* on the scale of the figure.

An explorer may find his position by pure calculation, and may not use the graphic method described, but the principle in the two methods is exactly the same, and the graphic method shows more clearly what the observations mean.

An important source of error enters all these observations, namely, atmospheric refraction, or the bending down of the light rays as they pass through the atmosphere. The amount of this bending increases rapidly as the sun is nearer the horizon; it also varies with the barometric pressure, and with the temperature. On April 21, 1908, the sun was only about 11¾ degrees, and on April 6, 1909, only about 6¼ degrees above the horizon at the north pole; on both dates the refraction was considerable, and it is hardly well enough known to prevent errors of several minutes of arc in the determinations of position. If, however, the observer should wait for twenty-four hours after his first observation and should measure a fifth altitude of the sun, he could find a fair correction for the refraction and greatly improve the determination of his position.

It would be unreasonable to expect an explorer, making a dash for the pole, to remain twenty-four or even eighteen hours at one camp for the purpose of exactly determining his position. By making daily observations on the sun, at different hours, so as not merely to fix his successive positions on a series of parallel lines, but on lines having different directions; by keeping his direction with the compass and estimating the drift of the ice and his rate of travel, he could always know where he was without too large an error. But when he was in the immediate neighborhood of the pole he should make as many observations, with the sun in different directions, as circumstances would permit.

Fatigue, severe cold, the condition of his commissariat, and the anxiety to return after having succeeded in his bold undertaking, might prevent him from making as many observations as would be desirable; but nevertheless they might be sufficient to be convincing that he had been within a few miles of the pole; it would surely be a quibble to dispute with an explorer the honor of having reached the pole if his observations showed, without reasonable doubt, that he had been within ten or fifteen miles of it.

There are two kinds of instruments used for measuring altitudes; the transit-theodolite and the sextant. The former consists of a telescope so mounted that it can turn in a vertical and in a horizontal plane; it is provided with vertical and horizontal graduated circles, to measure the angle turned through, and with leveling screws and spirit levels to adjust it in position. It is supported by a tripod, and after being properly leveled, the reading of the vertical circle gives the altitude of the object sighted through the telescope. It is by far the best instrument for an explorer on land, because it is very easy to use, and its adaptation to measure horizontal angles enables the explorer to carry on an ordinary survey.

The sextant was originally invented for use at sea, where a steady support can not be found. It consists of a telescope mounted on a frame, which is held in the hand. To measure the angle between two objects, one of them is sighted directly through the telescope, and the image of the second is reflected into the telescope by means of two mirrors, one fixed rigidly to the frame in front of the telescope, and covering half its field, and the other movable around an axis fastened to the frame. The movable mirror is turned by an arm, which moves along a graduated arc on the frame, and its reading, when the two objects appear in the telescope superposed upon each other, gives the angle beteween the objects. In determining the altitude of the sun at sea the edge of the sun is made to touch the horizon; a movement of the ship moves the sun and the horizon together and the contact is not destroyed. On land, when the sea horizon is not available, a so-called *artificial horizon* must be used. The ordinary mercurial artificial horizon consists of a flat dish about three inches wide and five or six long, filled to a small depth with mercury, the surface of which becomes perfectly horizontal. The image of the sun seen in the mercury will be as much below the horizontal plane as the actual sun is above it; and the angle between the sun and its image is twice the altitude of the sun. Except in very quiet air, the surface of the mercury must be protected from the wind by an accurately made glass cover.

The glass artificial horizon is a piece of perfectly flat dark glass, which will absorb the light which enters it and only reflect from its upper surface. It is provided with leveling screws and spirit levels so that it can be made perfectly horizontal. It is used in exactly the same way as a mercurial horizon.

Each form has its advantages; the glass horizon is easily transported, and can be used at temperatures below the freezing point of mercury (about 39° below zero Fahrenheit). On the other hand, it requires very careful leveling, and is liable to be broken. The mercury of a mercurial horizon is usually carried in an iron bottle; in pouring it back and forth it might be spilled and lost; and at very low temperatures it would be necessary to heat it to keep it liquid; but then it immediately takes a level surface and requires no leveling.

Lieutenant Shackleton, traveling over the Antarctic continent, determined his position by means of a small transit. Commander Peary and Dr. Cook, traveling over the floating ice of the Arctics, used sextants. The former used a mercurial and the latter a glass horizon.

It is interesting to note that if a man were taking an observation standing, with the sun about 6 degrees above the horizon and the artificial horizon on the level of his feet, it would have to be about 45 feet from him, and as he would look at it from an angle of about 6 degrees, it would only appear about half an inch long. If the altitude of the sun were 12 degrees, the artificial horizon would be 25 feet away and appear about an inch long. This can be easily imitated by putting a sheet of paper on the ground and looking at it from distances of 25 and 45 feet. Under such conditions the difficulties of making a good observation would be much increased. If, however, the artificial horizon were raised on a support, the observer would stand much closer to it, and the observation could be more easily made.

Another important instrument is the chronometer keeping mean Greenwich time; for, as has already been shown, the determination of position in general requires a knowledge of Greenwich time, though at the pole itself this is not necessary. Whenever an explorer remained as long as a week in one place he should determine, as well as he could, how much his chronometers were gaining or losing per day; and he should be most particular to determine the changes in their errors, between the times of leaving and returning to his base station.

A compass is of great value to keep one's course between observations on the sun; and an aneroid barometer and a thermometer make possible a more accurate correction for refraction. A pedometer, also, or some other form of distance meter, would be useful to estimate the distance traveled.

Although the methods of determining one's geographical position would be the same near either pole, there are slight differences in their applications; for instance, the solid land of the Antarctic continent precludes drift, and therefore this disturbance is absent. Moreover, when Lieutenant Shackleton reached his farthest south in the beginning of January, 1909, the sun was about 25 degrees above the horizon; at this altitude the refraction is not large and its value is well enough known not to introduce any great error. Near Lieutenant Shackleton's base camp, at the foot of Mount Erebus, the north pole of the compass needle pointed about 30 degrees east of south. Along the most southerly part of his route, on his dash toward the pole, the north end of the needle pointed very nearly to the south pole.

On the return trip Lieutenant Shackleton could have been guided by his compass, by the mountain range which ran very nearly parallel with his route, or by other landmarks, and, perhaps, to some extent, by his tracks: so that he found it unnecessary to make many astronomical observations. Commander Peary was guided, to a great extent, on his return by his tracks and those of his supporting parties; and Dr. Cook seems to have relied entirely on his astronomical observations.

Note.—For the sake of simplicity the sun has been generally taken, in this article, as the heavenly body on which observations are made. But the stars could serve equally well, and, for some observations, better. If the pole should be approached when the stars were visible, the altitudes of two stars lying on meridians about 90 degrees apart would determine one's position without delay; moreover, stars could be selected whose altitudes were sufficiently great to exclude errors due to refraction; or this correction could be determined by observations on a pair of stars having about the same altitude and lying on opposite sides of the zenith.

The sun's apparent motion around the earth is not uniform, and therefore a correction, known as the *equation of time*, must be applied to all observations on the sun: but this correction is accurately known and leads to no error.

Anton Dohrn.

THE PROGRESS OF SCIENCE

ANTON DOHRN, 1840–1909

In the death of Anton Dohrn zoology mourns a veteran leader, and many zoologists feel—though some of these may not have known him personally—that they have lost a genial and helpful friend. Every one knew him directly or indirectly, and one may even say that there are but few zoologists who are not in some way or another in his debt. For he founded the great station at Naples, and fostered its activities in many directions. It is no mean test of his successful management that it is supported by the funds of many nations and of many diverse institutions.

Dohrn's monument will ever be the Stazione Zoologica: its inception was his, its upbuilding, its policy and its completion—if such a work can ever be called completed. From the time of his early studies—while indeed he was in Messina, in the sixties—he had ever before him the vision of a completed zoological station, an international one, vast in size, splendid in equipment. And with prophetic eye he selected Naples as the field of his life-work. He soon found that his project was not an easy one to carry out, especially in days when sea-side laboratories were rare and obscure, and when indeed zoology had hardly come to its own in the scheme of sciences. But Dohrn surmounted the difficulties, scientific, political and financial. In the last regard, when the Academy of Berlin failed to endorse his project, he showed to friends and enemies his faith in his convictions by putting his personal funds, almost all of them, into the melting pot. In the end his arguments were so convincing that the German government granted him a handsome annual subsidy, and insured the success of his undertaking.

Dohrn's history can here be given only in the briefest lines. He was born in 1840, the son of a North German Fabrikbesitzer of scientific tastes. He became a student of Schnell in Jena, devoting himself especially to the study of the arthropods. He was appointed privat-docent; then he traveled, theorized and wrote, but he taught little; apparently he did not care for the class-room, and even at the end he could point to but few whom he had directly trained. At the outbreak of the war of 1870, Dohrn became a soldier and fought through the campaign; then he returned to his great plan of the stazione and his struggles in its behalf. The opening of the first building was in 1874, the publications (Mittheilungen and Memoirs) of the station began in 1879, the second building was completed in 1890, the third building (for physiology) in 1907. Through all these years he continued his difficult researches, publishing his results in a series of memoirs. From the first to the last Dohrn showed a rare many-sidedness; to many he was ever the genial friend, to a few the explosive and repentant enemy; at one moment he was the tactful executive, at another the amateur of music and art, at all times the idealist and the profound and conscientious scholar, ever ready (*too* ready some said) to accept the evidence of facts and to change his scientific views. He had qualities, all in all, which made him a personage of first magnitude in the annals of zoology.

Dohrn's activities in research could readily be made the theme of a volume. For he was a tireless worker and his publications touch many of the most important problems of his day. His earlier years were spent in the study of the embryology of the arthropods (1858–81): of this period is to be mentioned his beautiful monograph on the pantopods. In 1875 appeared his paper "On the Origin of the Vertebrata and on the Principle of the Change of Function"; it was a small brochure, but it touched with a master's hand some of the great problems of its day. This paper Brooks declared should be read by every one of his pupils before he would give him his doctorate—this in spite of Brooks's lack of sympathy with the tenets which Dohrn had laid down. It was this paper which paved his way for researches which were to extend over a third of a century. And one may follow the development of the subject—and of Dohrn himself—in a series of twenty-five voluminous memoirs.

It was the "momentous problem of the beginnings of the back-boned animals" which Dohrn sought to solve. And upon this matter his writings are encyclopedic. Vertebrates were to him descendants of chætopod worms; their typical organs did not arise *de novo* but as transformations of organs having a different function; animals of simple structures were not as often primitive as Haeckel, for example, would teach, but were frequently degenerate; Amphioxus and Ascidians were not in the line of descent of the higher vertebrates, nor were lampreys—the latter were rather degenerate bony-fishes. In his early papers his readers are carried along on the crest of a splendid wave of enthusiasm. "The problem is solved, . . . all but solved, . . . soon to be solved." But this stage of conviction comes to pass darkly into the background, new difficulties keep appearing, and in later papers one hardly realizes the genetic bearing of the data which Dohrn is bringing together. The method of the paper of 1875, which was essentially deductive, gradually gave place to an elaborate inductive method; separate organs of the vertebrata are studied in turn, especially in the head region, and the difficulties are traced gradually into finer and finer ramifications, until in the end he deals with what appears to be purely the puzzle of nerve histogenesis. For Dohrn would not admit that the head problem in the vertebrate was not to be solved with the present materials or by the aid of the embryo-

THE NAPLES ZOOLOGICAL STATION.

logical method; and one feels that he kept hoping against hope that some clue would yet be found to lead him triumphantly out of his labyrinth of difficulties. So he held fast to his plan of research, undismayed when his fellow workers deserted him. "The problem is difficult, not dead," he is said to have declared, when others entered some new and attractive field—"and it is in the difficulties of an old problem that one learns, not in beginning a new one."

Dohrn suffered, there can be no doubt, in noticing that as time went on "the problems of the head" attracted fewer workers. But such a man must have realized, none the less, that this was an inevitable result when new lines of investigation are suddenly developed and when the number of investigators available for all fields is small. And in his heart he must have felt that his theme would always be given a high place, even by those to whom it became "unfashionable." On the other hand if there was no general sympathy for his embryological work there was certainly no lack of appreciation of his work for the Naples station. He lived to see it in the position which he had planned for it, and he took keen satisfaction in seeing his son Reinhart installed as its executive. So he may well have felt in the end, as the solace of his long illness, that his work had been well done.

THE NON-MAGNETIC YACHT "CARNEGIE"

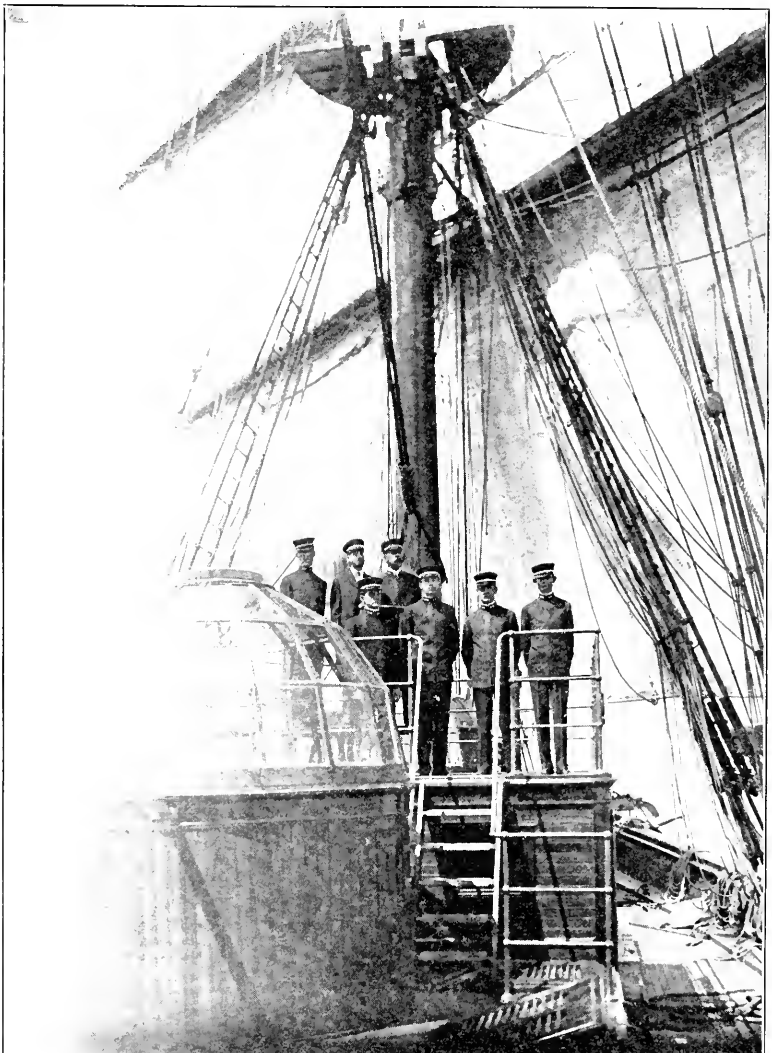
The *Carnegie* left Brooklyn, N. Y., on August 21 last, to carry out her first cruise, extending to St. John's N. F., thence to England and returning to New York, early next year, *via* Madeira and Bermuda. As may be recalled, this vessel has been built practically without any iron, or other magnetic materials, in order to adapt her to the needs of a magnetic survey of the oceans under the direction of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

She arrived at St. John's on September 25 and left again on October 2 with the director, Dr. L. A. Bauer, on board, accomplishing the passage across the Atlantic to Falmouth, England, in twelve days. She is now *en route* to Madeira and Bermuda under the command of W. J. Peters. In addition to the scientific and navigation staff, composed of seven persons, there are on board two watch officers, two cooks and nine seamen, or twenty persons in all.

The tests and observations made thus far have proved that the desired non-magnetic conditions where the various instruments are placed have been actually secured, so that no corrections whatsoever need be applied to the magnetic data obtained on the *Carnegie.* In consequence the work has been greatly facilitated and for the first time it has become possible to make known the results immediately upon conclusion of a voyage. The instruments, largely designed and constructed in the workshop of Dr. Bauer's department, have reached a high stage of perfection, permitting satisfactory observations to be made even under adverse conditions of sea and weather.

The introduction of sheltering observatories, circular in shape and having revolvable domes similar to those of astronomical observatories, is one of the new features which has contributed to the success achieved. Inside these observatories, of which there are two, the after one being shown in the view, both astronomical and magnetic observations may be made with full protection to the observer and instrument from wind and weather.

During a period of six weeks the work of this vessel has already disclosed errors in the magnetic data supplied to mariners of sufficient practical importance to require attention. Thus it was found that from Long Island to a point off St. John's the charts show too small west magnetic declination by



THE "CARNEGIE."

amounts running up to one degree and a half, *i. e.*, the compass was found to point farther to the west of north than indicated by the charts. On the portion of the trip from St. John's to Falmouth, an error in the reverse direction was revealed, showing that the compass did not, in general, point as far west as given by the mariner's charts—the errors almost reached a degree.

The effect of these chart errors, on account of their systematic and peculiar run, is to set both inward- and outward-bound vessels towards Sable Island or Cape Race whenever sole reliance must be placed upon the compass, as is the case when no sun or stars may be sighted. It appears that captains have been aware of these systematic errors and have learned how to make allowance for them, but their precise cause has not been known until this work of the *Carnegie*.

Another feature in which considerable interest attaches is the development of the producer-gas engine for the purposes of auxiliary marine propulsion. The *Carnegie* is said to be the first sea-going vessel equipped with such a plant. Her engine is of 150 horse-power, sufficient to drive her six knots in calm weather and give her a cruising radius of 2,000 miles with a coal consumption of but 25 tons, or at a cost of about $100.

THE CONVOCATION WEEK MEETINGS AT BOSTON

THE American Association for the Advancement of Science and the national scientific societies affiliated with it will meet at Boston, beginning on December 27. There is good reason to look forward to a meeting of unusual interest, perhaps to the largest and most important scientific gathering in the history of the country. In the summer of 1898 the American Association celebrated at Boston the fiftieth anniversary of its foundation with 903 members in attendance, almost the largest meeting up to that time, the largest having also been held in Boston—in 1880—with an attendance of 997. In 1898 the membership of the association was 1,729; it is now over 8,000. In the meanwhile, beginning with the Washington meeting of 1902–3, the convocation week meetings have been organized, and the national scientific societies devoted to the natural and exact sciences meet together during the week following Christmas. The attendance of scientific men at these meetings has been in the neighborhood of two thousand, and the number of scientific papers presented has approached a thousand. The meeting has become more technical in character, and it seems that the interests of those not professionally engaged in scientific work have been somewhat neglected. At the Boston meeting, however, it is proposed to leave the special papers to the special societies, while the association and its twelve sections will present programs of general interest.

Dr. T. C. Chamberlin, of the University of Chicago, eminent as a geologist and for his services to education, will, as retiring president, give the annual address on the evening of Monday, December 27. The address will be at the Sanders Theater, Harvard University, and will be followed by a reception in Memorial Hall. The vice-presidential addresses will be given by Professor Keyser, of Columbia University; Professor Sumner, of Yale University; Professor Herrick, of the University of Chicago; Professor Guthe, of the University of Michigan; Professor Richards, of Columbia University; Professor Kahlenberg, of the University of Wisconsin; Professor Howell, of the Johns Hopkins University; Professor Swain, of Harvard University; Professors Dewey and Woodworth, of Columbia University. All these addresses should be of interest to a wide audience, and each section is expected to arrange a discussion or series of papers that will not be technical in character.

The special societies meeting at Boston cover practically the whole range of the natural and exact sciences. The American Society of Naturalists has this year arranged a program devoted to problems of experimental evolution, which includes papers by the leading workers in this subject. The address of the president, Professor T. H. Morgan, of Columbia University, is on "Cause or Purpose in the Evolution of Adaptations." The American Chemical Society, which is the largest of the special societies, must be divided into numerous sections for the reading of papers. There are, however, general sessions, before one of which Dr. Whitney, of the General Electrical Company, will give the presidential address on the chemistry of artificial light. The mathematicians, the physicists, the geologists, the paleontologists, the biological chemists, the physiologists, the anatomists, the bacteriologists, the zoologists, the entomologists, the botanists, the anthropologists, the psychologists and other groups will hold meetings whose programs would fill many pages.

The railways have allowed the usual reduction in rates on the certificate plan. Apart from scientific programs of unusual attractiveness the educational and other institutions of Boston can under such circumstances be visited to special advantage. Those who are professionally engaged in scientific work and those who are interested in following the progress of science can to equal advantage be present at Boston during convocation week.

SCIENTIFIC ITEMS

The Nobel prizes for the present year have been awarded as follows: For Physics—Divided between Mr. Guglielmo Marconi and Professor Ferdinand Braun, of Strassburg. For Chemistry—Professor Wilhelm Ostwald, of Leipzig. For Physiology or Medicine—Professor Theodor Kocher, of Berne. For Literature—Selma Langerlof, the Swedish authoress. For the Promotion of Peace—Baron D'Estournelles de Constant, president of the French parliamentary group for international arbitration, and M. Beernaert, former Minister of State of Belgium.

The Royal Society has awarded its Copley medal to Dr. G. W. Hill, of Nyack, N. Y., for his researches in mathematical astronomy; royal medals to Professor A. E. Love, for his researches in the theory of elasticity and cognate subjects and to Major Ronald Ross, for his researches in connection with malaria; the Davy medal to Sir James Dewar, for his researches at low temperatures, and the Hughes medal to Dr. R. T. Glazebrook, for his researches on electrical standards.

The Philosophical Society of Washington held on December 4 a meeting commemorative of the life and services of Professor Simon Newcomb, late president of the society. The program included addresses by the Honorable James Bryce, Dr. Milton Updegraff, Dr. R. S. Woodward, Dr. L. O. Howard and Dr. E. M. Gallaudet.

At the recent meeting of the board of trustees of the Carnegie Foundation for the Advancement of Teaching, Dr. Ira Remsen, president of Johns Hopkins University, and Dr. Charles R. Van Hise, of the University of Wisconsin, were elected trustees to fill vacancies caused by the resignations of Dr. Charles W. Eliot, of Harvard University, and Dr. E. H. Hughes, of De Pauw University. Provost Charles E. Harrison, of the University of Pennsylvania, was elected chairman of the board to fill the vacancy caused by the retirement of Dr. Eliot.

By the will of the late George Crocker, of New York City, valuable property, said to be worth about $1,500,000, has been bequeathed to Columbia University for researches on the cause, prevention and cure of cancer.—The board of trustees of the Reed Institute will establish at Portland, Ore, a College of Arts and Sciences, with the bequest of $2,000,000 left by the late Mrs. Amanda W. Reed.

THE POPULAR SCIENCE MONTHLY.

FEBRUARY, 1910

SCIENTIFIC FAITH AND WORKS[1]

By Professor ARTHUR GORDON WEBSTER

CLARK UNIVERSITY

THE ancient poets, at the beginning of their great epics, invoke the muse, and forthwith proclaim their subjects:

Arma virumque cano, I sing of arms and the man, says Virgil, *Μῆνιν ἄειδε θεά*—Achilles' baleful wrath, O Goddess, sing, are the words with which Homer begins the Iliad. A modern poet, full of sympathy with the changed times of to-day, Rudyard Kipling, makes one of his most attractive characters, the old Scotch engineer, exclaim,

> I'm sick of all their quirks an' turns—the loves an' doves they dream—
> Lord, send a man like Robbie Burns to sing the Song o' Steam!

In undertaking to do my part in the dedication of this splendid temple of science, I can but echo McAndrew's prayer, and wish that I had the words of a poet to sing the song of science. For what true devotee of science does not look upon her as a star-eyed goddess, and feel within himself at times feelings akin to those of the poet when breathing the divine afflatus? For the chief characteristic of both the poet and the scientist is the creative spirit, the poet creates beauty, or the appreciation of it, the scientist creates truth, or if he does not create truth, he at least creates the appreciation of it and of its results. I have chosen for my subject "Scientific Faith and Works." According to the Apostle Paul, "faith is the substance of things hoped for, the evidence of things not seen." In an eloquent panegyric, he recounts to us the deeds of the Hebrew patriarchs, "who by faith subdued kingdoms, wrought righteousness, obtained promises, stopped the mouths of lions,

[1] An address delivered at the dedication of the Laboratory of Physics, University of Illinois, November 26, 1909.

quenched the violence of fire, escaped the edge of the sword, out of weakness were made strong, waxed valiant in fight, turned to flight the armies of the aliens." I shall make it my task to show, by a not too literal application of the text, that similar effects may be produced through science. The more practical and prosaic Apostle James, on the other hand, in a chapter somewhat disparaging faith, exalts works, and issues the challenge, "Shew me thy faith without thy works, and I will shew thee my faith by my works." It is no doubt easier in the case of science to play the rôle of James than that of Paul. The works of science are abundant, and are appreciated of all. To catalogue them is an easy and somewhat commonplace task. But in order to better appreciate them let us take a brief glance at the world before it was under the influence of science as it is to-day.

If we consider the differences between ourselves and the ancients, we are at once struck by the fact that the chief dissimilarity is that they had little or nothing that can properly be called science. Deep thinkers they had, poets that have never been surpassed for lofty imagination and noble diction, teachers who devoted their lives to the attempt to solve the mysteries of existence, but the systematic study of the workings of nature is essentially modern. The great Hebrew nation, to whom we are indebted for so much that is fundamental in our religion and morals, brought the laws of conduct and the purity of life to an extent never equalled by the other nations of antiquity. Being essentially a race of simple shepherds and agriculturists, although in close contact with nature they produced no art, graphic or architectural, and left no engineering works to arouse our admiration for their resourcefulness. The sacred writings of the Hebrews are full of allusions to nature, in both its kind and terrible aspects. "Canst thou bind the sweet influences of the Pleiades? or loose the bands of Orion? Hast thou an arm like God? or canst thou thunder with a voice like him? Deep calleth unto deep at the noise of thy waterspouts: all thy waves and thy billows are gone over me. The heavens declare the glory of God, and the firmament sheweth his handiwork." These are specimens of the Hebrews' attitude toward nature, one of deep awe and reverence for its mighty Creator rather than of admiration for nature itself. The idea of studying into the workings of nature would, no doubt, have seemed preposterous and irreverent to such minds. The bow in the cloud was naturally accepted as a pledge made by God to men, while its circular form and unvarying arrangement of colors led to no curiosity to know why. The Egyptians, who so long were masters of the Hebrews, surpassed them in their interference with nature, and carried on engineering operations on an extensive scale, though of a simple character. They devised simple engines for raising the water of the Nile, and developed great irrigation systems, while the pyramids still remain a source of wonder to moderns. If we may believe all that students of the pyramids tell us, the Egyptians had no mean knowledge of astronomy as well. Certain it is that the Assyrians had a knowledge not only of astronomy, but of mathematics, having highly developed systems of numeration and methods of calculation, their sexagesimal system of numeration having come down to us in the division of the circle into three hundred and sixty degrees, against which anachronism the decimal system is but now beginning to struggle. The engineering operations of the Egyptians, however, were of a very simple sort, and their construction of the pyramids was probably permitted rather by the unlimited supply of forced labor than by the employment of devices for taking advantage of anything but brute force.

As the Hebrews were specialists in morals, so the Greeks were specialists in beauty, and pushed its culture to a degree never before or since attained. Had the Greeks left to us no masterpieces of literature, we should forever remember them by their magnificent temples, their incomparable sculpture, and their beautiful vases. Such a people must inevitably have had great thoughts to express in prose and verse, and it is not surprising that they were sensible of the beauties of the intellect, and pushed the study of geometry to a very considerable extent. The value which they attached to this study may be inferred from the inscription over the door of Plato's academy, "Let none enter who is not a geometrician," a motto which, by the way, I would gladly see placed over the gate of the modern college. Archytas of Tarentum, about 400 B.C., had devised apparatus for constructing various curves, had recognized the spherical form of the earth, and its daily rotation. Aristotle wrote a voluminous treatise on animals, showing careful observation of their habits, and even left a treatment of mechanical problems in which he almost recognizes the nature of the parallelogram of motions and of centrifugal force. In the domain of physics, however, he is not particularly happy, and is better at asking questions than in solving them. A hundred years later, however, Archimedes, the greatest of the Greek scientists, not only makes great advances in geometry, including a method that is in a measure the precursor of the integral calculus, but displays an acute knowledge of the principles of statics, including the principle of the lever, and of the fundamentals of hydrostatics, especially the principle named after him. With Archimedes, as with the other Greek philosophers, the practical applications accompanied, and probably generally preceded, the theoretical inquiries, and indeed this is still usually the case. The Romans, who succeeded the Greeks in importance in the ancient world, certainly did not do so on account of their cultivation of scientific studies, in which they played a poor part. Their very clumsy system of numeration would show their lack of mathematical talent, but on the other hand their extremely practical nature led them to the execution of great engineering works, their roads, aqueducts and baths still remaining for our admiration to-day. After the fall of the Romans succeeds the long night of the dark ages, learning being kept alive only by the Saracens, and the achievements of the Greeks being so far forgotten as to require to be discovered anew. Finally came the fall of Constantinople with the dispersal in Europe of many Greek scholars, the Renaissance, and the revival of learning. Conditions were then ripe for the prosecution of all sorts of intellectual pursuits, and we find the study of nature for itself taking on a development never before dreamed of. To these the church, in many cases, did not offer a welcome. Accustomed, during the middle ages, to the supreme domination over men's minds, she did not look with favor on a movement destined to set them free from all bonds except the truth. Copernicus died too soon to come into conflict with the power of the church, but upon his follower Galileo she wreaked her vengeance, and Giordano Bruno she burned at the stake. Nevertheless, the powerful genius of Galileo gave rise to so many and so important discoveries as to constitute him the father of modern science. Not satisfied with the introspective methods of the Greeks, who often contented themselves with considering how nature ought to work, he developed the modern method of the direct appeal to nature, by means of experiment finding out how she actually did work. When in the presence of the scoffing schoolmen he dropped the heavy and the light weight from the top of the tower of Pisa, and found them both to reach the ground together, he sounded the death-knell of the old and outworn Aristotelian philosophy.

It is not my intention here to consider the history of science, and its development from the small beginnings of the cinquecento through its glorious burst in the eighteenth century to full fruition in the nineteenth. Let us briefly recapitulate some of the changes which the works of science have made in the face of the earth, and of mankind inhabiting it. First and most important is the production of power, by which man's energies are inconceivably multiplied. The discovery of coal at just the right time to be utilized in the invention of the steam engine enabled man to command hitherto undreamed of forces, making the constructions and manufactures of the ancients seem like child's play. The raising of cotton, made practical by the invention of the cotton gin, largely transformed the clothing of the world, while the development of the iron and steel industry revolutionized methods of construction. With the command of power in centralized units came the development of the industrial system, and the tendency to crowd together into cities, leading to so many scientific problems yet unsolved. With the tremendous increase in the wants of humanity brought about by the increased power to supply them, the supply of natural energy in the form of coal, which at first seemed inexhaustible, seemed menaced, and other natural resources had to be developed, and more efficient methods of application found. Thus in our day the development of the internal combustion or gas engine, which threatens to crowd the steam engine to the wall, has finally permitted the application of petroleum, which by the aid of chemistry has furnished not only great stores of energy, but numerous useful products. Not the least important aspect of the power development is that part which is applied to transportation. The covering of the whole known world with lines of railway has made possible and easy movements from place to place not only of peoples, but of products, so that while a few centuries ago a large proportion of the population never moved more than a few miles from their birthplaces, being as good as fettered to the soil, now even the poorest may be easily displaced from country to country, the seas being no more of a barrier than the land. The increase of education by travel, and the tendency toward peace produced by the increased acquaintance of nations with each other, is not to be overestimated. Perhaps no more impressive example of man's power over nature is to be found than the sight of a great ocean steamship, lying at her dock and towering over the surrounding buildings, or ploughing her way at express speed over the stormy waves, whose power she hardly seems to feel. A notion of the huge demands made by ocean transportation on our resources of energy is obtained when we think that one of these marine monsters is using sixty or eighty thousand horsepower, while an express train uses from a thousand to fifteen hundred only. In view of this depletion of our coal supplies the question of water power has become urgent, and science has succeeded in bridling our rivers and waterfalls for further supplies, while the transmission of this power by electricity has made manufacturing possible where it was not before, and is now being applied to transportation on a large scale. Not to be neglected in connection with the application of power is the question of illumination. When we think of the dark and dismal nights in the cities, not only of antiquity, but even of two centuries ago, making it impossible to go out in safety at night, and encouraging all sorts of crimes of violence, we must consider the successive application of gas, oil and electricity to have had no mean influence on the habits of mankind. The use of modern illuminants, especially electrical, has made possible the performance of more work, under more healthful conditions, and has completely changed the habits of man as regards the hours of darkness. Whether this has been entirely for his advantage we may leave until later.

Almost equally important with transportation is communication, which has in like manner changed the possibilities and habits of mankind. At the time of our revolution it took weeks to get any news to or from Europe, while even as late as the civil war our news was two weeks old when it reached England. What a contrast to the present, when the news of the fall of a cabinet or the overthrow of a sultan last night in any part of the world is put before us at breakfast this morning, and that not only in the centers of population, but in remote country districts. Nations can not now ignore each other's feelings and desires, while those misapprehensions which lead to war are made many times less frequent. The use of the ocean cable and of the telephone has largely transformed methods of doing business. Time is money, and although the increased facility of locomotion has led hosts of business men to circulate from one end of the country to the other, this can now in large measure be saved by the use of the telephone.

More important for the existence of man even than transportation and communication is food. The applications of science have made not one, but thousands of blades of grass grow where one grew before. Chemistry has shown how to fertilize the exhausted soil, engineering has furnished water where none was, and caused the desert to blossom as the rose. Its latest feat, in the anxiety due to the exhaustion of the nitrate beds, has been the fixation of the nitrogen of the air, which in Norway combines the harnessing of the waters with the compulsion, in the electric arc, of the nitrogen to unite with the oxygen, thus yielding unlimited nitrates for the restoration of our exhausted food supplies. Here also transportation comes in, so that the famines which formerly vexed large portions of the earth have now lost their terrors. When we think of the misery of the English agricultural classes before the abolition of the corn laws we may well praise the development of transportation which has enabled her to eat out of our full hand. At the same time the application of thermodynamics to freezing machinery has enabled us to send our meat across the ocean to become the roast beef of old England. The effects of all this upon the farmer can not be passed by. Commanding the markets of the world, ploughing his fields by steam or electricity, grinding his grain by gasoline, feeding his stock from silos, milking his cows by vacuum, cooling his cream by cold-producing machinery, separating it in a centrifugal creamer, making his cheese by the aid of chemistry so that he duplicates the product of any locality in the world, in easy reach of the city by automobile or trolley-car, and in communication with all his neighbors by telephone, he is no longer an object of derision, a hayseed, but an example of the works of science, demanding an equal part of influence in the government of the country, and gladly contributing of his rich store to the endowment of institutions like this for the education of his youth and the further advancement of science.

Again let us consider what science has done for the amelioration of health. When we consider the crowding, the filth, the misery of the greater part of the populace in the cities of antiquity, of the middle ages, and of our own times in many cities of the orient, we can but feel that the application of science to sanitation, to sewerage, water supply, and housing, has been of immense benefit, although it has by no means kept up with the needs of civilization. The discoveries of preventive medicine have removed the terrors from small-pox and yellow fever, and made impossible the wholesale devastation of great cities by plagues which were common only a few centuries ago. In our own days we have seen the work of the microscopist reveal the cause of the most various diseases, from malaria and cholera to the hookworm disease, while the marvelous work of the surgeon's knife fills us with amazement. If it be desirable to live long, science has largely contributed to benefit mankind in this way. With the improvement in the conditions of work has come the possibility for increased amusement. Music is stored up in the phonograph, to be carried to the remotest corners of Asia and Africa, while the kinematograph has rendered all corners of the earth accessible to the multitude, and has vivified the scenes of history.

Not the least important of the works of science is its effect in the promotion of general peace. As the nations are more closely linked together by the means of transportation and communication, their interests become more nearly alike, and they do not so easily plunge into wars. The applications of science to war have at the same time made it more terrible and deadly, so that nations do not dare to expose themselves to the chance of physical or commercial extermination thereby involved. If the development of the aeroplane shall make it possible for a fast cruiser like the *Lusitania* to be sent out equipped with rapid flying-machines which, on catching the strongest battleship shall make it possible to sail over her at too great a height to be shot at, but near enough to drop high explosives that shall destroy her, war will be at an end. The late Edward Atkinson once stated that all that was necessary to end war was the invention of a gun that should pick off generals at headquarters as the Boer sharpshooters picked off the British captains and colonels.

But I have said enough in praise of the works of science. It is no doubt possible to exaggerate their praise. A most judicious and learned observer, his Excellency James Bryce, in a Phi Beta Kappa address at Harvard two years ago, has examined the question, "What is progress," and whether all our modern improvements have constituted real progress from the times of the ancients. His conclusion is somewhat disappointing, and at the end the beam inclines very slightly in the positive direction. He does consider it probable, however, that the advances of science have rendered more tolerable human life, and have lengthened its span. We must not forget, indeed, that with nearly every new advance some disadvantage is connected, that with the development of industrialism there is connected great injustice, that the results of crowding in cities have led to great misery and sickness, problems not yet solved, and that the recent survey of Pittsburg has revealed conditions which could doubtless be paralleled elsewhere, but which cause us to blush for our boasted civilization. At the same time, these defects are not to be charged to science, but to the failure to utilize it. On the other hand the increase of insanity due to the greater strenuousness of life brought on by modern conditions is not so easily explained away.

It is not, however, for all these works of science that I wish to arouse your enthusiasm. As I have before stated, I consider James the more prosaic apostle, while it is Paul that stirs our feelings. What is the object of science, and is it worth our devotion? What are its purposes and methods, and what may we hope from it? Does it consist in building railroads and bridges, laying cables, digging tunnels and canals, and converting coal into ice? I believe it does not. Let us suppose that the advance of science, the adoption of socialism, or what not, has furnished every working man not only with three acres and a cow, but with hot and cold water, sanitary plumbing, steam heating, with cold brine for refrigeration, milk and beer laid on in pipes, with electric lighting, heating and power for the sewing machine, vacuum cleaner and the few remaining domestic necessities, with a telephone for communication and for the enjoyment of contemporary music, a phonograph and automatic piano for that of the past, an automobile and flying machine for transportation and sport, and that the hours of labor have been reduced to four, will universal happiness then reign? I fear not, if this is all. For life does not consist exclusively of eating and drinking, nor yet of pleasure. Unless what we call the soul is improved as well as the body, life is likely to be a poor thing. It is here that we come to the improvement of morals and of taste, and the need for art, literature and science. I mention these together, for their purposes are the same. They elevate the mind, kindle the imagination and give a more lofty outlook on the universe in general. It is the satisfaction of man's legitimate curiosity, his desire to know the how and the why of nature, that is, in my opinion, the true end of science. There are in the world, we are told by the late William Kingdon Clifford, three classes of persons: in the first place, scientific thinkers, secondly, persons who are engaged in work upon what are called scientific subjects, but who in general do not, and are not expected to, think about these subjects in a scientific manner, and lastly those whose work and thoughts are unscientific. Scientific thought is not determined by the subject thought of. The subject of science is the universe, its limitations those of the human mind. When the captain of a ship finds its position by means of observations with the sextant, or when an engineer constructs a dynamo with the aid of a drawing and data known to be correct, he does not engage in scientific thought, although he makes use of experience previously collected. When the computer in the office of the Nautical Almanac computes an eclipse of the moon, foretelling it to a second of time several years before the event, he is not engaged in scientific thought, but is making use of technical skill. When, on the other hand, Adams and Leverrier, computing the positions of the planet Uranus, found them not verified in fact, but by the assumption of a new hypothesis, were able to discover the planet Neptune, they were engaged in scientific thought of a high order. The collection of facts, as one collects postage stamps or coins, does not constitute science. In order to have science the facts must be fitted into a definite system, in accordance with a classification on the basis of what we call laws. It is a prerequisite for the existence of any science whatever that we admit that nature is subject to uniformity, that is, that similar circumstances of similar things will be followed by similar results. The belief that the order of nature is reasonable, that is, that there is a correspondence between her ways and our thoughts, and that this correspondence can be found out, is what I have called scientific faith. The method of the inductive sciences, those that concern the facts of nature, is first to observe a class of seemingly related facts in order to find out what they have in common, then if possible to form some hypothesis as to their relation, then to compare the different cases with the hypothesis in order to see whether it is justified. When this process has been successfully carried out, we are able to predict what will occur in given circumstances, although these circumstances have not occurred. This is what we mean by discovering a law of nature, namely, finding a common property of a class of phenomena, such that under all circumstances the phenomena which will ensue can be described. This is what constitutes the difference between scientific and technical thought. Technical knowledge enables us to deal with cases that have occurred before, while scientific knowledge enables us to deal with what has not occurred before.

This is a matter that is not always understood in this country. It is a matter of common knowledge that this country stands very high in technical knowledge, but it is not so often pointed out that her contribution to science has as yet been distressingly small. Numerous examples might be given. We have just been celebrating the anniversary of Fulton's steamboat, with well-deserved enthusiasm. Nevertheless we must remember that Fulton did not invent the steamboat, nor did he construct the first one. He combined knowledge then existing with practical sense and business acumen, and was able to build a boat so large and successful as to convince the world of a new mode of transportation. In recent times the question of developing the power of Niagara involved the construction of turbines larger than had ever been built. These were built in Philadelphia, by means of the technical skill there existing, but the designs were made in Geneva by the well known engineers Faesch and Piccard. As a matter of fact the Swiss had long since developed the theory of the turbine, and were prepared to design one of any size on the principles already found sound. More recently the steam turbine has come into the field formerly the exclusive possession of the reciprocating steam engine. Curiously, the first successful turbines came from England, then a large number were developed in Germany and France, while at the present time we have one very successful American turbine. Now the physical principles involved in the turbine are quite different from those of the reciprocating engine, and involve considerable theoretical knowledge of the properties of fluids in rapid motion, some of which were familiar in the case of water, but which were of a different sort for an expansive vapor like steam. It is very noticeable that the best treatises on the steam turbine to-day are German, and begin with a large amount of theory on the properties of rotating discs, then of the thermodynamics of vapors, and finally of the flow of steam through jets, before the technical matters are touched. We are now hoping for the development of the gas-turbine, which shall combine the two advantages of the gas-engine and the turbine, and which will demand for its success all the knowledge of thermodynamics which we possess. As a final example take the case of wireless telegraphy. This country was a pioneer in ordinary telegraphy, having not only Morse to contribute the technical knowledge, but before him Henry with his scientific development of the electromagnet, but the wireless telegraph was imported in an advanced state of development, from England, where the scientific acumen of Maxwell had predicted the action of the electric waves. I am sorry to say that I feel that there is a tendency among our engineers or at least among our engineering students to try to do their work with a very small amount of scientific thinking, and it seems to me that this tendency must be overcome if we wish to maintain a successful competition in either science or technology with such a thorough-going scientific nation as Germany.

There is a tendency to-day in some quarters to disparage the use of hypotheses. With this tendency I do not sympathize. It is difficult to see how scientific advances can be made without the use of hypotheses, nor has that been the ordinary custom. The phrase of Newton has been quoted, "*Hypotheses non fingo,*" but certainly that must be interpreted as meaning that he did not form unnecessary explanations of phenomena rather than that he did not proceed by means of working hypotheses, for he did. By making the hypothesis that the earth attracted bodies according to the inverse square of the distance, and calculating whether the fall of the moon toward the earth was of the amount required by this supposition, he was able to predicate the law of gravitation, and by the calculation that the orbit of a body attracted according to this law would be an ellipse he was able to explain the law of planetary motion discovered by Kepler. It is difficult to see how Kepler could have arrived at his law of elliptic motion if he had not first guessed that the orbits of the planets were circles or conic sections, and then verified it by comparison with the observations on their apparent positions.

The chief test of the success of a scientific hypothesis and of a train of reasoning therefrom is found in the ability to make predictions. Of this probably the most striking example in all science is the law of gravitation just alluded to. All the observations of the last two hundred years have only resulted in confirming Newton's conclusion, while the accuracy of astronomical prediction exceeds that of any part of science. Such is an example of scientific faith. Another famous example is Hamilton's famous discovery of conical refraction. On looking through a piece of Iceland spar at an object one sees it doubled. The laws of this double refraction had been thoroughly described by Fresnel, who related them to a certain geometrical surface invented by him. By the study of the geometry of this surface, which was found to possess two singular points, Hamilton showed that on looking through the crystal in a certain direction at a point, one would see not two points but a whole continuous circle. This experiment was made by Hamilton's friend Lloyd, who saw the circle, confirming in the most brilliant manner the wonderful imagination of Hamilton, who saw in his mind's eye what never yet man had seen.

Another example of successful hypothesis is afforded by the kinetic theory of gases, which explains the properties of gases by the hypothesis that they consist of extremely small particles in very rapid motion, which by striking each other and the walls of the containing vessel by the impacts give rise to the pressure which the gas exerts. On this theory the friction which a current of gas exerts on a portion moving less rapidly, thereby setting it in motion, is of the same nature as the action that a crowd of men jumping from a moving train to a car upon a parallel track would have, their momentum tending to set the second car on which they alighted in motion. One of the remarkable predictions of this theory is the result of Maxwell that the viscosity of the gas is independent of its density, a result which has been well verified by experiment.

As a final example of scientific thought, let me briefly refer to the hypothesis of the luminiferous ether. About one hundred years ago, this hypothesis, that light consisted of a motion of the nature of waves, obtained the victory over the old notion that light consisted of small particles shot out from the luminous object with great rapidity. The laws of the propagation of these waves were thoroughly described by Fresnel, but what the properties of the substance in which they were propagated, and called the ether, might be, was long a matter of difficulty. Green had shown that an elastic solid of a certain sort would possess many of the properties of the ether, but this mechanical theory was insufficient in certain ways. It was the conjecture of Faraday that the actions of electrified and magnetic bodies upon each other, so thoroughly investigated by him, were transmitted to each other by means of the ether, and it was the genius of Maxwell and his wonderful scientific imagination, that enabled him to erect this conjecture into a remarkably perfect theory. By means of the hypothesis that electrical and magnetic actions are subject to the laws of mechanics, Maxwell was able to apply to electric currents the equations of Lagrange for dealing with the motion of the most general mechanical systems of bodies. In this way Maxwell explained the laws of the induction of currents, the difficulty of starting or stopping a current corresponding to the inertia of a heavy body. Presently by the aid of an auxiliary assumption the properties of the ether were described, and the remarkable result found that electrical and magnetic effects would be propagated with the velocity of light. From this it was a short step to declare light waves to be electromagnetic waves. Such waves were not known at the time of Maxwell's paper in 1865, and his theory waited long for acceptance. In 1888, however, Heinrich Hertz, guided by his great master Helmholtz into acceptance of Maxwell's theory, succeeded, in a most brilliant series of experiments, in producing the very waves predicted by Maxwell, and in showing that they traveled with the velocity of light. These are the waves made use of by Marconi for transmitting intelligence, and conquering the sea in peace and in war. But this is not all, for Maxwell, in his description of the manner in which the ether transmitted the electromagnetic waves, assumed that it was subject to certain stresses, so that a surface receiving a beam of light would experience a certain pressure, the amount of which he calculated. This result awaited verification until 1900, when the Russian physicist Lebedew, and in 1903 still more exactly the Americans Nichols and Hull, now president and professor, respectively, at Dartmouth College, gave it a magnificent verification. Thus by faith Maxwell subdued kingdoms, obtained promises, out of weakness was made strong, turned to flight the armies of the aliens of ignorance.

An interesting conclusion that may be drawn from the history of scientific endeavor is that there is an accepted time for each discovery, that is, that a certain stage of human progress the discovery is certain to be made, independently of the existence of any particular investigator. Such a truth is apt to put the scientist in that humble mood characteristic of the true man of science, and to show him how unimportant in the scheme of nature is any particular individual, but it need not leave him in the state described in the hymn, "Great God, how infinite art Thou, what worthless worms are we!" Examples of this conclusion are numerous. The discovery of Neptune simultaneously by Adams and Leverrier has already been mentioned. Singularly enough the planet was seen first by Galle, at Berlin, on September 23, 1846, and then independently by Professor Challis, at Cambridge, on September 29, he being ignorant of Galle's discovery. The statement of the Second Law of Thermodynamics in 1850 by Clausius and Lord Kelvin, and the discovery that the specific heat of saturated vapor is negative by Clausius and Rankine and others. The published work of Sir Oliver Lodge on electric waves shows that it admits of no doubt that had not Hertz published his researches when he did Lodge would have obtained many of his results. The work of Helmholtz and Lord Kelvin is full of interesting parallelisms, while the important application by Helmholtz of thermodynamics to chemical phenomena was anticipated by our own Willard Gibbs. Coming down to the present time, it is no disparagement to Wilbur and Orville Wright to say that had they not succeeded in the conquest of the air the same result would shortly have been achieved by Blériot, Voisin and others. I have no doubt that, had not Columbus discovered America in 1492, some other intrepid navigator would have done so in ten years. Had not Peary discovered the pole—but I pause, as fiction is sometimes stranger than truth.

I will now, with your permission, undertake to make a rough classification of the sciences, and make some remarks on the differences in their methods. Sitting serene at the head as queen of all is mathematics. Ready she is to serve all, and what a servant she can be is witnessed by those other sciences that have most need of her. Mathematics is probably the most misunderstood of all the sciences. Huxley called it "that science which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation." To this a sufficient answer might be that she does not need to, but a better one is that it is not true. Intuition and induction have a great part in all mathematical discoveries, as all of the great mathematicians agree. Mathematics has no subject matter, but may be applied to anything that has exact relations. To sing the beauties of mathematics to those ignorant of that subject is as futile as to praise music to the tone-deaf, or painting to the color-blind. I have a friend who describes a symphony as a horrid noise. The president of a great eastern university has said that the manipulation of mathematical symbols is a mark of no particular intellectual eminence. Presumably he had never tried it. To the often-repeated charge that mathematics will turn out only what is put in we may reply that while from incorrect assumptions it can not get correct results it has the power of so transforming the data as to reveal to us totally unexpected truths. Witness the magnificent generalizations of Adams and Leverrier, of Hamilton, and of Maxwell already quoted. There is no doubt that the invention of the infinitesimal calculus has furnished man with the most powerful and elegant instrument of thought ever devised. Allow me to try in a few words to tell why this is so. Natural phenomena are not, as a rule, discrete, like integral numbers, but continuous, like points on a line, so that there is no least difference between one and another. We say that they are continuous, and that they vary continuously. The examination of continuous change is the function of the differential calculus. When we undertake to define so simple a matter as the speed of a point, we can not say that the velocity is the distance traversed in a given time, unless during the whole of that time the speed is the same. If it is continually changing we must divide the time into less and less intervals, and find the ratio of the distance to the time required when both become smaller than any quantity conceivable, in other words we must find the *limit* approached by this ratio. Thus all questions relating to rates of change, to slopes of curves, to curvature, and the like, require the method of limits, as applied in the differential calculus. On the other hand, consider the case of two bodies attracting each other according to any law of the distance. Since the body is more than a point, from what point of the body shall the distance be measured. Obviously each small portion of the body contributes its part in the attraction, with a different amount according to where it is, all these amounts requiring to be added together to make the whole. But how many parts shall there be, and how large. Obviously there is no bound to the number, nor to the size, one increasing as the other decreases. We must accordingly take the limit which this sum of all the actions approaches as we increase the number of parts while diminishing their size below any limit whatever. This is the method of the integral calculus, Now as observation enables us to deal with bodies of finite size only, the inference to the laws of the ultimate parts can be made only deductively by the calculus. In practise, however, the inverse process is more frequently employed, that is, the actions of points infinitely near each other in space, time or other circumstances are assumed to follow some simple law, thus giving us what are called differential equations, the integration of which gives us conclusions as to what happens on the large scale, which conclusions can be compared with experiment. It is on account of the logical importance of the method, the universality of its applicability, and the intellectual power developed, that I could wish that as a counterpart to Plato's motto should be placed over every college gateway, "Let none depart hence who knows not the calculus," at least as to what it deals with, and its fundamental principles.

I am glad to say that in some of our colleges are now given courses in what is termed "culture calculus." It seems to me that this subject is more deserving of the name of culture than the familiarity with the immoralities of the Greek gods.

Of the natural sciences there are two fundamental ones, physics and biology. Physics has to do with all the universe, in so far as it possesses energy, and exerts forces one part upon another, and in so far as it does not possess life. Biology deals with all matter possessing this difficultly defined attribute, but so far as we know, even the phenomena of living matter are subject to the laws of physics. I presume that every biologist will admit that life does not create energy, but merely directs it. Nevertheless, the question of vitality is to-day far beyond the explanation of the physicist. The subdivisions of physics have been, for convenience only, set off as individual sciences, chiefly because the whole subject would be too large for the treatment of any individual scientist. The most important part of physics is dynamics, which treats of the laws of motion, and the forces which are associated therewith. Of this a great division is celestial mechanics, which, as we have seen in the cases of Galileo and Newton, contributed in great part to the inductive establishment of the laws of motion in general. The remainder of astronomy is now catalogued as astrophysics and is dealt with by purely physical methods and instruments. As a subdivision of astronomy may be reckoned geodesy, which deals with the form of the earth, deduced from astronomical measurements and from its gravitational attraction.

Chemistry is that part of physics which deals with the properties of substances that have individual characteristics by which they may be always distinguished, and which combine with each other in definite proportions. Its methods are those of physics, its main instrument is the physical balance, and it is in recent years concentrating more attention upon those physical relations connected with temperature, pressure, and electrical relations, all of which are now found to yield to mathematical treatment in a manner until recently unsuspected.

The methods of physics and chemistry usually involve the controlling of certain of the circumstances under which phenomena occur, so that the changes in others may be more easily observed. This is usually done in a laboratory furnished with many means of controlling circumstances, for instance, temperature, pressure, electrical or magnetic state, so that the same circumstances may be reproduced again and again. Meteorology, or as it is now somewhat grandiloquently called, cosmical physics, has to do with those phenomena of the atmosphere, the ocean, or the magnetic state of the earth, which are not controllable by man, and which can not, therefore, be repeated at pleasure in the laboratory, but must be observed when and where they occur. The same applies to geology, which is the application of physics, chemistry and even biology, or any science whatever, to the earth, in relation to its physical constitution and its history. Geography deals with the face of the earth, and uses the results of geology to study the earth as fit to be the dwelling place for man. There remain the technical applications of physics in all kinds of engineering, civil, mechanical, electrical, chemical or mining, involving the strength of materials, elasticity and the direction of the natural sources of energy to the purposes of man. All these applications of physics need, and are highly susceptible to, mathematical treatment, and for that reason they are the most perfectly developed of all the sciences.

Let us now turn to the biological sciences. The two fundamental divisions, zoology and botany, dealing with animals and plants, seem to run continuously one into the other, like chemistry and physics. Under both we have the subdivisions of morphology for the study of form and physiology for function. Under zoology we put anatomy, and the various more specialized sciences which find their technical application in medicine. There still remain anthropology, the study of man and his practises, psychology, which deals with the workings of what we call his mind, or that of animals, sociology, properly a part of anthropology, dealing with man when living with his fellows, and economics striving to teach him how to get along with them still better.

This classification is admittedly rough, but it does not separate closely connected things as some that I have seen do. For those who desire finer splitting I refer to the classification of the Scientific Congresses of St. Louis in 1904. Of these biological sciences the methods are somewhat different, they are mostly still in the descriptive stage, and have rarely attained sufficient quantitative information to be capable of mathematical treatment. And yet that must be their ultimate object, for without mathematics there is no exact description. That this is not impossible even in biology may be seen from the following example. If a bacterial culture be inoculated into a jelly with the point of a needle, it will be seen under the microscope to grow in all directions from the original center, and if pains are taken to ensure the physical homogeneity of the jelly the shape of the colony will be an almost perfect circle. If the diameter of this circle be measured at regular intervals, I have no doubt that a quantitative law of growth can be deduced, and even a differential equation found, which will turn out to resemble that of certain physical phenomena, say the conduction of heat. We may observe that the instruments and methods of the physiologist and the experimental psychologist are already largely physical, and their researches are carried on in laboratories. In proportion as the various circumstances are rendered more amenable to external control, so the methods of biology will more nearly approach those of physics. Whereas biology was until recently chiefly a science of observation, it has now become in a high degree experimental. The physiologist removes or alters organs, removes eggs from the natural parent and places them in a foster-mother, cuts off the heads and tails of worms and observes the conditions of survival and regeneration. If the force of gravity were removed, in what direction would a plant grow? If an egg be subjected to centrifugal force in which direction will the head of the animal appear? These are the sort of questions that the biologist is now attacking. Nor is he without mathematical statements. The great generalization of Darwin of fifty years ago has ever since concentrated attention on problems of development and heredity. Darwin's conclusions were the results of the observations of a long life. Now the experimental method enables one to hasten and accelerate conclusions. The gentle monk and acute man of science, Gregor Mendel, forty years ago in his cloister at Brünn by his careful experiments on the crossing of thousands of peas, and by comparisons of their seeds, flowers and stems, succeeded in unveiling a law which has profoundly influenced ideas on heredity, not only in plants but in animals. He finds that in the process of hybridization there are certain characteristics which are transmitted entire to the offspring, and are termed dominant, others which seem to disappear or become latent in the process, which he terms recessive. When however the hybrids are bred together both qualities reappear in the offspring, and in a definite proportion of three of the dominant to one of the recessive. In the next generation another definite proportion occurs, and so on. We here have a very definite arithmetical relation, which is susceptible of very exact study and confirmation.

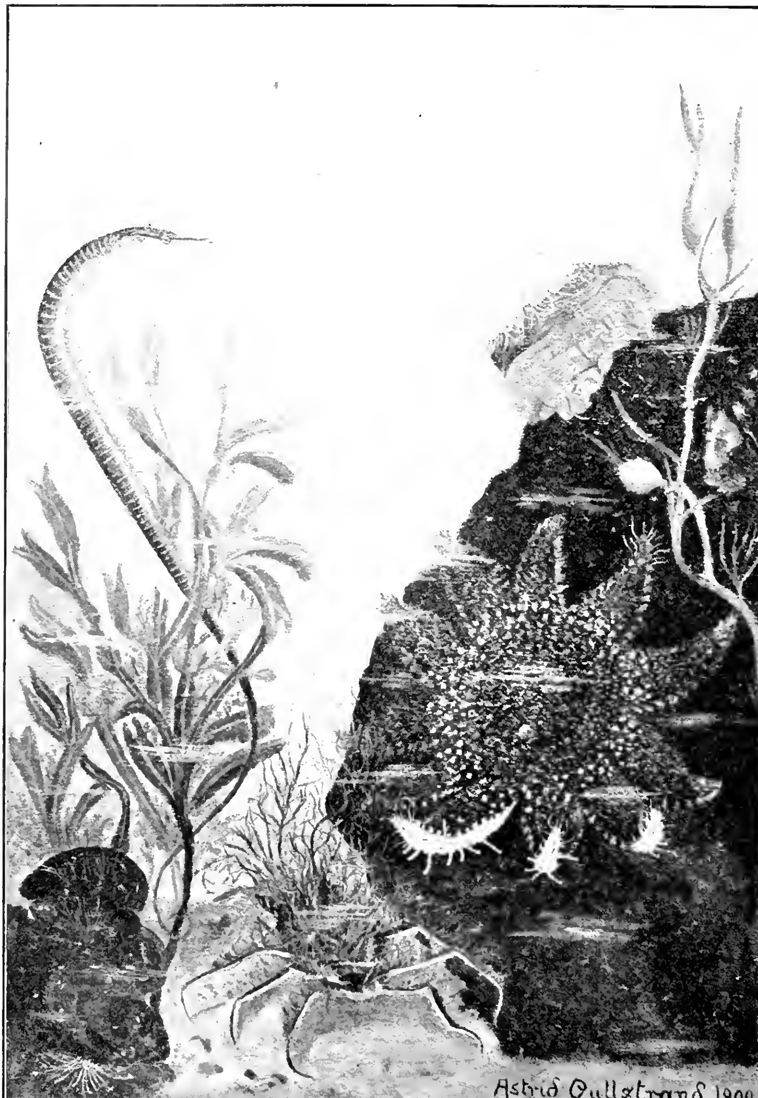
The method of Mendel, which we may call that of experimental evolution, is now of wide application, and there are laboratories which do nothing else but breed and cross under very exact control. Among one of the large-scale experimenters in this line may be mentioned Mr. Luther Burbank, who, though a master of method and subsidized by the Carnegie Institution, seems to be devoted rather to practical than to scientific results.

In connection with the laboratory or experimental method in evolution, must be mentioned a most promising application of mathematics to biology in the new science of biometrics, or the application of the methods of probability or statistics to great numbers of similar objects. If the doctrines of evolution or of variation are ever to be accurately proved it must be in this manner. To illustrate, suppose we have a phenomenon in which chance is involved, and that two events are equally likely, such as throwing head or tail with a coin. Suppose we have a vertical board in which are stuck horizontal pegs in a regular arrangement of rows and columns. Suppose a shot be dropped over the middle of this array of pegs, and assume that if it strikes a peg it is equally likely to drop to the right or the left. The next time it strikes a peg the chances are the same. It is obviously very unlikely that a shot will continually fall on the same side, while the likeliest thing that can happen is that it shall fall in the middle. Hence if a large number of shot are let fall they will be found, if caught where they fall, to be arranged in a form limited by a curve highest in the middle, and gradually falling symmetrically toward both sides, known as the curve of errors. This curve represents graphically the result of an infinite number of causes acting, each as likely to produce a certain effect as its opposite. Let us now take some biological subject of investigation, say the length of a certain kind of shell. Many thousands being measured, it is found that they vary from the average, but in such a way that very few differ very far from the mean. If the number having any given length is plotted vertically corresponding to the deviation from the mean laid off horizontally, we shall obtain a curve which will generally closely resemble the curve of errors. If this is the case we shall conclude that the causes of the variations in length are perfectly at random, but if we find that the curve is unsymmetrical, or for instance has two summits, we shall know that at least two sorts of causes are acting. Thus questions of heredity and variation may be mathematically studied. This method has been greatly developed by the mathematician, Karl Pearson, who has now devoted himself to the study of evolution by mathematical means.

Finally, that apparently most remote of the sciences from the exactness of physical laws, economics, has been brought under the treatment of mathematics, not only by statistical methods like those just described, but by methods of the calculus. The distinguished mathematician and economist Cournot applied to the theory of wealth methods like those used in mechanics to treat of equilibria, so that very complicated economic principles were amenable to treatment by symbols.

I have, I think, said enough to show the power of science to transform the world, and to develop the mind of man. Is not this development of high spiritual value, and is not the pursuit of truth irrespective of prejudice and authority a noble object, worthy of the devotion of a lifetime? Of the moral values of science it would be easy to give arguments. One has but to consider the self sacrifice of many of its devotees, who consider neither toil nor time if only the good of the race be advanced. Galileo was tortured, Giordano Bruno was burned, and to-day the daily papers bring us news of lives lost in the study of the cholera, of the plague, of the sleeping sickness. The spirit of science is well illustrated by the gift to the Pasteur Institute by M. Osiris last summer of thirty millions of francs. He was led to do this by the fact that the director, Doctor Roux, having won a prize of one hundred thousand francs for the discovery of a diphtheria serum, though not a rich man, immediately turned it over to the institute. Feeling that a cause capable of producing such unselfishness must deserve support, M. Osiris made it this large bequest. Lord Rayleigh, in like manner, donated his Nobel prize of forty thousand dollars to the physical laboratory at Cambridge.

In closing, permit me to recommend the scientific career to young men as one of great satisfaction, whether one succeeds in it or not. To be even a soldier in this noble army, to feel oneself the follower of Faraday, of Helmholtz and of Maxwell, to push on the standard of truth, is worth more than to dress in purple and fine linen and to own many automobiles. There are in this country of eighty millions only about five thousand scientists. The country needs you, young men; it is a patriotic duty to put her where she should stand intellectually among the nations. Would that I might reach the rich, and sing to them the praises of this sort of service. In other lands the rich serve the state, why not here? Surpass your less fortunate brothers not in your pleasures, but in your achievements. And then the American college will be exempt from some of the criticism that it meets to-day. Finally let us bear in mind that while we admire the palaces of science like this, they are not necessary for the performance of good work, and that those of us who are obliged to work in less sumptuous abodes may be consoled with the reflection that most of the great discoveries in science were made with simple apparatus, in humble quarters, but by great men. It is the *spirit* that quickeneth. For the true scientific spirit may we ever pray, for the works of the Lord are great, sought out of all them that have pleasure therein.



FROM AN OIL PAINTING BY FRU GULLSTRAND.

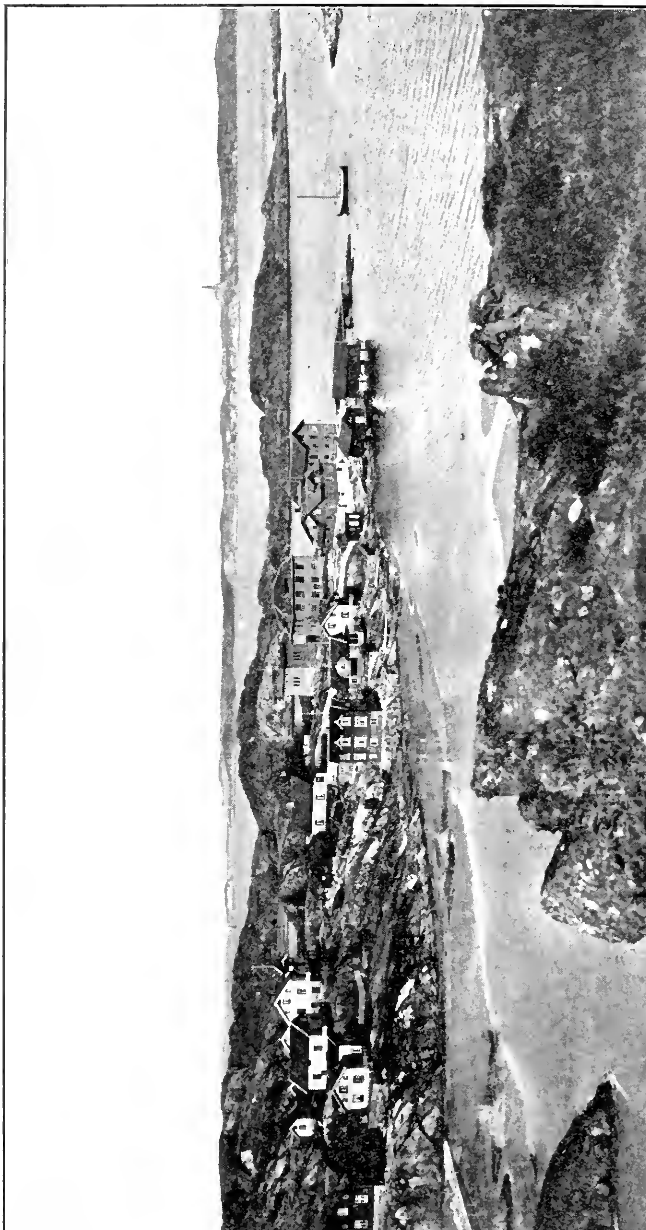
THE SWEDISH KRISTINEBERG MARINE ZOOLOGICAL STATION

BY PROFESSOR CHARLES LINCOLN EDWARDS
TRINITY COLLEGE

NESTLED among the outcropping granite ledges and islands of the west coast of Sweden, lies the village of Fiskebäckskil, near which on Skaftö has arisen the Kristineberg Marine Zoological Station. The primordial mass of the surrounding rocks and hills was planed off in curved and deeply-scratched surfaces by the vast ice-sheet of the glacial epoch. From the crests of the hills one can see the blue waters of Gullmar fjord penetrating inland and, off to the west, beyond Gasö, Flatholm and others of the protecting archipelago of islets, the white capped waves of the Kattegat.

Lichens and mosses partly incrust the rocks, and from every soil-collecting crevice, grass and wild flowers give life to the hills near at hand, while at some distance the great rocks seem bleak and desolate. In these patches of wild flowers the colors are brilliant, pink heather contrasting with blue-bells and golden hökfibla. Beside the pools of

THE KRISTINEBERG ZOOLOGICAL STATION, APPROACHED FROM THE BAY.



THE KRISTINEBERG ZOOLOGICAL STATION, AS SEEN FROM THE CLIFFS.

rainwater the white, downy "field-wool" waves from dried stems, and from the more shaded niches in the granite arise the graceful fronds of ferns. The large black-hooded gray crow flies from hill to hill, while on the ground the pert gray backed white wagtail nods its head and flirts its white bordered tail.

S. Lovén.

It was near the end of the eighteenth century when the Danish zoologist, O. F. Müller, made the first trawl in a form still in use for the collection of animals living upon the sea-bottom, and thus began the special study of marine zoology. Fiskebäckskil was visited for zoological research by Professor Bengt Fries in 1835. Four years later Sven Lovén and others joined the colony of naturalists, who worked with such meager facilities as the place could offer. Around the islands in the bays and fjords of the region they found a rich and interesting fauna distributed from the shallow flats to depths of eighty fathoms, over bottom varying from rock, sand, shell, clay and ooze, to a carpet of grass and algæ. The foundation here of the Kristineberg Zoological Station by the Royal Academy of Science in 1877 was due to the initiative of Lovén, who had become the most famous and influential Swedish zoologist of the nineteenth century. For almost sixty years Lovén investigated problems in the morphology, comparative anatomy, embryology and taxonomy of various classes of invertebrates, especially of the echinoids, or sea-urchins. He had been a pioneer in Swedish Arctic scientific expeditions and deep-sea exploration, and hence it was fitting that he should suggest the creation

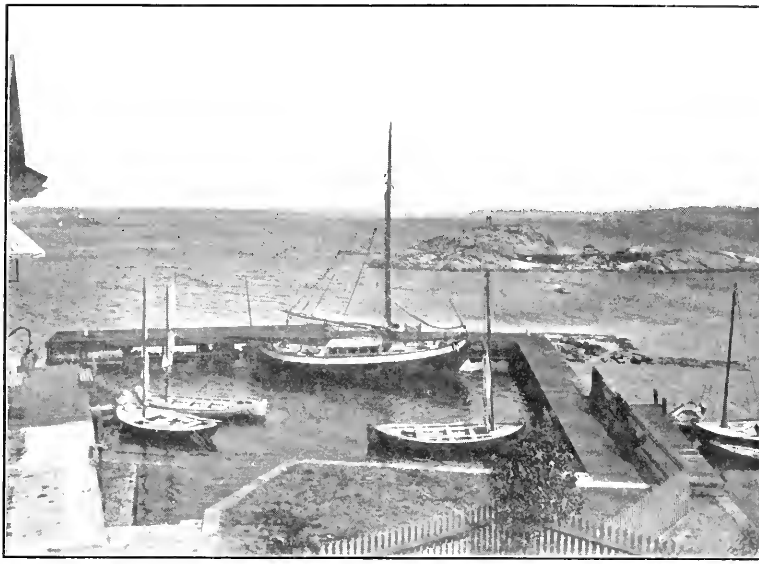
Hjalmar Théel.

of this station in the region where so much work of value had already been accomplished. It was not possible to have a good marine station nearer Stockholm on the east coast because the waters of the Baltic in former times was a vast lake and now receiving the outflow of many rivers, has a comparatively small percentage of salt, and consequently its fauna is poor in marine species. The physician A. Regnell gave the necessary funds to primarily establish the Kristineberg station.

In 1892 Lovén's friend and biographer, Professor Hjalmar Théel, succeeded the founder as director and to him is due the reorganization and enlargement of the station now not only open during the summer for university students and public school teachers, but also all the year

A Winter View of the Kristineberg Zoological Station.

for the investigating naturalists. Many animals which in the summer live in the depths in winter come up into the littoral belt, where their life-history can be studied to the best advantage. Almost nothing is known of the fate of the littoral fauna of the shallow bays when in winter the sand and slime in which these animals live is often frozen solid. Professor Théel's experiment demonstrated that a frozen mass of barnacles will not only resist —18° Centigrade, but revive after the ice melts and leave many young. For the solution of such physiological problems it is necessary to have the station available in winter as well as in summer. This was made possible in 1901 by a gift of 40,000 crowns from Konsul Broms, Mæcenas of the Swedish expedition to Spitzenbergen and eastern Greenland. The funds were used to the

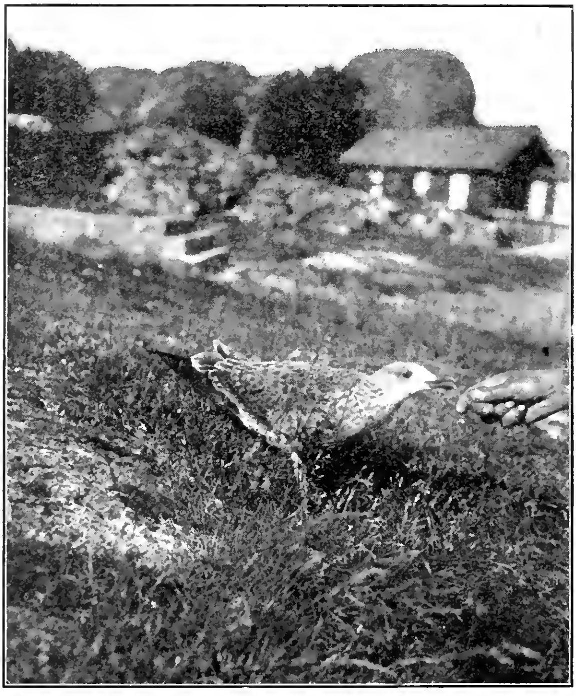


THE SAILBOATS AND THE MOTOR SLOOP "SVEN LOVÉN" IN THE HARBOR.

best advantage, so that now the station has a very substantial granite building in addition to the old laboratory erected in 1884. There are also three residences, a water tower reservoir and smaller houses for pumping salt-water and generating acetylene gas. A motor sloop of ten tons, the *Sven Lovén*, completely fitted with winding-reel, and the various patterns of trawls and dredges, as well as an enlarged granite wharf, were the gifts of Fru Anna Broms. A complete collection of well-preserved specimens illustrates the marine fauna and enables the stranger to readily identify any of the animals he may find. In a sunny room where the busts of Charles Darwin and Sven Lovén face one another, is a working library of 4,500 zoological journals, monographs and shorter papers mainly presented by Professors Théel and Retzius. Any writings not at hand can be supplied from the library in Stockholm within a few days. The station has an annual income of 10,000 crowns, 6,000 from the Royal Academy of Science and 4,000 from the Swedish government.

The grounds are fenced from the summer visitors of the neighboring Fiskebäckskil and the more fashionable Lysekil on the other side of the entrance to Gullmar fjord. The rules, firmly but courteosly enforced, establish an atmosphere of quiet. Investigators and students are provided with the animals desired, as well as all of the necessary apparatus and chemical reagents, and every assistance is most generously extended. Besides the *Sven Lovén* a fleet of sail and row boats is equipped and ready for the work of collecting, or for the observation of the animals in their own environment. The very slight tide makes the sea here almost like an inland lake, and gives none of the many tide-pools which constitute such an important part of the collecting grounds in our American stations.

In the two laboratories there are many large and small aquaria, with such an abundant supply of sea-water that animals from a good sized shark to the most delicate coral polyp will live in contentment. The frontispiece from a painting by Fru Astrid Gullstrand represents a corner of one aquarium. The orange colored anemone, like a veritable flower, unfolds its stinging tentacles to entrap the unwary minute animals swimming by, while below, the eleven-rayed sun-star pulls itself by the contraction of hundreds of adhering sucking tube-feet. With sharp pincers the spider-crab has broken off pieces of algæ and hydroid colonies and then planted them among the bristles on its back. Thus the creature is completely masked both from the game it hunts and its own carnivorous foes. The edible mussel spins strong threads from its byssus gland firmly attaching the bluish, or sometimes brownish, shell to the rock or to another mussel. Protectively colored by the olive-green alga around the stem of which his prehensile tail is entwined, *Nerophis*, the needle-fish, as a model father, broods his young, which are glued fast to his ventral surface during development.



THE LABORATORY PET.

The station is primarily under the direction of Professor Théel as Prefect, while director Dr. Hjalmar Ostergren is the very efficient administrator of affairs. Under such leadership one may feel confident that the dream of Lovén and Théel will be fulfilled and that here in Kristineberg, as at Naples, will evolve a great station, not alone for work in marine zoology but as well for the investigation of allied problems in botany, chemistry, hydrography and meteorology. Thus Kristineberg is a link in the chain of the more than fifty world encircling marine biological stations. Here and in Bergen, Kiel, Plymouth, Roscoff, Banyuls-sur-Mer, Villefrance, Trieste, Naples, Batavia, Misaki, San Diego, Pacific Grove, Cold Spring Harbor, Woods Holl, and the other sea-side stations, as well as upon the vessels designed as floating laboratories, investigators are solving the mysteries of life in the sea, the primæval birth-place of life itself.

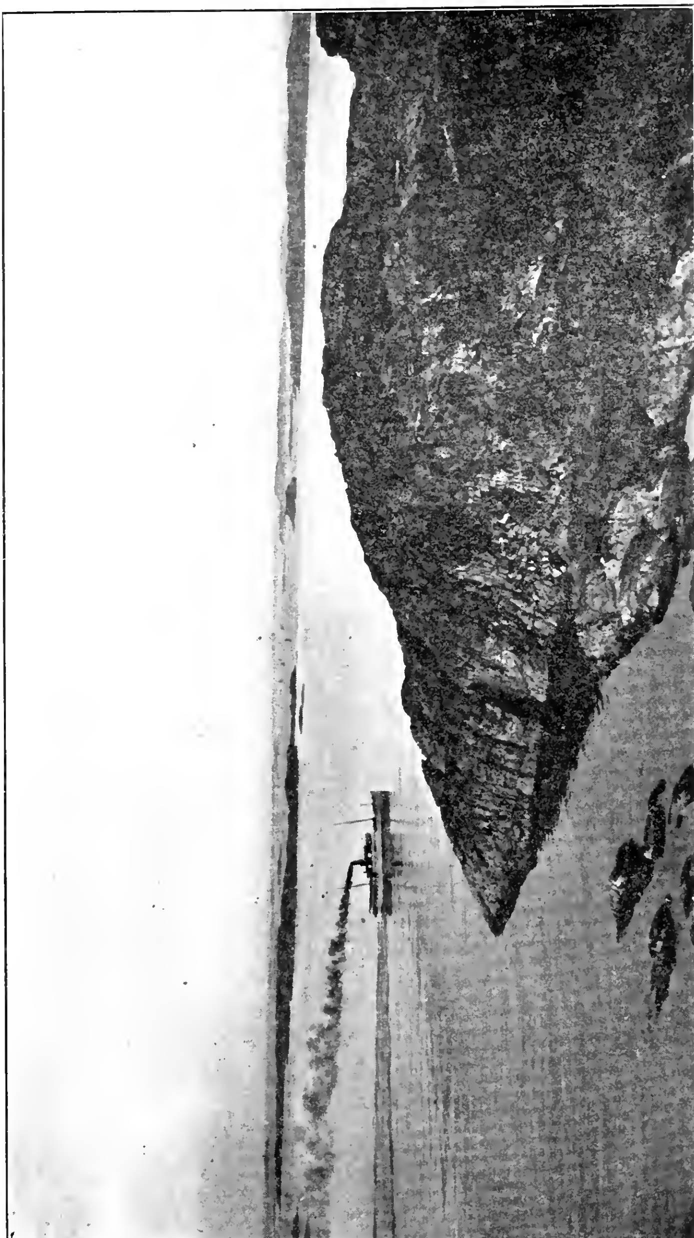
A Group of Investigators and Students.

One is reminded that it is the land of the midnight sun by the twilight lasting until after ten o'clock and the break of dawn at three, when the gulls awaken us with a chorus of hoarse cries like those of migrating geese. One of their number is the laboratory pet. It was taken, as Director Östergren naïvely remarked, "When the parting from its parents was without pain," and reared with no fear of man. It is of adult size and strong enough to fly over land or water wherever it pleases. When hungry, and that is most of the time, it sounds a shrill whistle, throwing its head up and down, until a fish is offered, when it comes to one's hand to be fed. But gradually the racial instinct has been asserted until, at the last, the gull follows the call of the wild so much of the time that little is seen of it within the laboratory precincts.

By seven o'clock the engine of the *Sven Lovén* is warning us by a series of sharp explosions, accompanied by a cloud of dark smoke and fumes from the burning crude oil, that everything is in readiness for a collecting trip. We scramble aboard and Albert Henriksson, the capable draggmästaren, swings the tiller around so that we head up Gullmar Fjord.

In the distance the hills rise from the water like banks of purple mist while the nearer rocks are as clean cut as cameos. In an hour we come to the deeper waters where under fifty fathoms the beautiful red holothurians browse. Our object is to study the embryology of these cousins of the star-fish and we get them with a trawl built like the front half of an old fashioned bob-sled from which a long hood of netting runs out behind. In a half hour the engine gear is shifted and the piano-wire cable carrying the trawl is wound in. With rope and tackle we lift the great mass of slimy ooze and organisms on deck, pick out our holothurians, place them in a weighted box and again lower them to the bottom, in the hope that eggs will be laid and fertilized for our work on the unknown life-history of this species.

Again by means of the fine meshed plankton net we seek some ctenophores and in a short time a number of these exquisite ovoid jelly-fishes are found in the glass collecting-jar at the blind end of the net. Each bilaterally symmetrical body, transparent as crystal, is propelled by eight meridional rows of minute paddles, which shimmer in the sunshine like rainbows. At the upper end of the globular creature is a sac filled with clear fluid, in which delicately balanced otoliths vibrate. What does the ctenophore feel when the microscopic otoliths lightly touch the sensory cells? We know that this animal has a very primitive type of nervous system and there is experimental evidence that the apical organ responds to mechanical stimuli while it is indifferent to light. To ascertain the nature and extent of ctenophore psychology is a most difficult task. First must come the skilful, patient stimulation of each part of the animal with the most delicate physical apparatus and chemical reagents, varying the light, temperature and other elements of the environment under all the possible conditions of existence. The more difficult part however is the interpretation of the observed results of experimentation. The investigator must now be a philosopher, able to resist the inclination to regard the creature as a mere mechanism because its behavior seems so simple, and on the other hand not yielding to the temptation to project his own mind into the ctenophore when he finds its responses are an elementary edition of his own. That such primitive organisms have the psychic, just as they have the assimilative excretory, respiratory and reproductive functions,



The Cliffs of Skaftö.

is demanded by the logic of the law of evolution. But just what they feel and to what degree they think is largely unknown. In the solution of these fascinating problems enduring biological research will give us knowledge where metaphysical speculation has left us groping and fencing with a jargon of terms.

Among the general problems to be solved in marine stations none are more interesting than those concerning the countless millions of organisms, that float in the surface waters as the plankton. Professor Théel has investigated these matters in the neighborhood of Fiskebäckskil since 1874 and has published important conclusions as to the origin and fate of the plankton. While most of these organisms constitute the holoplankton, always swimming freely, yet many, especially in the breeding season, belong to the meroplankton, swimming as larvæ only part of the time and then going to the bottom to form the benthon population, or to become anchored for the rest of life like the corals. One mystery at Kristineberg is that while many chætopod worms live in the bottom ooze their swimming larvæ appear but rarely in the plankton. On the other hand some forms occur at times in such masses as to make the water thick. Here, as on other seashores, the phosphorescent protozoan *Noctiluca miliaris* has been cast up in windrows of glowing greenish blue living fire. This tiny creature, in common with many other organisms, emits light when touched or rolled about, or upon chemical or electrical stimulation. It is possible on a dark night to read by their phosphorescence, which after all is but a secretion of their photoplasm on fire.

In the bay near Kristineberg from 1890 to 1900, the irregular sea-urchin *Echinocardium cordatum* occurred in large numbers but in the summer of 1902, none of the adults were found and only the young of one centimeter, or less, in size. It is the view of Professor Théel that in such cases, during some unfavorable years, the currents of the sea bear the swimming larvæ away from the ancestral breeding ground where, during their metamorphosis, they may be eaten by hungry hunters, or else sink in the abysmal waters and perish. If they find favorable bottom they will there establish a new race while the old unreplenished parent stock dies out. Thus in 1902 new larvæ of *Echinocardium* came to Kristineberg bay and reestablished the colony in its former home.

So animals appear and flourish in a region only to die out, while others come in to take their places. The rise of the herring fishery in these waters within the last forty years has seen the decline and practical extermination of the oyster business. In view of the fact that the planktonic larvæ, while free-swimming yet depend upon the sea-currents to place them upon the right bottom, it is no wonder, that many perish in the constant struggle for existence. It is only because of the enormous production of eggs that the species does not die out. If, for instance, only one half of the descendents of one pair of cod-fish should survive, then in the third generation the whole Atlantic Ocean would be packed full of cod-fish! So overpopulation brings its own dangers when members of the same species must fight for space and food and kill one another, or migrate to new regions, before the marvelous balance in nature is readjusted.

Standing in the west wind, on the ocean-ward cliffs of Skaftö, one feels the deep-stirring obsession of the sea. It is no wonder that the Vikings could not resist the siren call of wind and wave. To-day their descendants Lovén, Nordenskiöld and Nansen, sailing forth into the great unknown, have made conquests in the realm of nature that will endure forever.

ERNST HAECKEL: DARWINIST, MONIST

By Professor VERNON LYMAN KELLOGG
STANFORD UNIVERSITY

IN 1859 Darwin's "Origin of Species" appeared, and the struggle was on. In 1862 Huxley began his active participation in it, a participation brilliantly maintained until his death. In 1863 Haeckel, before an association of German naturalists in Stettin, declared the Darwinian theory to be the greatest step forward in the study of life that had been taken in modern times; and he prophesied for it the same importance in the understanding of organic nature that Newton's law of gravitation had had in the understanding of the inorganic world. Steadily, since that day, Haeckel has been carrying on the fight for Darwinism and its corollaries.

Of greatest popular interest among these corollaries or logical conclusions and most opposed by all tradition and ecclesiastic and metaphysical authority are, first, the direct descent of man from the lower animals, with all his attributes mental and spiritual as well as physical; and, second, a strictly monistic conception of the world as opposed to the old strongly-established dualistic conception. As Huxley was in England, so Haeckel is in Germany, the special battling champion of the theory of descent and its conclusions. And even more conspicuously than Huxley, Haeckel has maintained and fought for the revolutionary and "irreligious" logical conclusions of the full acceptance of the theory of cosmic and organic evolution.

Such a complete acceptance unites God and nature into an indissoluble unity, even as it does matter and force, body and soul. It leaves no place in one's philosophy for a supernatural, creating God, or for a distinct and peculiar vital force or for a personal immortality of the soul. It accepts completely the cosmic and organic evolution explanation of the earth and its life, holding that life originated on the cooling earth naturally out of non-living materials "by catalysis from colloidal carbohydrogen combinations," and that man is, in his entirety, the outcome of biological transformation, his nearest relatives among living animals kinds being the tailless apes.

Obviously the man who should stand as the champion in poetic, metaphysical, religious Germany of such a *Weltansschauung* must be a man of unusual strength to stand at all, much less to make head against the great forces that would necessarily bar and dispute his way; indeed would combine to overwhelm and trample him under foot. Haeckel has certainly shown great strength and great courage. Since 1863 he has been, and in this his seventy-sixth year still is, the champion who has almost single-handed made the open fight for the evolution conception and for that complete and extreme dominance of it in sociology, philosophy and religion which he terms monism. And he has made this fight with such success that the two chief opposing combatants, "throne and altar," as he terms them, see in him one of the greatest dangers in the world to their special interests. For Haeckel is no longer merely the German champion of Darwinism and monism, but the world champion. The heresies of "The Riddle of the Universe" and "The Wonder of Life" have penetrated all lands and circles of reading and thinking people.

Born in February, 1834, and educated soundly in a Jena gymnasium and then in the universities of Jena, Würzburg and Berlin, Haeckel early showed his strong predilection and special capacity for the study of nature. He was fortunate in coming in these early formative years under the direct tuition and into the close personal companionship of some of Germany's greatest naturalists. He was variously student and assistant of Schleiden, Alex. Braun, Albert Kölliker, Franz Leydig, Rudolf Virchow, Carl Gegenbaur and Johannes Müller, a brilliant array of names, and a guarantee for the young naturalist's thorough grounding in the facts and principles of botany, zoology, physiology and medicine. Haeckel's first love was botany, but his father's wish led him to make his degree (M.D., Berlin, 1857) in medicine. The later semesters of his university work and his doctor's dissertation were, however, given to zoology, and it was as an active investigating zoologist that he began his post-student career. This career opened with a year's trip to Sicily, where Haeckel commenced that study of the radiolarians, minute shell-secreting one-celled animals, which he has continued as an authority all through his life. This zoological journey was the first of many, especially to tropic lands and waters, that Haeckel has made, the last one being an expedition to Java and Malay in 1900–1901 in search of prehistoric man!

For forty-five years he has taught, investigated and written in the small Thuringian University at Jena. His calls to larger universities he has steadfastly refused, to remain with the institution that has given him from the first full freedom, if not, perhaps, always full faith and adherence. In the earlier more critical years of his bold declarations and the bitter attacks they excited he felt himself becoming an incumbrance, possibly an actual danger, to his university, and he offered to resign his professorship. But the head of the corporation, Seebeck, said to him: "My dear Haeckel, you are still young and you will come to a riper understanding of life. Anyway, you will do less harm here than elsewhere, so stay!"

In quiet little Jena, then, Haeckel's many and extensive and valuable investigations have been carried on and from here has issued that long and brilliant array of monographs, books and published addresses that has excited variously the admiration, the wonder, the scorn and the bitter anger of the world. Like Huxley, Haeckel is most widely known to the world, and to the lay world almost solely, by his more popular and generalizing books and by his brochures and pamphlets dealing with his philosophical propaganda. But also like Huxley, Haeckel has to his credit a large and important original contribution to zoological science. This contribution consists of monographs on the classification and general biology of the protozoans, sponges and medusæ, and represents an extraordinary industry and devotion. And it is largely on a basis of the revelations of the methods and truths of nature as revealed to him in this personal original work that Haeckel claims to have come to his radically monistic world conception.

I do not wish to over-paint the likeness between Huxley and Haeckel. The differences are obvious. The German has more egoism in him. Haeckel fights more for himself; perhaps he has to. His position has a certain difference. But in his polemic he is inclined to more personal defense, more personal reference, more personal exploitation. It is a trait that becomes even slightly uncomfortable for his admirers to face. And Haeckel has had more criticism from his scientific confrères to meet than Huxley had. These brother critics, not gentle ones, accuse him of a certain carelessness in his handling of biological facts. The sharper ones call this carelessness willful overlooking and distortion. His published illustrations are accused of inaccuracies favorable to his argument. He is reproached of a too lively imagination exercised in filling in gaps in his ancestral series with plausible hypothetical links. He gets too swiftly to generalization; he is too speculative. "Der Haeckelismus in der Zoologie" has been for long the subject of much strong writing and talking among German biologists.

But there is no doubt of the unescapable truth of all the larger biological facts upon which Haeckel builds his philosophy and his "scientific religion." The criticisms of this superstructure and its manner of rearing are more to the point than the picking of flaws in the details of phyletic arrangement or embryologic description. And it is these criticisms of Haeckel's monism, Haeckel's materialism and atheism that interest the world at large.

These criticisms are of various types. Some are simply bitter denunciation and epithet, coming mostly from bigoted church men. They have no interest more than a future historical one, nor any real value. They harm neither Haeckel nor his philosophy. Another group of criticisms is less bitter and more would-be analytical and reasoned. But the critics are misinformed; they lack the knowledge of science and modern *Natur-philosophie* necessary to enter the lists with any strength. These critics are less bigoted and more intelligent churchmen and philosophical dilettanti. Finally there is a third type of criticism, becoming now, with the startlingly swift spread of monistic acceptance among the German people, more abundant and important in character. It is the criticism, keenly analytical, strongly put, of professors of philosophy, liberal and informed clergymen and scientific dualists like Oliver Lodge.

But still more to be reckoned with by the monists in their attempt to remake the philosophy and religious belief of the world is the strong and positive, if less outspoken and active antagonism, of all those who are deeply imbued with the feeling that a religion or philosophy which does not distinguish soul from body and which denies any hope for a persistent life for the soul is a conception in some way negatived by the very life and consciousness of man.

Haeckel manfully, even joyously, faces all these kinds of criticism and charges valiantly against the forces of entrenched belief. We can not too much praise the fighting qualities of this champion. He is a world-figure; at any rate he looms a world-figure in German eyes. We can hardly understand in America how much reading and attention are given by the whole body of German people to the serious problems of philosophy and religion. Haeckel's books and pamphlets are issued by scores of thousands and eagerly read. The "Lebensräthsel" alone is in its two hundred and fiftieth thousand. And in all the bookshop windows are displayed the pamphlets answering and denouncing the atheist philosopher of Jena. The Haeckel and monism subject is only second in interest to the eternal problem of the Kaiser temperament!

Through it all one turns with keen interest to the kindly-faced white-haired figure of the protagonist. Seventy-six years old and still[1] carrying on steadily the duties of his professorship, lecturing simply to students, speaking occasionally to popular assemblies and uttering steadily in direct and plainest sentences his iconoclastic and radical philosophy. His hearers and admirers and followers come chiefly from the lower and middle classes, and especially from the ranks of the growing social-democratic party. He is essentially a people's prophet. Actually how large his following is it would be difficult to say, but the tremendous demand for his writings, all the popularized ones of which are issued in cheap "people's editions," indicates in some degree the number of his adherents. Many of the social-democrats and all the "free-thinkers" take up his cause with enthusiasm, and his "Theses

[1] Since this was written (last winter in Europe) Haeckel has given up his university chair to devote himself exclusively to the care of his new phyletic museum.

of Monism" are the avowed creed of an already large and undoubtedly rapidly growing fraction of the German people. They have besides been "substantially adopted by the Universal Free-thought Congresses of Europe and North America, at Rome and St. Louis, 1904," and are making their way over all the civilized world.

These "theses," as succinctly formulated by Haeckel, number thirty, of which "twenty have to do with theoretical and ten with practical monism." The latter ten are "intended merely to elicit general suggestions according to their subjective interpretations; but the former twenty, namely, "the objectively accepted and established truths of modern science" are considered by Haeckel to be a firm foundation for the monistic conception of the world. These theses affirm (1) that the monistic world conception has its foundation exclusively in scientifically established truths which (2) have been arrived at "partly by sense-observations in the external world and partly by conscious ratiocination in our internal mentality." They deny (3 and 4) that important and profound apperceptions can be gained through supernatural revelation or through *a priori* reasoning independently of experience. They recognize (5, 6, 7 and 8) the dynamic unity of the cosmos, and its government by unchangeable natural laws, denying the dualistic world conception of a material and a spiritual world. Biology is really but a branch of physics, as living matter is subject to the same natural laws that govern dead or inorganic bodies. There is (9) no special or peculiar vital force "directing and controlling the physical and chemical processes within organisms." The whole cosmos is the result of a great monogenetic process of evolution which results in or is an unbroken succession of transformations and variations. This holds for both inorganic and organic nature. "Part of this universal process of evolution is directly accessible to our apperception, while its beginning and its ultimate goal are unknown to us." The world thus (10) was not created by a personal Creator.

The science of organic descent (11) is firmly established, and shows that "all organisms existing to-day on our planet are the transformed descendants of an extensive series of extinct organisms and have in the course of long periods of many millions of years in duration descended from them by evolution." This descent is an established fact whether its causes be explained by means of selection, mutation or any other theory of variation. Organic life (12) began on the earth after the latter had cooled from its molten liquidity into a sphere solidly encrusted with a superficial temperature below the boiling point of water. Life then originated naturally out of inorganic materials "by catalysis from colloidal carbohydrogen combinations." This first life was of the nature of "structureless plasma globules represented in our time by the Chromaceæ (Cyanophyceæ)." By the "grand process of biological transformation" (13) all the variety of life has come into existence. All this diversified life manifestation is the result of a common physico-chemical process, the metabolism of the plasma. "Its two most important factors are the physiological functions of adaptation (variation) and heredity; the former is related with metabolism (nutrition and growth), the latter with propagation (transgressive growth)."

All organisms are (14) genealogically related and man's place in nature "is fully understood." There is no room left to doubt (15) that man is in every respect a genuine vertebrate, or, more precisely, a mammal and that he has evolved from this highest family of animals not earlier than the latter part of the Tertiary period. Man (16) is plainly most nearly related to the tailless apes, but none of the living representatives of this group can be considered the direct ancestor of man.

On the contrary, the common ancestors of all these anthropoid apes and man are to be looked for in extinct earlier species of apes of the old world (*Pithecanthropus*) or in their relatives.

(17) The soul (psyche) of man taken as a distinct supernatural being in both the mystic realms of metaphysics and of theology, has been recognized as the totality of cerebral functions, a discovery brought about chiefly through the astounding progress made in modern biology and particularly in comparative brain-research. The function of the higher soul or thought-organ in man (pronema)—a certain area of the cerebral cortex—takes place perfectly in accordance with the same laws of psycho-physics in the other mammals, and especially in the nearest relatives of man, the anthropoids. This function, of course, ceases at death, and in our time it appears utterly absurd to persist nevertheless in the doctrine of a "personal immortality of the soul."

Like all other functions of the brain (sensation, imagination, ratiocination), the will of man (18) is a physiological function of this central nervous organ and is dependent on the latter's anatomic structure. The peculiar individual potentialities of the human brain, partly inherited from ancestors and partly acquired through adaptation in the life of individuals, necessarily determine the will. The ancient doctrine of a "free will," indeterminism, therefore appears untenable and must give room to the opposite doctrine of determinism.

(19) If under the ambiguous term of "God" is understood a personal "Sublime Being," a ruler of the cosmos who, after the fashion of man, thinks, loves, generates, rules, rewards and punishes, etc., such an anthropomorphic God must be relegated to the realm of mystic imagery—no matter whether this personal God be invested with a human form or be assumed as an invisible spirit or as a "gaseous vertebrate." For modern science the idea of God is scrutable only so far as we recognize in this "God" the last irrecognizable cause of things, the unconscious hypothetical "first cause of substance."

All these theses are Haeckel's expression of a complete acceptance of the evolution conception and its apparently logical conclusions. Haeckel's constant question is "Do you accept the evolution conception of the world and life?" His constant rejoinder to any who answer Yes is: "Well, then you have to accept, if you are scientifically and philosophically honest, my monism. There is no escape from it."

As a matter of fact, of course, there are plenty of people who accept the evolution conception and do not accept Haeckel's monism. These people do not see that one necessarily follows the other. Many of them indeed think they see that Haeckelian monism does not follow evolution, that it, in fact, has no fundamental connection with it. There are other people still, who are monists, but who do not accept Haeckel's alleged consequences of a monistic, as opposed to a dualistic, conception of nature. But Haeckel undoubtedly believes all he says he does and believes too in the duty of propaganda. That he has a considerable following can not be overlooked.

THE KNOWLEDGE OF GOOD AND EVIL

BY PROFESSOR T. D. A. COCKERELL
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IN an ancient story, it is told how primitive man ate of the tree of knowledge, and thus lost his original simplicity. "And the Lord God said, Behold, the man is become as one of us, to know good and evil." In later years, we have reason to suspect, our ancestors returned at frequent intervals to the fateful tree, and took therefrom cuttings to plant in their own gardens. The universities, if I mistake not, had their origin in this manner; and it is even possible that the faculties within them have a distant relationship to the serpent of Eden. The modern Adam and Eve are perhaps not so easily beguiled; but, on the other hand, the fruit has been improved by selection and cultivation, and it is no longer necessary to go to the trouble of picking it off the tree; it is served up in dainty dishes, cooked, flavored and predigested. Even those who will not taste acknowledge that it pleasantly stimulates the olfactory nerve.

For all this, the curse has not been lifted. Our animal ancestors were, under ordinary circumstances and for vast periods of time, strictly orthodox. They traveled the straight and narrow path, turning neither to the right nor to the left. Life to them meant the performance of certain acts as their fathers performed them, under conditions such as their fathers enjoyed. Mediocrity—the middle line—was the true standard of excellence. They were not conscious of sin, for they sinned not.

Man, with his dawning self consciousness, found himself in possession of a new power. From this moment he must choose and judge; and thereby usurping the functions of God, be to a considerable extent his own creator. His whole history is a story of how well or ill he played this part, his whole future depends upon his ability to face this responsibility. The ancient curse of failure serves but to spur him on; it is the whip which awakens him from the constantly recurring tendency to sink back into mere animality.

This is the truth at the bottom of the doctrine that all men are evil, and must become conscious of the fact before attaining salvation. Progress depends upon a "divine discontent," and this, like charity, may best begin at home. It has been well said that he who has reached the age of twenty-five without at any time holding himself to be a fool, is indeed one, with small chance of cure. It is a common error to suppose that all great men, standing upon a pedestal above the common herd, are serenely conscious of their perfection; whereas the fact is that these, of all others, are at war, day and night, with their own shortcomings. Just so far as their judgment of good and evil is developed, to that extent must they suffer from a sense of failure. This is true not merely of men, but also of communities; it has been pointed out that the most civilized societies are those which recognize most crime. Acts which our ancestors would have regarded with cheerful tolerance, stir us to spasms of indignation, accompanied by a growing sense of responsibility.

Are we, then, becoming more and more uncomfortable, and is education merely fanning the flame of our discontent? There are, of course, various kinds of so-called education, comparable to the various diseases in their powers of infection. For the purpose of discussion we may assume the view, which I have known to be entertained by children, that genuine superiority depends upon the number of diseases one has had. Develop this idea a little, and suppose universities established for the purpose of giving young people smallpox, scarlet fever, measles and the like. It would be held, of course, that one who had had smallpox was much more educated than one who had merely acquired measles; the latter undoubtedly would be offered in the freshman year. Ostensibly, every one would be anxious to acquire these diseases; but still, it would be privately recognized that they were a lot of trouble, and even sometimes positively dangerous. Hence there would be a strong temptation, when the infection did not take, to sham sickness, and no doubt there would arise agencies selling substances which, placed upon the skin, would produce rashes simulating those of scarlet fever or measles.

Within the university itself, these influences would have their silent potency. Some would come forward with attenuated virus, which though producing scarcely any—or perhaps no—effect, would be declared to be in reality just as good educationally. If one did not believe it, there was proof in the fact that the recipient was subsequently quite immune to the genuine thing. Others would urge, with much show of reason, that the more violent diseases, heretofore offered to seniors, should really only be taken by a small minority of exceptionally talented persons; and anyhow it was not the proper thing to send men out to serve as centers of infection in communities where these particular affections, though undoubtedly of great merit in the abstract, were not at all desired.

All this is absurd, of course; but after all, is there not a similarity between such an educational institution and those which at present grace the land? Is there no tendency to evade the things which "take," no temptation to simulate an attack while yet in perfect health? I am not going to be so indiscreet as to specify any of the courses which seem to me relatively or absolutely innocuous; but I am going to assume that our present opinion is, that the knowledge of good and evil is what the university really seeks to impart, and that it accepts, frankly and fearlessly, responsibility for creating shadows as well as light. In a certain sense, it may be said to *produce* evil as well as good; what it really does is to create judgments, whereby these ideas enter the field of human consciousness, in response to the stimulation of objective realities.

The university standard of success, as we must now regard it, is the ability to recognize values. In order to do this, it is necessary to heighten the consciousness of objective reality, and to develop especially a sense of that stability in things which we call truth. It is essential to cultivate imagination, controlled by reason, so that the value of the flower may be seen in the seed, the value of the soul in the form of clay.

Scholarship, culture, judgment, can not be bought at the second-hand store, "a little soiled, but as good as new." They must be created by the fiat of that divinity which we have assumed, re-made from the fruit of the tree in a process of transcendental assimilation.

It is for this reason that I think every university—some day perhaps every high school—should be a center of productive scholarship; not merely of some such, but should glow with the ardor of scientific, literary and artistic creation. Only so may the judgment of fitness be properly established; only thus may the divine gifts be widely received. True it is that comparatively few have strong creative power, such as attracts the attention of the world—but my proposition is that all have some, and that whatever there is, it is the true function of education to develop and sustain it.

This will be more apparent when the scope of recognized scholarship has grown broader. If one may be "a scholar and a gentleman," why not "a scholar and a merchant," or "a scholar and a farmer"? We are beginning to find out, indeed, that these latter professions call for a good deal more scholarship than was necessary for the dilettante gentleman of the old school. When the avenues for creative effort have grown wider and more numerous, and we have learned better to recognize this form of activity under its various aspects, it will no longer be said that all forms of original scholarship are the monopoly of doctors of philosophy.

To those who have tasted of the fruit of the tree, there has never been any doubt of the value of the experience. Whatever the disadvantage, the advantages are enormously greater. The curious point is, that this does not admit of argument, because it is exactly the power of judgment which decides the relative values. So well assured are we of the precious character of our value sense that we would not exchange it for the whole world; which, without it, would be robbed of all esteem.

It must be confessed that a purely materialistic philosophy—if such a thing were possible—would know nothing of values. It would regard our judgments as it regards all other phenomena, and would point to their endless diversity as proof that they have no special sanction. What it would offer in defense of its own judgment upon this matter, is perhaps not evident.

For ourselves, the diversity of opinion which we find among men is in part the necessary and desirable result of the different angles from which things are viewed, and otherwise the product of that imperfection which is the price we pay for progress. Most of us, perhaps, do not trouble ourselves overmuch about the ultimate sanction, and yet I think that deep down in our hearts we all have some of the feeling embodied in the saying that "One man, with God, is a majority." Without such a philosophy, I am afraid we could not take ourselves quite seriously.

AUSTRALIAN MORALITY

By Professor IRVING KING
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ACCORDING to the earlier explorers and missionaries and the careless travelers of even recent years, the morality of the Australian aborigines was of a very low grade. Almost all such observers agreed in placing them in the very lowest stages of culture. They were described as bestial in habits, naked, lacking all sense of virtue; the men cruel to their children and wives. They were said to be addicted to infanticide and cannibalism, were cruel in their tastes, shiftless, lazy, stupid, deceitful, in fact were possessed of all conceivable evil qualities; they were deaf to the lessons of religion and civilization, ready at theft, and had almost no regard for the value of human life. They were naturally, moreover, given up almost constantly to destructive inter-tribal wars.

The investigations of more recent students of the natural races have thrown a somewhat different light upon the matter. It is now recognized that morality is not to be judged by relationship to some fixed and absolute standard, but rather that it is fundamentally related to the system of social control which holds within the group. It is consequently unjust to apply civilized standards of morality to such peoples. The goodness or badness of an act must be adjudged according to its place within some social context. It must, moreover, be borne in mind that the "higher race," in its first contact with the lower, seldom sees it at its best. Without doubt the ignorance and brutality of many of the first white settlers and explorers of Australia was constantly provocative of retaliation on the part of the natives. The so-called treachery of the latter, their cunning and their dishonesty were merely reflexes of their treatment by the whites. Hence it is impossible to judge of the morals of a race by the acts produced by its contact with another race. It may be admitted that a savage will do many things that a civilized man would not do, but *mere* difference does not render either one or the other immoral. The morality of an act can be determined only when it is known whether it conforms to the standard recognized by the group. This does not, of course, preclude the further inquiry as to whether some social standards are relatively higher than others, but such an inquiry lies beyond the scope of the present article.

In the first place, then, the unfavorable light in which the Australian first appeared is to be explained partly by the treatment he received from the whites and partly from the inability of the whites to understand him. Thus, the laziness of the native may be attributed merely to his inability to fall in with the enterprises of the settlers, or to appreciate the objects of their endeavor or their interests. In activities of their own the natives show the most surprising industry, for example, in the collection of food (Henderson, p. 125), the preparation for and performance of their elaborate ceremonials. The observations which follow should not, however, be taken as applying to the Australian race as a whole, but only to the section directly observed, for there is no question but that there is much diversity in the customs and characteristics of different tribes and groups.

As to personal virtues, the natives of Queensland were said to be generally honest in their dealings with one another. Aside from murder of a member of the same tribe, they knew only one crime, that of theft. If a native made a "find" of any kind, as a honey tree, and marked it, it was thereafter safe for him, as far as his own tribesmen were concerned, no matter for how long he left it.

The Australian native in general was and is possessed of fortitude in the endurance of suffering in a marked degree. There is abundant opportunity for the development of this quality of mind in the painful ordeals of initiation, which ceremony is always accompanied by fasting and the infliction of bodily mutilations of various kinds, differing with the tribe and the locality. These mutilations include the knocking out of teeth, circumcision, subincision and various scoriations of the trunk, face and limbs. Among some of the tribes there are permanent food restrictions imposed by custom upon different classes. There are also food restrictions imposed upon the youth and younger men, and all of these are faithfully complied with, although at considerable personal hardship.[1]

The food restrictions form such an important phase of aboriginal morality that they warrant further discussion. The following regulations of the Kurnai tribe are typical: A man of this tribe must give a certain part of his "catch" of game, and that the best part, to his wife's father. Each able-bodied man is under definite obligation to supply certain others with food. There are also rules according to which game is divided among those hunting together. In the Mining tribe all those in a hunt share equally, both men and women. In all tribes certain varieties of food are forbidden to women, children and uninitiated youths; there are also restrictions based upon the totem to which one belongs. The rules regarding the cutting up and cooking of food are as rigid as those regulating that of which the individual

[1] *Vide* Howitt, p. 561; Fraser, p. 90.

may lawfully partake. Howitt says of these food rules and other similar customs that they give us an entirely different impression of the aboriginal character from that usually held. Adherence to the rules of custom was a matter on which they were most conscientious. If forbidden food were eaten, even by chance, the offender has been known to pine away and shortly die. Contact with the whites has broken down much of this primitive tribal morality.

The oft-repeated description of the black fellow eating the white man's beef or mutton and throwing a bone to his wife who sits behind him, in fear of a blow from his club, is partly the new order of things resulting from our civilization breaking down old rules (Howitt, p. 684).

Under the influence of the food rules, a certain generosity of character was fostered and unquestionably it was present in the blacks to a marked degree. He was accustomed to share his food and possessions, as far as he had any, with his fellows.

It may, of course, be objected to this that in so doing he is only following an old-established custom, the breaking of which would expose him to harsh treatment and to being looked upon as a churlish fellow. It will, however, hardly be denied that, as this custom expresses the idea that in this particular matter every one is supposed to act in a kindly way towards certain individuals, the very existence of such a custom . . . shows that the native is alive to the fact that an action which benefits some one else is worthy of being performed.[2]

The apparent absence of any excessive manifestations of appreciation or gratitude in the blackfellow has been interpreted by some adversely. But *giving,* as far as the natives were concerned, was such a fixed habit that gratitude did not seem to be expected. It does not necessarily follow that they could not feel gratitude because they did not show any sign of it to the white man when he bestowed upon them some paltry presents, for, as Spencer and Gillen point out, they might not feel that they had reason to be grateful to him who had encroached upon their water and game and yet did not permit of them a like hunting of his own cattle.

Although as a rule perfectly nude, they are said to have been modest before contact with the whites (Lumholtz, p. 345). Of the north Australians, we are told that the women were never indecent in gesture, their attitude being rather one of unconsciousness (Creed, p. 94f). The low regard for chastity, reported by some observers (*e. g.,* Mackenzie, p. 131), may, in part, be explained by the failure of the outsider to understand their peculiar marriage customs, on account of which the relation of the sexes is to be judged by different criteria than with ourselves. Spencer and Gillen, the most recent and the most scientific of all who have studied this race, say of the central tribes that chastity is a term to be applied to the relation of one group to another

[2] Spencer and Gillen, "The Native Tribes of Central Australia," p. 48.

rather than to the relation of individuals. Thus, men of one group have more or less free access to all the women of a certain other group. Within the rules prescribed by custom, breach of marital relations was severely punished. No one would think of having sexual relations with one in a class forbidden to himself or to those of his own class. It would thus appear that, within the bounds of their own customs, they were extremely upright. When under certain conditions, chiefly ceremonial, wives were loaned, it was always to those belonging to the group within which the woman might lawfully marry.[3] Among the natives of north central Queensland a competent observer (Roth, p. 184) holds that there is no evidence of the practise of masturbation or of prostitution. The camp as a body punished incest and promiscuity. Howitt, writing of the natives of southeastern Australia, says that the complicated marriage restrictions expressed in a very definite way their sense of proper tribal morality. Here also looseness of sexual relations was punished, although at certain times it was proper to exchange wives and at other times there was unrestricted license among those who were permitted to marry (*cf.* Fraser).

Of the treatment of wives and children there are conflicting reports, the more recent investigators holding that there was less cruelty than was at first represented. There was, however, doubtless much difference in this respect in different tribes. One early observer (Earp, p. 127) affirms that wives were always secured by force, the girl being seized from ambush, beaten until senseless, and thus carried off by her "lover." Others, in like manner, emphasize the brutality of obtaining wives (Angas, p. 225). Lumholtz says that stealing was and is the most common method. The researches of Spencer and Gillen do not confirm these statements as far as the natives of central Australia are concerned, while Roth refers to the commonness of the practise of stealing wives and eloping among the north central Queensland natives. According to Spencer and Gillen, wives may have been so secured, but such was assuredly not the customary method in central Australia at least. They know of no instances of girls being beaten and dragged away by suitors. It is probable that cases of exceptional cruelty more easily came to the notice of the first travelers and they inferred that such cases were characteristic. The last named authors affirm that the method of securing wives among these tribes was definitely fixed by tribal usage and involved no cruel practises whatsoever. Howitt, the authority upon the southeastern tribes, says that cruelty was often practised upon elopers, but this is manifestly because they had themselves been guilty of breach of tribal morality. Looseness of sexual relations among these tribes originally always met with severe punishment.

[3] See also Cameron, *Journal Anthropological Institute*, Vol. 14, p. 353.

As to treatment of wives among the central tribes (Spencer and Gillen), there were undoubtedly cases of cruelty, but they were the exception rather than the rule. The savage husband has a hasty temper and in a passion might act harshly, while at other times he might be quite considerate of his wife. Among the aborigines of the Darling River, New South Wales, quarrels between husband and wife were said to be quite rare (Bonney), and Smith says that love is not rare in Australian families, while another observer (Palmer) says that the life of the women is hard and that they are much abused by their husbands. Dawson, who wrote expressly to show that the Australian blacks had been misrepresented, maintained that in Victoria, at least, there was no want of affection between members of a family (p. 37). Lumholtz (pp. 161ff.) holds that the Queensland husband felt little responsibility for his family, that he was really selfish and hunted only for sport, often consuming the game as caught, bringing nothing home. The same author refers to one case of a wife being terribly beaten because she refused, one cold night, to go out and get fuel for the husband. Over against this testimony, we have that of Spencer and Gillen, referred to above, that the husband was ordinarily by no means cruel. In hard seasons men and women suffered alike. A woman, however, suspected of breach of marital relations, was treated with revolting severity. They point out that many things which to us seem harsh were by no means so in their eyes, and that the savage woman recovers easily from wounds that to a civilized woman would entail the greatest suffering. Treatment which we should naturally think cruel was to them merely rough and in conformity with the rest of their life. Howitt (p. 738) says that among the Kurnai tribe family duties were shared by husband and wife, each performing an allotted part toward the support of the family. The man's duty was to fight and hunt, the woman's to build the home, catch the fish and cook them, gather vegetable foods, make baskets, bags and nets.

With reference to their children, much affection was usually shown, and this in spite of the fact that abortion and infanticide were practised in many localities (*e. g.*, in northwestern central Queensland, (Roth, p. 183); and among the southeastern tribes, Howitt, pp. 748ff.). In this connection Howitt says, " . . . they [the Mining tribe] are very fond of their offspring and very indulgent to those they keep, rarely striking them," a mother often giving all the food she had to her children, going hungry herself. Infanticide was by no means so unrestricted, or as indicative of cruelty of nature and lack of parental affection as is implied by Mackenzie, writing in the year 1852.[4] Among the north central tribes[5] infanticide was practised, but only

[4] *Vide*, "Ten Years in Australia," p. 130.

[5] Spencer and Gillen, "Northern Tribes," p. 608.

upon rare occasions at any other time than immediately after birth, and when the mother thought she was unable to care for the babe. The killing of the new-born child was thus an effort at kindness on their part and to them was certainly devoid of cruelty, since they believed the spirit part went back to the spot whence it came and was subsequently born again to the same woman. Twins were killed as unnatural, a practise to be explained in part by the natives' dread of everything uncommon or rare. On infrequent occasions a young child of a few years was killed that an older but weaker child might eat it and thus get its strength. Howitt mentions the same practise among the southeastern natives (p. 749). He also says that in some places infants were eaten in especially hard summers. Sometimes, also, after the family consisted of three or four, all additional children were killed because they would make more work than the women could manage. Among the Kurnai, infanticide unquestionably arose through the difficulty of carrying a baby when there were other young children, some of whom might be unable to walk. Infants, under these circumstances were simply left behind when they were on the march, it not being regarded as killing to dispose of them in this way (Howitt, p. 750). Palmer, writing of the natives of Queensland, says that the killing of a new-born child was lightly regarded, but not common. On the lower Flinders River the fondness of the natives for their children was noted (Palmer). Spencer and Gillen say that, with rare exceptions, children were kindly and considerately treated, the men and women alike sharing the care of them on the march and seeing that they got their proper share of food. Howitt mentions the case of a mother watching a sick child, refusing all food, and, when it died being inconsolable (p. 766). One woman for nineteen years carried about a deformed child on her back (Fraser; vide Henderson, p. 121). Natural affection was certainly keen and much grief was manifested over the loss of children.

In the aborigines' treatment of the old and infirm most observers depict them in quite a favorable light. Dawson, it is true, reports that the natives of Victoria killed them, but this is certainly not a widely prevalent custom. Lumholtz (p. 183) says that the Queenslanders were very considerate of all who were sick, old or infirm, not killing them as with some savage peoples (*cf.* Bonney, p. 135). In northern parts of Australia there were many blind and they were always well cared for by the tribe, being often the best fed and nourished (Creed, p. 94). In the central tribes the old and infirm were never allowed to starve. Each able-bodied adult was assigned certain of the older people to provide with food, and the duty was fulfilled cheerfully and ungrudgingly.[6] In some tribes the old and sick were

[6] Spencer and Gillen, "Northern Tribes," p, 32.

carried about on stretchers. In the Dalebura tribe a woman, a cripple from birth, was carried about by the tribes-people in turn until her death at the age of sixty-six. On one occasion they rushed into a stream to save from drowning an old woman whose death would have been a relief even to herself. Fraser emphasizes the respect in which old age was held by the aborigines of New South Wales, and the fact that they never desert the sick (see also Smith).

Cannibalism among the Australian blacks was by no means a promiscuous and regular practise as was at first supposed. It is true, Lumholtz says of those observed by him, that human flesh was regarded as a great delicacy.[7] Palmer, writing of Queensland also, says that cannibalism was practised to a certain extent; in some sections those killed in fights being eaten, and often children who had died. An early writer reports that in South Australia bodies of friends were eaten on their death as a token of regard.[8] Spencer and Gillen found difficulty in gathering evidence of its being practised among the central tribes. They were often told by one tribe that it was customary among others who lived farther on, they in turn saying the same thing of those beyond themselves. They think, in general, that human flesh was eaten as a matter of ceremony or at least for other than mere food reasons. They found much more evidence of it among the northern tribes. Howitt says the Dieri tribe practised cannibalism as a part of their burial ceremonies, that it was a sign of sorrow for the dead. Among others only enemies slain on their raids were eaten; the Kurnai, for instance, would not eat one of their own tribe. Among still other tribes, if a man were killed at initiation ceremonies he was eaten, as also any one killed in one of the ceremonial fights, and others again did *not* eat their enemies. Howitt is positive that there is no such thing among any thus far observed as propitiatory human sacrifice, and he denies emphatically the statement made current by some that sometimes a fat *gin* (woman) was killed to appease their craving for flesh when they chanced to have been long upon a vegetable diet. He also says that at the tribal meetings of the Bunya, men, women and children, killed in fights or by accident, were eaten, but that there is no evidence that women and children were killed for cannibalistic purposes.

The morality of the Australian native was, in a word, the morality of tribal custom, and, if fidelity to duties so imposed may be taken as a criterion, it was of no low order. Recent investigators unite in testifying that the black-fellow, especially before contact with Europeans, was most scrupulous in his obedience to the sacred duties imposed upon him by tribal usage. Of the Queensland natives Roth says (pp. 139ff.):

[7] See also Bicknell, p. 104, who holds it was quite common.

[8] Angas, p. 225; Fraser, p. 56, as a sign of regard or in ceremonial.

The life of the tribe as a whole seemed to be well regulated. Custom, with the old men as its exponents, was the only law. Where there were few old men, each individual, within limits, could do as he pleased.

Howitt writes of the tribes studied by him that custom regulated the placing of huts in the camp, and even the proper position of individuals within the huts. In the Kaiabara tribe single men and women lived on opposite sides of the camp. The old women kept an ever watchful eye upon the young people to prevent improprieties. In another tribe the women could not come to the camp by the same path as the men, a violation of the rule being punishable by death. The law of custom thus controlled almost every phase of the life of the individual, including many individual matters as well as conduct toward others; the intercourse of the sexes is or was most definitely limited and regulated; the women who were eligible to each man in marriage were also rigidly determined by custom, as well as the proprieties of conduct toward the wife's family. Reference has already been made to the severe restrictions entailed by the initiation and other ceremonies, and also to the minute regulations regarding the choice of food. In all cases these customs were enforced by severe penalties. In some tribes the local group or camp united to punish any member who was guilty of overstepping these bounds as well as complicity in more serious crimes such as incest, murder or the promiscuous use of fighting implements within the camp. Most customs were, however, probably obeyed from habit, the native being educated from infancy in the belief that infraction of custom would produce many evils such as premature grayness, pestilence and even cosmic catastrophes. In fact, among the tribes observed by Howitt authority was generally impersonal, though not always, for the headmen were often men of great personal ability and were greatly feared and respected by the rest of the tribe or group (Howitt, pp. 296–300).

Questions of right and wrong for the Australians seem to have centered chiefly about food restrictions, secrets relating to the tribal ceremonies, the sacred objects and wives. Moral precepts probably originated in association with the purely selfish idea of the older men to keep all the best things for themselves.[9] In this way, at least, may be explained many of the regulations regarding what the younger men might eat. So also as to marriage, for aside from restrictions as to totem and class into which a man might marry, all the younger women were reserved by the old men, the less desirable ones, alone, being available to the young men. But, granting the selfish character of many of the rules, there was still a certain amount of morality which transcended anything of this sort. The old men in their leisure "instructed the younger ones in the laws of the tribe, impressing on

[9] Spencer and Gillen, "Native Tribes," etc., p. 48.

them modesty of behavior and propriety of conduct . . . and pointing out to them the heinousness of incest" (Howitt, p. 300). The rigid duties of manhood centered especially in the ceremonies of the tribe. The obligations which these involved were regarded as extremely sacred and inviolate. "As he (the youth) grows older he takes an increasing share in these (ceremonies), until finally this side of his life occupies by far the greater part of his thoughts" (Spencer and Gillen). He must continually show strength of character, ability to endure hardship, to keep secrets, and, in general, to break away from the frivolity of youth and all that savored of femininity. There were, among the central tribes, certain sacred things which were only gradually revealed by the older men, and if a young man showed little self-restraint and was given to foolish chattering it might be many years before he learned all that was in store for him.

It is interesting to learn that under the traditional régime the Australian natives lived a harmonious and certainly far from unhappy life. Fraser says they were a merry race (p. 43). Howitt, who was instrumental in gathering together the Kurnai tribe for the revival of their initiation ceremonies some years ago, reports that the people lived for a week in the manner of their old lives, and that the time passed without a single quarrel or dispute (p. 777). In their wild state the Dalebra tribe were noted to have lived most peaceably, *e. g.*, a camp of three hundred is known to have continued for three months without a quarrel. Their method of settling disputes was usually by means of a fight between the parties who were at odds. When blood was drawn, the fighting ceased and all were henceforth good friends (Dawson, p. 76). They were generous in fighting, taking no unfair advantage. They loved ease and were not quarrelsome, but were nevertheless ready to fight (Smith, p. 30, Vol. I.). Mortal wounds in such conflicts were rare (Lumholtz, p. 126). Spencer and Gillen likewise say of the central tribes that whenever compensation in any form had been made by an offending party the matter was ended and no ill-will was cherished (p. 31).

In some tribes theft was regarded as the greatest crime aside from the murder of a fellow tribesman. As there was so little private property, however, crimes arising from this source were rare. The stealing of women is said to have been the most common cause of inter-tribal trouble.[10] There were no fights for superiority, no suppression of one tribe by another. Within the tribe there was, in large measure, absolute equality. There were no rich or poor, age being the only quality that gave preeminence (Semon, p. 225). The inter-tribal fights were certainly not so serious as some have represented. That they were constantly attacking and trying to exterminate one another is not con-

[10] Lumholtz, p. 126; Spencer and Gillen, "Northern Tribes," p. 31.

firmed by those who have known them best. Their fights were probably half ceremonial or of a sportive character and they were usually stopped when blood flowed freely.

They undoubtedly did fear strangers, and a man from a strange tribe, unless accredited as a sacred messenger, would be speared at once.[11] On the other hand, delegations from distant tribes were received and treated with the utmost kindness if they came in the recognized way. They were even permitted to take a prominent part in the ceremonies of their hosts.

The relations subsisting between members of the same tribe or group were, according to Spencer and Gillen, marked by consideration and kindness. There were occasional acts of cruelty, but most of them can be attributed to something else than a harshness of character. Thus, much cruelty resulted from their belief in magic (The Central Tribes, p. 48). The revolting ceremonies practised at initiation were all matters of ancient tribal custom and hence cast little reflection upon the real disposition of the native.

All things considered, we are obliged to say that their life was moral in a high degree, when judged by their own social standards, and not even according to our standards are they to be regarded as altogether wanting in the higher attributes of character. Dawson holds that, aside from their low regard for human life, they compared favorably with Europeans on all points of morality. Howitt says (p. 639):

> All those who have had to do with the native race in its primitive state will agree with me that there are men in the tribes who have tried to live up to the standard of tribal morality, and who were faithful friends and true to their word; in fact, men for whom, although savages, one must feel a kindly respect. Such men are not to be found in the later generation.[12]

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[11] Spencer and Gillen, "Northern Tribes," p. 32.

[12] As many of the accounts refer to tribes, or at least to customs which are practically extinct, it seems best to use the past tense consistently throughout.

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THE GEOGRAPHIC ASPECT OF CULTURE

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THE dynamic influence of geography in history has recently attracted general attention. The idea was developed from a philosophical standpoint by Hegel,[1] about the middle of the last century, but only recently has it come to be regarded as of special significance. In the light of the discoveries of Hedin[2] and Huntington[3] in central Asia, however, there can be no doubt that the characteristics of primitive races are profoundly modified by environment. As an instance of this, Huntington has shown that the Kirghiz nomads inhabiting the deserts and plateaus of the Lop Basin in Chinese Turkestan are forced to lead a roving life by reason of the scantiness of subsistence. This in turn limits their occupations to the manufacture of portable articles such as rugs and felts, while it also accentuates certain characteristics such as hardihood and hospitality. In contrast to this type, the Chantos inhabiting the oases are tied down to intensive agriculture, the effect of which is also distinctly apparent in their character and occupations. This is further intensified by the lack of sufficient rainfall, which in their case has imposed such a severe limitation upon increase in population as to have given rise to the institutions of monasticism and polyandry.

The United States also furnishes a notable instance of the effect of physiographic environment.[4] The colonization of America was in itself a matter of latitude, the tier of early colonies along the Atlantic seaboard following practically the same arrangement as their European prototypes. Again the barriers of sea and mountain gave coherence to the New England colonies, which, reinforced by favorable latitude, ripened the spirit of independence. Other natural features, such as the great river valleys and mountain passes, were instrumental in determining the great trade routes, as well as in shaping the campaigns of the revolution and the civil war.

In connection with topography, the related factor of climate is also

[1] Hegel, "The Philosophy of History" (1st ed., 1837), English translation, Bell & Sons, 1902.

[2] Hedin, "Central Asia and Tibet," Scribners, 1903.

[3] Huntington, "The Pulse of Asia," Houghton, Mifflin, 1907.

[4] Semple, "American History and its Geographic Conditions," Houghton Mifflin, 1903.

of primary importance.[5] In polar and tropical regions, as well as in certain other isolated sections such as the deserts of central Asia, it is an absolute barrier to progress. Even in the most favored localities it has a marked effect upon the trend of social evolution. The invigorating effect of clear, cold weather is commonly recognized, but it is equally true that excessive moisture depresses the vital processes and thereby hampers development, an effect strikingly exemplified in the case of Ireland. On the other hand, dry weather if sufficiently prolonged creates a surplus of energy and at the same time weakens the emotional control, resulting, as shown by statistics, in a notable increase in misconduct and crime, apparent not only locally in times of drought, but habitually in dry countries like Mexico.

A remarkable synchronism of climatic changes has also been shown to exist throughout the world, recurring in cycles of approximately thirty-six years. In America this has made itself felt in the great financial crises, each of which has been associated with the deficiency in rainfall occurring at the low point of one of these cycles. This in turn has reacted upon politics to such an extent as to be of national import.

As yet the study of geographic influences in history has related only to such external and obvious manifestations as are apparent in social, industrial and political development. It may be interesting, therefore, to point out how these results may be extended to include intellectual development. In any attempt of this kind, it is necessary at the outset to set up some universal and fundamental principle of thought to serve as a standard for comparison of racial traits, and an index of mentality. Since racial traits become more distinct and divergent the more remote the period considered, few principles are sufficiently general to answer this purpose. There is, however, at least one form of thought which has always been characteristic of the human mind wherever historically manifested. Primitive culture, however remote, has always been accompanied by some form of mathematical reasoning. It is, in fact, noteworthy that all oriental nations ascribe the origin of both their culture and their mathematics to a single personage whom they also regard as the founder of their race. With the Chinese this was the Emperor Fohi, whose reign, about 2800 B.C., marked the beginning of Chinese history. As the Chinese have no earlier records to indicate the origin of their mathematics, their traditions relate that the number system was revealed to this emperor inscribed on the back of a dragon which rose from the waters of the Yellow River. In Egyptian history the first historical personage is the King Menes, who ruled somewhere between 5000 and 3000 B.C., and was the founder of the first dynasty of Pharaohs. Here also, from lack of earlier records, the Egyptians regarded Menes as the father of numbers, calculation and writing.

[5] Dexter, "Weather Influences," The Macmillan Co., 1904.

Even such an enlightened and careful historian as Josephus relates that Abraham taught mathematics to the Jews, and instances might be multiplied to show that this idea is prevalent throughout history.

The intimate connection of mathematics with early culture is further apparent in its relation to religion and philosophy. In Egypt mathematics was the peculiar possession of the priesthood, and was guarded by them with the utmost jealousy. When it passed to the Greeks it was made by them a prerequisite for philosophical study, their great philosophers being primarily mathematicians. At the beginning of the christian era mathematics again passed into the keeping of the priesthood, its preservation during the dark ages being due to the care with which it was preserved in catholic monasteries. Even the pope openly gave it the sanction of the church, threatening Galileo with the Inquisition for his heretical astronomical doctrines, and refuting them by issuing a manifesto to the effect that the sun moves around the earth in accordance with the time-honored Ptolemaic system. During the period of the reformation, mathematics was regarded as one of the most powerful weapons of Protestantism, many noted mathematicians of the time devoting all their efforts to proving that Pope Leo X. was the antichrist mentioned in Revelation 13: 18.

The history of mathematics begins in the valley plains of Egypt. On this border line between the tropical and temperate zones, climate and soil were so adapted to the needs of primitive man as to force intellect to its earliest manifestation. As Aristotle expressed it, "When pressing needs are satisfied, man turns to the general and more elevated," and consequently, as Hegel points out, the temperate zone is the true theater of history, since where heat or cold are intense, external pressure is never relieved. As the rigors of climate lessened and man attained a greater mastery over nature, these two factors conspired to force culture out of its primitive seat in the river valleys of the Nile, Tigris and Euphrates towards the northwest, its northerly progress being determined by climatic changes, and its westerly course by topographic features. If the course of mathematical development is traced out on a physiographic and isothermal map, it will be clearly apparent not only that it has followed the lines of least resistance topographically, but that it has crossed successive isotherms in its northerly progress with great regularity, due, as has been suggested, to the increasing need of the nervous system, as it becomes more complex, for a more bracing climate.

The three chief geographic features which exhibit fundamental differences are valley, mountain and sea. In the valley plains of China, India, Babylonia and Egypt, the fertility of the soil assured a plentiful subsistence, while the regularity of the seasons, combined with landed values resulting from agriculture, gave rise to a fixed social relationship. In more elevated regions, such as the plateaus of Africa and South

America, and the steppes of Russia, the scarcity of subsistence necessitates a nomadic life. In this patriarchial form of existence the size of the community is limited by the productiveness of the soil, as illustrated in Genesis 13 : 5–11. Fixed relationships are therefore unknown, and hence the political and social order called the state is impossible.

Each of the great river valleys of antiquity developed an independent civilization. Egypt first by reason of its tropical location, closely followed by China and the Tigro-Euphrates basin, lying five degrees farther north. The beginnings of Chinese culture were equally promising with those of the other great nations of antiquity. The art of writing was probably originated by the Chinese, while the elements of mathematics and astronomy, the art of printing and various manufactures, were known to them centuries before they reached Europe. The geographical isolation of China, however, put an effectual barrier to progress, resulting in a sort of inversion of character, whereby reverence for precedent took the place of progressive development. As an instance of this inversion, it is related of one of the Chinese emperors that when he wished to confer honors upon his prime minister he conferred them upon the minister's father. Chinese culture has petrified almost at the outset, and is therefore of no significance except as a case of arrested development, due largely if not wholly to geographic limitations.

In contrast to China, the civilizations originating in the valleys of the Nile and Euphrates found a natural outlet eastward and northward by way of the Mediterranean. Here culture in all its phases reflected the influence of the soil. Religion took the form of a gross nature worship, the divinities being the great rivers, the sun and moon, and other natural sources from which their physical wants were supplied, while arts and manufactures were also limited to the practical and prosaic. In Egypt the peculiar physical conditions presented by the annual overflow of the Nile led to the invention of surveying, and of necessity to the elements of arithmetic and geometry required to apply it. In architecture also the effort to orient their temples gave rise to certain fundamental geometric theorems, still in use, such as the properties of right-angled triangles, while in art the enlargement of small drawings or paintings for their temple walls was accomplished by means of a network of squares closely related to the modern Cartesian system of coordinates. The entire absence of rainfall and consequent clearness of atmosphere also had an important effect in directing the attention of the Egyptians to the heavens, which, supplemented by the oriental use of the roof as a terrace, led to the study of astronomy.

In Chaldea the similarity of race and physical conditions to those in Egypt led to identical results, the earliest fragments of Chaldean literature disclosing a considerable knowledge of mathematics, astronomy, architecture and various practical arts and manufactures. The Assyrian temples were adjuncts of the palaces, and were also used as observatories where the priestly astrologers consulted the stars and cast horoscopes. Even before Abraham left Ur of the Chaldees, that city possessed a royal observatory and a calendar. In short, action was based upon nature, although interpreted by each race in accordance with its racial characteristics. Thus, with a more esthetic people, out of door life under the clear skies of Judea found expression in the poetic description of the heavens embodied in the Hebrew Psalms, instead of in the practical astronomy which the Egyptians and Assyrians associated with their religion.

"Egypt and Assyria," said Lenormant, "were the birthplaces of material civilization; the Phœnicians were its missionaries." This describes in brief the part taken by the Semitic race occupying the little strip of seacoast, 180 miles long by 12 broad, on the eastern littoral of the Mediterranean in transmitting ancient civilization to Europe. Here again the geographical element was strongly apparent, both subjectively in their national culture and objectively in their relation to history. While the effect of mountain ranges was to shut off such regions as central Africa, eastern Asia and northern Europe from the general course of historical development, and that of the great valley plains was to intensify human activity, the sea formed a bond of union and at the same time stimulated bravery, independence and breadth of vision. To this characteristic difference between coastal and interior regions is due their frequent separation, as, for example, Holland has separated itself from Germany and Portugal from Spain. The influence of the sea was especially apparent in the development of the nations surrounding the Mediterranean. Here were three continents surrounding a sea of such shape as to afford a long coast line and of such width as to stimulate adventure. The effect was to make the Mediterranean the center of world history. On its shores arose the great centers of civilization, Athens, Rome, Carthage and Alexandria, as well as of religious faith, Jerusalem, Mecca and Medina.

The geographical location of Phœnicia, midway between Egypt, Assyria and Arabia, naturally made it first to develop commercial activity. From their rich commercial cities of Tyre and Sidon the Phœnicians pushed out in all directions, settling Cyprus, Sicily and Sardinia, founding Cadiz in Spain, and Utica and Carthage in Africa. As early as 1500 B.C. the Mediterranean was already the great highway of Phœnician commerce, their vessels penetrating the eastern archipelago, the Hellespont and the Black Sea. When these avenues were closed to them by the Greeks in the eleventh century B.C., the Phœnician commerce turned westward, bringing silver from Tarshish in southern Spain, and even passing the Pillars of Hercules and braving the perils of the Atlantic to bring tin from Britain and amber from the Baltic.

In connection with their maritime trade they also established great overland routes, their caravans bringing gold from Ophir in southeastern Arabia, and passing through Palmyra, Baalbec and Babylon, whence they penetrated all the east.

Although the Phœnicians were thus brought into intimate contact with all the great nations of antiquity, their culture was essentially different. Forced to rely upon the sea for their livelihood, they developed an industrious and hardy manhood in marked contrast to the dependent attitude characteristic of nations relying upon agriculture for their subsistence. In religion the same contrast was apparent, the religion of the Egyptians and Assyrians being a crude and sensuous idolatry, whereas the Phœnicians worshipped Hercules, a divinity whom the Greeks said raised himself to Olympus by virtue of his own courage and daring. In mathematics the Phœnicians developed commercial arithmetic, necessitated by their enormous commerce. According to Strabo, the Syrians applied themselves especially to the science of numbers, navigation and astronomy. They were, in fact, the first to notice the connection of the moon with the tides, and make a practical application of astronomy to navigation. It is also said that the Phœnicians regularly supplied the weights and measures used by their neighbors, the Chaldeans. In all respects, therefore, their culture was a natural consequence of the commercial spirit engendered by the sea.

With the rise of Grecian culture, a new topographical principle entered to alter the trend of development. Numerous mountain walls fence off the Grecian peninsula into a large number of isolated districts, each of which became the seat of a separate community or state, which never coalesced into a single nation. Moreover the coast is indented with numerous deep inlets, forming excellent harbors and giving every inducement to commerce. So numerous and deep are these inlets that the country is practically an archipelago, no place in Greece being forty miles from the sea. To this combination of mountain and coastal elements was largely due the versatility of the Greeks, while the exhilarating atmosphere and brilliant skies of Attica were also intimately related to their intellectual vigor and attainments.

The same principle of diversity is also met in the origin of the Greeks. There was here no such inbreeding of native stock as characterized Egypt and China, but at the outset a mixture of races, partly autochthonous and partly foreign, from which there evolved a higher type of intellect than had yet appeared. The diverse sources of their civilization was acknowledged by the Greeks in their mythology. Thus the introduction of agriculture was ascribed to Triptolemus; fire was introduced by Prometheus from the Caucasus; Æschylus speaks of iron as "Scythian"; while Poseidon introduced the olive, the horse and the arts of spinning and weaving. The foundation of the various states was also ascribed to foreigners. Thus Athens was said to owe its origin to Cecrops, the Egyptian; the Peloponnesus derived its name from Pelops, of Phrygia; Argos was settled by Danaus, of Egypt; and Thebes by Cadmus, of Phœnicia. Even their religion was borrowed from more ancient nations. For example, the twelve labors of Hercules rests upon the ancient idea of the sun performing its cycle through the twelve signs of the zodiac.

With the general shifting of the tribes which succeeded the Trojan War, the Dorians and Ionians came to be the dominant races of Greece. The Dorian band which invaded Lacedemon, called also Sparta from its grain fields, was at first forced by the scantiness of its numbers to be constantly on the defensive, which developed in them the warlike and hardy spirit which finally made the Spartans dominant in the Peloponnesus. The Ionians inhabited Attica, where the contending geographic factors of plain, coast and mountain transformed their original monarchy into a democracy, and their little fortress upon a rock into the mighty Acropolis of Athens, for centuries the synonym of learning and democracy. "The Athenians," said Herodotus, "then grew mighty, and it became plain that liberty is a brave thing."

No phase of Greek culture was more expressive of their national characteristics than their mathematical attainments. Heterogeneity, which formed the basal element of their national character, was here apparent in the diverse sources from which their mathematics was derived. Thales, the first great Greek mathematician and the founder of the Ionian School, was a native of Miletus, but spent much of his life in Egypt as a merchant, where he studied geometry and astronomy. Pythagoras, who was a contemporary of Thales and founder of the Pythagorean School, was of Phœnician origin, and in his early life studied for several years in Egypt and traveled extensively in Asia Minor. The Ionian and Pythagorean schools were jointly the founders of Greek mathematics, which took the form of an abstract deductive geometry, as distinguished from the practical empirical geometry of the Egyptians. It was, in fact, the boast of the Pythagoreans that they sought knowledge and not power, and had raised mathematics above the needs of merchants. One of their maxims was, "a figure and a step forward; not a figure to gain three oboli." The disciples of Pythagoras were required to pass through a preliminary training, consisting in a moral and religious preparation for life, which included the elements of music and mathematics. In fact Pythagoras made the science of numbers the basis of his philosophy in the belief that accurate measurement was essential to the definition of form, and consequently that the entire universe was founded upon a numerical basis. Thus among other attributes of number, the cause of color was the number 5; the origin of fire was to be found in the pyramid; the four elements, earth, air, fire and water were represented by the tetrad; 8 was the symbol of death, because the sum of the figures in the successive multiples of 8 decreased successively by one; 9 was the symbol of immortality, since the sum of the figures in the multiples of 9 remains constant, etc.

Plato, the great philosopher of the later Athenian school, also regarded mathematics as the basis of his philosophy, placing over his door the famous inscription, "Let none ignorant of geometry enter here." It is also noteworthy that when he was questioned as to the occupation of the Deity, Plato replied, "He geometrizes continually." This lofty idealism was characteristic of Greece and entirely foreign to the prosaic civilizations of Egypt and Assyria. Only the combination of sea, mountain and climate found in Hellas could produce the unique type of the Grecian genius. This dependence of type on surroundings is evidenced by the fixity of type apparent in ancient races. Thus the Fellaheen still bear the imprint of the Pharaohs on their countenances, and draw water with the Shadoof as at the dawn of history, while the Chinaman is still found reckoning with the beaded "swan pan," invented twenty-six centuries before Christ.

Passing from Greece to Italy, as the next stage in the evolution of culture, another great change is manifest. Italy presents no such natural unity as offered by the valley of the Nile and the Tigro-Euphrates basin, nor does it present the diversity of Greece. A narrow peninsula bounded by the sea on three sides and lofty mountains on the fourth, the physical peculiarities of Italy naturally cemented the diverse tribes with which it was originally peopled into a single state. The origin of the Imperial city dated from a predatory band of Latin shepherds who received into their community the outcasts of the neighboring tribes, so that even at the outset the dominant idea was that of physical force, a principle which pervades the whole fabric of Roman civilization. The rape of the Sabine women confirms the tradition that the band, being without women, was a predatory union of outcasts, or what Livy calls a "colluvies." The growth of the Roman state was throughout a process of accretion, rather than the unfolding of a vital principle. The civilization of the Romans was likewise due to this policy of absorption, borrowing their religion and culture from surrounding nations. But while the gods of the Greeks and the Egyptians found a home on the banks of the Tiber, they were there worshipped in a spirit entirely foreign to that of their nativity, for whereas the Greeks worshipped their divinities from an innate love of abstract beauty, the Romans worshipped the same gods from a spirit of necessity, bargaining with them for physical protection and material success. Again, although the Romans borrowed the Grecian games, they had no idea of the esthetic pleasure derived by the Greeks from perfect physical development, but degraded them into mere gladiatorial combats or exhibitions of brute force in which they were spectators and not participants. Science and art were neglected, and in literature they were largely indebted to the Greeks. Only in building and public works did the practical spirit of the Romans assert itself with any originality. Even here outside assistance was relied upon to furnish the necessary technical skill, the order issued by Augustus Cæsar that all the world should be taxed being based on a survey by Egyptian surveyors.

The fifth century A.D. was known as the "Era of the Great Migration." Owing, it is supposed, to climatic changes, the Teutonic tribes inhabiting the great central plain of Europe were forced outward, and poured east and south into the Roman empire. So great was the disturbance occasioned by this outbreak that nearly two centuries elapsed before the turbulance subsided sufficiently to note the changes that had taken place. Meanwhile an invasion from the east threatened for a time to give an Asiatic cast to civilization. With the fanaticism bred by the inaccessible deserts of the Arabian peninsula, the Saracens in the seventh century swept westward until they reached southern France, where the tide was finally turned by Charles Martel on the field of Tours. No less astonishing than their conquests was the facility with which the Arabs assimilated the culture and learning of the nations whom they subjugated. Their capitol Bagdad, situated on the Euphrates midway between Greece and India, soon became by reason of its location the meeting place for the scientific thought of these nations, whence it was transmitted by their conquests to western Europe. The mathematical attainment of the Arabs was, however, distinct from those of either Greece or India, its trend being determined by their religious observances. Thus the extent of the Moslem dominions coupled with the requirement that a believer should face toward Mecca during prayer, made a determination of direction necessary. Also the performance of prayers and ablutions at definite hours of the day and night required an accurate determination of time, while the motion of the moon had to be observed in order to fix the dates of their feasts. From these and similar reasons the Arabs became active in astronomical research, and in consequence developed the auxiliary science of trigonometry.

The turmoil attendant upon the invasion of the ancient world by the Teutons and Saracens so obscured the progress of civilization that this period, although in reality one of beginnings, is known in history as the Dark Ages. The most important feature of this vast influx of barbarians, so-called, was the rapid conversion of the Teutons to Christianity. A colder climate had bred in them a more vigorous mentality and a higher type of morality than that of the south, and Christianity appealed with especial force to their innate love of freedom and spirit of brotherhood. History thus far had been a record of the physical evolution of humanity. Egypt, China, Chaldea, Assyria and Babylonia typified the childhood of the race with its characteristic dependence upon nature apparent even in its culture; Greece with its love of form, self-consciousness and passion for freedom represented the adolescent stage; while physical development culminated in the forceful and prosaic Roman spirit, typical of manhood. The birth at this time of the Child, in Bethlehem in Judea, was then not a casual event but a necessity. The first Adam had been made a living soul, and in slow process of time had attained his majority. The second Adam was made a quickening spirit, creating a new form of energy which thenceforward was destined to transform religion, philosophy, art, music, science, language and sociology. Well may the Germans call its founder "der Einzige."

The connecting link between ancient and modern civilization during this transition period was found in the church. Early in its history the church had developed the institution of monasticism in the attempt to check the flagrant social evils of the east and preserve the purity of the northern races. The institution so established soon spread over all Europe, one order alone, the Benedictines, having at one time over 40,000 monasteries. The spirit of brotherhood thus manifested by the church was also apparent in the state in the development of feudalism from slavery, and more especially in the principle of chivalry.

The church, however, had a more direct influence upon culture by reason of the schools which sprang up in the shelter of the monasteries, and later developed into the early medieval universities. All learning, and particularly mathematics, was confined to these conventual schools, and comprised practically nothing more than was essential to the church. Learning was divided into the trivium and quadrivium, the trivium consisting of grammar, logic and rhetoric, or, in short, the mastery of the Latin language in which the services of the church were conducted, and the quadrivium consisting of arithmetic, music, geometry and astronomy. The latter were also limited to the needs of the church, comprising arithmetic for keeping accounts, music for use in church services, geometry for surveying the extensive property of the church, and astronomy for the calculation of Easter. These constituted the seven liberal arts, as enumerated in the line

lingua, tropus, ratio; numerus, tonus, angulus, astra,

and marked the limit of attainment, or, as expressed in a verse of the eleventh century,

Qui tria, qui septem, qui totum scibile novit.

The most significant effect produced by the church upon culture, however, arose in a manner unintentional and unforeseen. The rapid growth of papal authority had led the church to undertake violent measures for its own aggrandizement, chief of which was the crusades.

The activity incident to these great movements made Florence and Venice renowned for their wealth, while it also gave the Hanseatic League command of the trade of the north. With the growth of prosperity came increased leisure for intellectual development, resulting in the Italian Renaissance and the European Revival of Learning. The crusades also influenced development still more directly by opening lines of communication with the east, whereby the learning that had lain dormant in the Byzantine empire became current in Europe.

Toward the close of the fifteenth century the discovery of America, closely followed by the circumnavigation of the world, gave dominance once more to the influence of the sea. The effect of such a strong suggestion of boundless and unknown possibilities, intensified by the element of hazard and daring, became at once an important factor in development, stimulating ambition, creating moral fiber and inspiring a passion for freedom. With the opening of the sixteenth century the narrow and vague ideas characteristic of scholasticism began to give place to clear and strong thinking. As the church had been the center and source of medieval authority, the struggle for freedom naturally centered around this institution. Beginning with the reform of certain abuses, the spirit of the reformation ended by repudiating the entire authority of the church, epitomized by the action of Luther in nailing his ninety-five theses to the door of the church in Wittemberg, thus undermining the whole system of tradition and inaugurating a new principle of action based on individuality.

The relation of this mental attitude to the development of culture was nowhere more evident than in the trend taken by mathematics. Everywhere old methods were questioned and new ones substituted. The first great advance naturally occurred in Germany and Italy. In the former the time-honored system of Ptolemaic astronomy gave place to the Copernican theory, and notable advances were also made in other branches of mathematics, especially algebra and trigonometry. The intervention of the Thirty Years' War, followed by the Prussian war, stayed German development for a time, but with the return of peace the German spirit again manifested itself in the critical attitude toward science and religion which found expression in mathematics in the function theory, and in philosophy and religion in agnosticism.

In France where the invigorating effects of climate and race were less marked, the sixteenth century was characterized by such acts of religious intolerance as the massacres of Vassy and St. Bartholomew, leaving no energy for scientific pursuits. The ascension of Henry IV. to the throne, however, followed by the Edict of Nantes which terminated the religious strife, produced an immediate effect, the Age of Richelieu being remarkable for scientific and cultural progress. Great literature was produced and in mathematics the period was made illustrious by the names of Roberval, Descartes, Desargues, Fermat and Pascal, who in brief founded modern analytic and projective geometry, and laid the foundations for the calculus.

The latitude of England made it later in development than either France or Germany, while its insular position also introduced an important modification. Extensive commercial relations were developed, which, as in the case of the Phœnicians, forced arithmetic into prominence. The first advance consisted in substituting for the old Boethian arithmetic, inherited from the Romans, the more powerful algorism of the Arabs, introduced by way of the trade routes between England and Italy. In the hands of the English, however, arithmetic was soon transformed into the practical art demanded by their commerce and characteristic of their genius, the most notable addition being the invention of logarithms. So rapidly was this transformation effected that within a decade after the invention of logarithms they had come into general use.

With the growing mastery of man over nature the effect of environment in modifying history becomes somewhat less apparent. Sufficient has been said, however, to suggest the dynamic influence of geography upon culture, and indicate the new light thrown upon intellectual development when studied from the standpoint of physiography.

THE SCIENTIFIC PRESENTATION OF HISTORY

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THE question, "Is history a science or can it become a science?" has long both fascinated and irritated historical students. A few think that they have already discovered a science of history, but in reality have made only a premature and primarily speculative attempt at a philosophy of history. Some would limit their ideal to indiscriminate verification of the greatest possible number of "facts" and to indiscriminate exposure of the greatest possible number of historical fictions—sometimes adding the hard requirement of setting forth their unsystematic results in attractive literary form. Some are pessimistic because the historian can not perform experiments in the past and because even his observation is seriously limited by the scantiness of the material at his disposal. This is true, but of course does not exempt the historian from dealing with the data he does have in a scientific spirit. It only renders it the more imperative. Others more hopefully point to the progress made in modern times in the publication and criticism of sources as a sign of history's conversion to scientific method. But of scientific method in the process by which the sources are transformed into history and presented to the public one hears little. On the contrary, one finds prominent writers on historical method not merely admitting but almost rejoicing in, the impossibility of fixed principles of research, of scientific exposition of results.

Bernheim, in his "Lehrbuch der historischen Methode," after designating history as "Wissenschaft" and describing its purpose as not esthetic but informing, in proceeding to speak of the process of converting the sources into history draws all his similes from the fine arts. History is like a pianoforte rendition of an orchestral performance; it should, like a painting, make use of perspective; in it, as in a drama, the characters should be silent part of the time; gaps to fill in as between the scenes of a play should be left to the reader's imagination. In short, the turning out of the finished product is a fine art according to Bernheim, despite his denial. He says that it ought not to be poetry, but implies that it must be prose. His model historian's aim is to present the past vividly, not necessarily to prove anything. He should give specific bits from the sources occasionally, but more in order to make a story realistic than to make an exposition scientific. This story should follow either chronology or geography or "the logic of events."

It should emphasize some "facts" as essential, treat others as subordinate, omit others entirely. The only standard in this process of selection and discrimination, the sole guide in finding what the logic of events may be, seems to be the source material itself which Bernheim expects will suggest modes of treating the "facts" derived from it. These vague and inadequate recommendations as to method in historical writing at least show Bernheim's ideal of history to be not a detailed and systematic investigation of the past by analysis and classification but a well-proportioned narrative bringing events, characters and conditions vividly before the reader. Indeed he goes so far as to say, "Die litterarische Form der Darstellung welche man wählt, in entsprechender Weise die Auswahl des Mitzuteilenden bestimmt." [1]

Justin Winsor, writing in 1890 in *The Atlantic Monthly* on "The Perils of Historical Narrative," [2] affirms distinctly that history's proper method is epic and that connected action should be its exclusive theme. He wants no "maundering method"; he desires with Milton an absence of "frequent interspersions of sentiment or a prolix dissertation on transactions which interrupt the series of events"; he demands "training and large familiarity," but instead of scientific presentation is content with a "story that travels steadily to the end." "To tell the story with Herodotus," he says, "is what we have come to, after all experimenting." In the writer of history Winsor thinks desirable the same faculties that make for the merchant his fortune, by which is probably meant a sort of snap judgment. Indeed we presently hear of the historian's divination. Moreover, the historian's personality and environment are sure to affect his work. "The interlacing of the ages makes the new telling of old stories a part of the intellectual development of the race and this retelling is necessarily subject to the writer's personality and to the influence upon him of his day and generation." But Winsor does not draw the conclusion that in an age of science history too should attain to scientific form.

M. Gabriel Monod, in two recent articles in *La Revue Bleue* on "La Méthode en Histoire" writes in much the same vein.[3] For him again the historian seems to be the spinner of one connected story and rather more of an artist than scientist. He "reconstructs in his brain the image of the past." [4] Again we hear of the essential facts, of others merely accessory to these, of still others to be omitted entirely from the history, though all should be present in the historian's thought to influence his selection or to aid his constructive imagination in bridging the gaps in the sources by logical inference. Monod, however, believes that the historian can not only pick out the nuggets of "essential

[1] Bernheim, "Lehrbuch der Historischen Methode," Leipzig, 1903, p. 724.

[2] Volume 66, pp. 289 et seq. The quotations which follow in the text occur on pp. 292–294.

[3] Fifth Series, Vol. IX., April 11 and 18, 1908.

[4] *Ibid.*, p. 487.

fact" from the chaos of ore before him, but also mint the coin of general truths.[5] Indeed he is hopeful of deriving a sound generalization even from a mass of particular facts some of which are doubtful. He recognizes further that to accomplish this is no simple matter, as when, for instance, he says that the evaluation of the relative worth of the facts is a problem "délicate et sujette à mille causes d'erreurs." But it is also in his opinion a problem where "rules are insufficient" and where individual genius is called for, where sometimes "even a sort of intuition penetrates further than study and reflection."[6]

That is that divination of which Winsor spoke—a feeling-it-in-one's bones method. History written thus would be more like a feat of magic than the work of science. To identify historian and magician is of course absurd, yet it must be said that a certain mystery enveloping the labors of the historian lends further color to the fancy. The historian has too much the air of entering a holy of holies of the sources where none but he dare tread and whence he will in due time emerge bearing precious secrets from beyond the veil. Rather cabbalistic footnotes make the mystery the more esoteric. He judges the past not in open court with the evidence made public, the press admitted, a jury hearing all the facts and then rendering its verdict, but in secret inquisition where he alone is both advocate and judge—and sometimes torturer. Another historian may retry the case if he wish, but will need to start again almost from the beginning. So sixteenth century mathematicians published their new formulæ but kept from the world the processes by which they had been attained. Only there is the difference that those formulæ justified themselves in use; the historian's results must be taken entirely on faith. Of course the conscientious historian of to-day has no desire to cover his tracks, he makes by bibliography and references an endeavor to indicate them to the reader, but he seems to despair of a complete scientific exposition of his labors. Yet even if he can not always hit the truth, even if history has no scientific laws, surely his thought about history can give an account of itself. Surely, too, its methods must be ones of which it can give an account.

Monod, to do him justice, to some extent realizes the former possibility if not the latter requirement. He finally gives three "general rules" of historical presentation. First, the sources used by the historian should be indicated; second, proof of his statements should be furnished as far as possible; third, he should sharply distinguish those points of which he feels sure from those which are more or less uncertain. These rules, vague in their wording and inadequate in their scope, are a faithful reflection of the present unsatisfactory and indefinite status of historical presentation. "Indicate" the sources:—

[5] The metaphor is mine, not Monod's.

[6] *Ibid.*, p. 489.

what does that mean; how far should such indication go? "Furnish proof":—how is it to be got in order to be furnished? What constitutes proof? "As far as possible":—surely a weak-kneed and half-hearted phrase, but probably meant to leave way for the undemonstrable results of intuition and divination. As for the third rule:—how shall he make the sharp distinction, and further, ought he not rather to supply that which will make his readers certain or uncertain than merely to state his own convictions and doubts. Professor James Harvey Robinson writes on this point, "The historian has no accurate means of representing his own dubiety, strongly as he may be conscious of it. Much less can he impart his doubts and uncertainties to his reader"[7] since history "possesses no special terminology adapted to its specific uses and historical writers content themselves with vague and uncertain expressions which are in their nature literary rather than scientific."[8] Robinson, it should be said, both in the article just cited and in a lecture on "History" published in 1908 by the Columbia University Press, makes several incidental suggestions stimulating to one interested in scientific presentation, although his main aim is to expose the defects of the literary method of presenting history and he does not go on to attempt a theory of scientific presentation.

The most recent noteworthy instance of discouragement of endeavor to present history scientifically was the last annual address by a president of the American Historical Association. Professor George Burton Adams did not, like Bernheim and Winsor, disregard the possibility of scientific history; he clearly put the question, "In ascertaining and classifying the objective facts with which history deals can methods which are really scientific be employed . . ."?[9] But he went on to say coolly, "History must remain one of the branches of literature"—a servitude incompatible with scientific status. Then a little later, when wisely discouraging present attempts to philosophize history, he tended towards the opposite extreme and declared that, "The field of the historian is and must long remain the discovery and recording of what actually happened,"[10]—thereby abandoning Monod's hope of attaining to general truths and taking up a position not much more consoling to scientist than to philosopher.

On the other hand, there are tendencies toward scientific presentation outside the pages of writers on historical method. Even those who would incontinently discover some one hypothesis—for instance, the economic interpretation of history—to charm the "facts" of history from a chaos into a system, have at least invoked the name of science.

[7] "The Conception and Methods of History." Congress of Arts and Science, Universal Exposition, St. Louis, 1904. Vol. II., p. 46.

[8] *Ibid.*, p. 41.

[9] "History and the Philosophy of History," *American Historical Review*, January, 1909, p. 232.

[10] *Ibid.*, p. 236.

True, these makers of hypotheses may be in too great haste to reach their goal and base their results on dubious and insufficient data rather than undertake a thorough examination of the source material. They may resemble the Ionian philosophers with their single world grounds rather than the slow, painstaking observers and experimenters of modern science. But, like the Greek sages, those who would conquer history at a blow have not led their forlorn hope quite in vain. However faulty their execution, they have at least corrected the assumption of Bernheim and Winsor that history is merely something to narrate and have held it to be something to study, to classify, to evaluate.

Nor does present orthodox historical practise lag behind with historical theory as sketched above. Original research of to-day would generally scorn intuitive methods, and the presentation of the results of such research is seldom primarily literary. But unfortunately, since the methods of research employed are seldom fully exposed, even if we take their validity for granted so far as the particular results are concerned, we are still left without the needed data for a theory of scientific presentation. No common and accepted methods have been formulated. Moreover, while such preliminary work as the editing of the sources is painstaking and while original research is done more or less scientifically, there is a marked tendency to limit the sphere of scientific investigation to the bare "facts," to "what actually happened"—to use Adams's phrase—and to look at least for the present upon further analysis and synthesis, upon the composition of history for the public, upon the manufacture of the final product, as an art either not needing or not permitting regulation, and as sufficiently scientific if it employs the results of the two earlier processes, no matter how it may use them. Thus is built on rock a house of sand. But that is not all. The flimsy superstructure is two-storied, for there are no bare "facts" of history.

The first step towards a correct theory of scientific investigation and presentation is then to show that there are no separate and particular objective facts of history; that consequently investigation having them as its object must be fruitless; and that methods of writing history based—as were all those which have been outlined—upon the assumption that they exist are wrong. When this is done, we shall be in a position to see much better what is the task of historical investigation and hence what is its fitting method. Only when we understand that "ascertaining and classifying objective facts" is not history's true business, may we with hope of success put the question, "Can methods which are really scientific be employed?"

What then are meant by the "facts" of history? Is there in the field of history any such definite and fundamental unit as the cell in biology? Are facts indivisible, elemental entities, found hanging ripe as it were on the branches of the sources and needing only to be plucked and picked over according to their essentiality and then to be canned in works of particular research until the day when all fruit shall have been gathered and shall be crushed together to make one surpassing syrup—the philosophy of history? No; as yet no historical units have been discovered. The word "fact" is, like the word "event," merely a convenient but exceedingly indefinite term. A fact is any fragment of historic truth just as an event is an arbitrary division of the past. To speak of "objective facts" of history then is impermissible. How much a fact or an event shall include is an entirely subjective matter. A war is a fact or event, so is any battle in it, so is the death of any soldier in the battle.

Qualitatively a fact or an event is quite as difficult to limit. Bernheim and Winsor displayed a tendency to restrict the "facts" of history to epic material and Adams seems at first sight to give the same thought its most recent expression in saying, "The field of the historian is and must long remain the discovery and recording of what actually happened." But it is idle to try to study "past action" by itself. We must know the *milieu*, the material, social and intellectual environment in which an event happened, in order properly to understand the event. But why single out "events" for our attention? Why not study the past without qualification? And again, what are "events"? Every external act had its inner concomitant, cause or result. Science and art have their "connected action," as well as states and dynasties. The very conditions which form the *milieu* for some act are themselves really in constant flux and so "happening" from day to day. In the last analysis, therefore, "what actually happened," like "facts," is no other limitation upon the scope of history than the negative one of excluding fictions and philosophizing. Truth and unvarnished truth are all they mean. Everything in the past is still left as the province of history.

There is, however, another possible explanation of the expression "the facts of history." One might narrow the definition of history by accepting roughly the limited scope of past historians and trying to discover only "facts" of the sort which they give. Of course, exactly to define what sorts of past phenomena they recorded would be difficult but it is also not easy apparently for modern investigators to strike out along new lines. The tradition though vague is powerful. Herodotus and his successors too often not merely—witness Winsor—suggest to moderns their method, but also their matter. Yet if history were narrowed down from its possible scope as investigation of the past in the interest of and with especial reference to man to a study of only the writings of those men in the past who were called historians, it evidently would become mere scholasticism, a barren commentary upon traditional authorities. It is only less unsatisfactory to confine history to material additional to but similar to that with which they dealt. Their standards can be bettered, not merely as they have been by the modern attitude to sources and the modern historical sense, but also in point of the content of history and the mode of presenting it. The historian to-day must not impose on the public the limited round of topics which satisfied Greek warriors or medieval monks. He must tell us what we wish to know and also what we need to know; he must write not merely for his readers, but for science.

Within history itself there may be boundaries mapping it off into departments, as political history, the history of literature, the history of philosophy. But these very names imply that beyond them there is a broader science, history, investigating the past in its entirety so far as it concerns man. Whatever in the past influenced human life appreciably then, or has significance for human life of the present day, may well be included in the science of history, or in some great science. The historian's task, writes Robinson, "is nothing less than the synthesis of the results of special sciences."[11] Moreover, it is something more than this. The architect, for example, studies the history of architecture for the sake of his art of building; the historian includes the past of architecture in his study because of its relation to human life and progress. While, therefore, the technical researches in such partial fields as the past of architecture, of literature or of philosophy may be of great assistance to the historian, he can not content himself with compiling their results, for the reason that their technical interests are different from his broader aim. He must refashion and interpret their results before they will be available for his purpose and he must do original work of his own.

Returning to consideration of the phrases, "the facts of history" and "what actually happened," it is to be noted that they may further involve a stricture as to method. Their implication is that the investigator must occupy himself for the present with the content of history, with phenomena; that the time has not yet come for discovering its form, that is, laws and general truths. This is perhaps the fairer way to interpret Adams's utterance, and there is prudence in the attitude. The beginnings of the science of history must be cautious; science must not be impatient and race after irresponsible speculation and theorizing. It also must not be backward and rest content with aimless empiricism. It is true, as Adams says, that we must have foundations before we can build; but we must lay them with a view to building. A fact we have seen to be a vague and arbitrary division since in history's continuity and complexity no particulars having reality have yet been discovered. Consequently for investigators merely to cut out "facts" from the sources and store them up for future study is unlikely to lead to much progress, since there is no significance in the detached parts and since it will scarcely be possible to fit them together again into anything except the original chaos from which they were cut. "Facts," then, will not do as an intermediate stage in historic research any more than as a final goal. There must be something to give form to research. A more purposeful and direct method will be to

[11] "The Conception and Methods of History," p. 51.

seek to demonstrate scientific propositions immediately from the sources. Surely we have questions to put to the past, problems whose solution will be of scientific value far beyond any epic recital. Anything approaching a complete philosophy of history is and long will be out of the question, but none the less we may even now deal in a small and humble and tentative way with generalizations and hypotheses, provided we never make them except to test them by the source material at our disposal and by rigorous scientific methods, and make them only of such extent as our original investigation can compass.

There is another reason why the historical investigator must take the initiative and address inquiries to the source material rather than count upon it for indication of "the logic of events" or for other direction and guidance. It is the scantiness and fragmentary character of the source material. If we had fairly complete records we might from a mere reading of them, from mere "study and reflection"—to use Monod's phrase—get a fairly complete picture, provided the mind could comprehend and digest so great a mass of data. But with things as they are a different method than that of mere open-mindedness and absorption is practically forced upon us. Hypothesis and analysis are called for. The fragments by themselves often suggest little or nothing; it is, at least as yet, impossible to reconstruct from them the original complex whole; it accordingly remains to take up point after point which we wish to know about man and the world and see how far the fragments will contribute to the solution of these simpler and partial problems. This is not to say that we shall take no hints from the source material as to the themes of our investigation. Where the fragments suggest some generalization, some hypothesis of value, the historian may well follow it up: where they do not, let him be the aggressor.

With such the aim of historical investigation, what shall be its method? Is present historical presentation adequate to portray this method? If not, what will be the new scientific presentation that will effect this? These are the questions that remain to be considered.

Since the historian is to ask definite questions of the past instead of indiscriminately collecting "facts," his method both in investigation and presentation will gain greatly in definiteness and unity. He will know what source material is essential and what not, since his inquiry furnishes a standard; Bernheim's historian had only the source material to tell him what source material was essential. The historian will not be at a loss for a plan by which he may conduct his investigation and order the presentation of his work, since he has a definite subject and also a definite method—to prove or to disprove. He will not be left to grapple with a theme as it may chance to present itself, to discover this or that phase or fragment, and to present these discoveries to his readers according to any plan that hits his fancy. He will escape that frequent failing of German scholarship—the squandering of Herculean labor in the compilation of specific details, "facts," in other words, upon an inadequate conception of the general bearings of the subject. There comes to mind a "standard" work upon the humanism of the Renaissance, a book cited among the best in bibliographies. It consists almost entirely of a series of little essays on various humanists, containing very miscellaneous information and tacked together by artificial literary transitions. One might take a large sheet of paper, write the names of the humanists in a vertical column, set against these in succeeding columns such points as date of birth and death, parentage, patrons, pupils, chief writings, purity of Latinity, knowledge of Greek, religious attitude, and have before one not merely the whole volume but more, since now one would be in a better position to grasp the subject as a whole and see to some slight extent how individuals worked together to make a movement

The scientific historian will see not only that his theme must be developed systematically, but also that every concept which may be implicated in his investigation must be sharply defined and henceforth consistently treated from that one point of view. The field must be fenced in, if any truth is to be corralled. If one is trying to bring out characteristics of a given period of time, evidently one must limit oneself to it. If a "movement" or an institution is concerned, it should be as exactly defined as possible in terms of those phenomena, qualities, and tendencies which are peculiar to it. Thus its gradual beginning, height and fading may be adequately recognized and discriminated from each other and from events contemporary but unconnected with either. Indeed, the historian who has denied the existence of "facts" will be inclined to look askance also at periods, movements and institutions. He will shake himself free from unjustifiable historical conglomerates as well as from false historical units. We shall get from his pen no dreary historical miscellanies, no omnibus biographies. He will be trying to prove something and will assume nothing.

While then the scientific historian will sharply define every concept and field, he will not make the mistake of thinking that some portion of the historical field can be fenced off and studied by itself, as investigators of periods and places too often do now. In history's continuity and complexity not only have particulars no reality, but generalizations have no truth unless followed through the whole stream. They may take on a different significance when brought into contact with other truths. Historical measurements have relative rather than absolute value. They must be in more than one dimension. Is this asking too much? Must the historical investigator know everything before he can find out anything? Not if he does not attempt to discover too much or to measure that which has too many relations—as does a period. Not if he takes a problem sufficiently precise and limited to be covered, as it should be, by considering everything that is likely to have any relation to it. This is the direction in which original research has been tending but has not wholly attained, owing to its attachment to the false conceptions of historical "facts" and groups of facts, and to its dependence upon the source material for form as well as for matter.

In short, the historian should take the measure of everything he has to deal with, just as the scientist takes into account every factor affecting his experiment. That he can not measure as accurately and completely as the chemist or the physicist is the very worst reason for his not measuring at all. If periods, movements and human motives are so uncertain—as historians sometimes tell us by way of excuse—how can one venture to assume them instead of trying to remove to some extent that uncertainty or of frankly recording it as an element of error in the investigation? Much could be measured that never has been. While some of the researches in which historians are engaged give no promise of sure results and offer rather a broad choice of plausible or ingenious theories, extensive past literatures teeming with human prejudices, motives and ideas are waiting for accurate measurement and estimation. Were extant Greek literature, for instance, sifted thoroughly and its utterances on different topics collated and evaluated, many existing notions about Greek civilization might be modified, many new truths about it and its relations to the culture of other periods might be revealed. Or at least we should gain firm ground to stand on. For while classical scholarship is intent on minute points of ancient customs and language, for ancient ideas we have no statistics, only opinions. Such opinions have been formed no doubt as a result of acquaintance with the source material, but that fact alone is not enough. Science is not satisfied by a sort of alchemistic process in which various ingredients of source material are thrown by the historian into the seething kettle of his intellect, whence, after long subjection to the fires of unconscious cerebration and the juices of ripe reflection, they are supposed to emerge fused and transmuted into historical truth. There must be a complete and accurate analysis and measurement of that material and a sound process of deducing historical truth therefrom. This may be illustrated in more detail.

The necessity of qualitative measurement of statements not only *per se*, but with reference to the sources from which they are drawn, is generally recognized; but historians as yet seldom heed the twin requirement of quantitative measurement of our data in comparison with the sources whence they come. It is well understood that one must take into account the reliability of the source from which the statement comes, the circumstances under which it was written, the attitude of its author—whether superstitious or sceptical, rhetorical or sober, gossipy or official, spiteful or eulogistic, contemporary or hearsay, doctrinaire or unconscious and objective. On the other hand, while the scarcity of source material is often noticed, the amount of relevant material is seldom discounted to affect the worth of a particular point supported by specific statement in the sources. Yet a point is not proved by two or three bits of favorable evidence if the available sources are such that ten or twelve confirmations might be expected. Or the available source material may be so scanty that it does not offer sufficient basis for any positive conclusions. One should try to determine not only how much evidence there is on the point in question and in what degree it bears upon that point, but also how much there ought to be. The quantity of evidence pro and con must be measured not only absolutely, but also in proportion to the available source material, and further with regard to the source material which is missing.

After adopting and working out in full detail through practise the method of research which has here been but suggested, historians will still have the duty of showing others, not only their results but the solid foundations on which these rest and the process by which they were attained. This obligation is recognized to-day to the extent that a historical work without bibliography, footnotes or references to the sources is not considered scholarly. But this is not enough. A list of the books that the historian has used is far from fulfilling the requirement which science makes of a complete analysis of the source material. It gives little idea of the character, scope, applicability and reliability of the source material, even though some word of comment be attached to each title. Fault may be found, moreover, with the footnote as a means of proof. And here is criticized the footnote at its best, rather than when, with pretentiously long quotations in foreign tongues and with superfluity of scholarly digression and learned small talk, it degenerates from a pillar by which science supports its results into a pedestal upon which erudition poses; or when, instead of bearing upon the main point, it gives specific references merely for some accompanying illustrative detail which proves nothing. At its best the footnote less actually proves a point than furnishes indications how one can set about proving it for oneself. Then, owing to the erroneous notion about "facts" of history, each footnote attaches itself to some one point in the text. Thus all the notes taken together supply means for verifying particular statements, but do not substantiate general truths nor lead us to scientific propositions. That must be done in the text, if at all. But here is a third disadvantage that the proof contained in the notes, besides being subdivided there and so losing the strength of union, is further detached from the proof in the text. Yet the very existence of the footnote bears witness that the literary method of presentation at present employed in the text is unsatisfactory for scientific purposes, testifying that the whole would become even clumsier and more confused were the attempt made to embody the notes in the text.

The remedy is a presentation primarily scientific, a unified and uninterrupted presentation of the complete historical process from raw material to finished product. The historian will reveal his investigations as well as their results. After stating and defining his problem with scientific exactness, he will make perfectly clear the material available and utilized for the solution of the problem, and will inform us of the plan by which that material will be exploited. Then will follow naturally the subjection of that material to these methods and the consequent results, positive or negative, partial or complete. Presentation will follow investigation step by step.

Moreover, since investigation will be so completely a matter of accurate measurement and of accurate conclusion therefrom, the method of presentation will probably somewhat resemble that employed by mathematics and the sciences. We shall come, not merely to the historical terminology which Robinson desires, but also to standards of historical measurement, modes of historical reckoning, historical symbols, curves, charts and other graphic means of presenting briefly and accurately what prose could compass only in many pages or fail to express with requisite precision and discrimination. Thus, while historians will present proof as well as results, this greater detail than is at present given will be so put that it can be looked over in less time. Historians will no longer be handicapped as were the medieval algebraists who wrote out their equations in words. Other sciences of human life, psychology, economics, sociology, have already turned to such methods; history alone remains backward and awkward. Yet the scantiness of the material at its disposal, in comparison with the abundant opportunity for experiment and observation possessed by the others, requires from it even more accurate inspection, calculus and presentation.

Even in historical manuals, text-books, general treatments of countries and ages, and other works of too pretentious scope and abbreviated form to be based directly on the source material and use of scientific processes, there will be no reason why scientific propositions may not in increasing measure constitute the contents, the field be definite, the form in accord with the true spirit of history. Possibly fewer persons would study the reformed presentation than read histories at present, but they would learn more truth of value, gain a deeper insight into the true nature of history, and have a greater respect for it. One could not then dismiss it as "a branch of literature." Its utterances would rest neither on vague consensus of opinion, nor on the reputation, nor on the footnotes of this and that individual; but upon a common method, open to the scrutiny of all and worked out in its fullness by generations of scholars, though applied in each particular investigation by an individual mind.

THE NATURE OF FATIGUE[1]

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To the conscientious schoolmaster the contemplation of a dissertation on the nature of fatigue can hardly seem an unmixed joy; for the subject is one with which he is already practically and sadly familiar. I may say at once, however, that I have not come here to remind you too acutely of this aspect of your professional work, your sensations at the end of a busy day in the class room. I, too, have felt those sensations, and I know how dully depressing, to both mind and body, they may be. They must be reckoned with and eliminated in the reform of the school. Much is written on the fatigue of the school child, but the ideal school course will allow the teacher too to bring an unjaded spirit to his successive tasks. In his Utopia the teacher will have his playground, as the child now has his. My present task, however, is not to limit myself to a discussion of the fatigue that is incident to life in the schoolroom, but to present to you a study of a specific topic in physiology, and to try to show that it has broad biological bearings.

In popular usage the term fatigue is employed loosely, for while it signifies, in general, a depression of physiological activity, resulting strictly from previous activity, physiological depression is often called fatigue when it is not at all clear that previous activity is at the bottom of it. It does not, however, appear to me at present necessary to hold always to the strict significance of the word, since in a given case there are still too many unknown causative factors. Moreover, in the marvelously complex weft of the human organism, where the physical and the psychical are inextricably intermingled, illusion is so readily mistaken for reality, especially in the phenomenon now before us, as often to make the detection of a genuine fatigue well-nigh impossible.

Let me proceed at once to an analysis of the phenomenon of fatigue. Every one is familiar with its sensations; but not every one realizes that the sensations are but signs of physical and chemical conditions permeating the whole body. Fatigue is a general physiological phenomenon; not only is the whole body subject to it, but every organ, tissue and cell of which the body is composed. Like other general physiological phenomena, its study may be best approached by considering its manifestations in the parts of the organism. I propose to

[1] An address delivered before the Section on Hygiene of the Connecticut State Teachers' Association, at New Haven and Hartford, October 22, 1909.

examine it first in the tissue of voluntary muscle, which affords certain advantages for study over other tissues, because of the ease of employing the graphic method and other physical, as well as chemical, methods.

If, shortly after the death of an animal, a single muscle, such as a muscle of a leg, be removed from the body, be attached to the usual muscle lever of the physiological laboratory, and be stimulated in the usual manner at regular intervals, beginning when the muscle is fresh and continuing until it is well fatigued, the graphic record of the

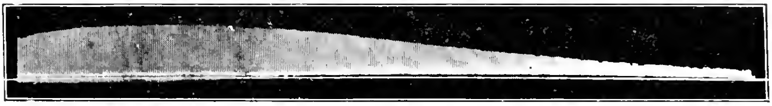


FIG. 1. Series of contractions of a frog's sartorius muscle, excised and stimulated at intervals of two and one half seconds. Each successive vertical line is the record of a single contraction. The contractions at first increase in extent, this stage constituting the treppe, and later decrease, this stage constituting fatigue.

series of resulting contractions presents a striking picture. Both the extent and the duration of the contractions may be affected. There appears early an increase in the extent of the contractions, which proceeds gradually to a maximum. This is shown in the graphic record as an increase in the height of the successive muscle curves (Fig. 1) and has been called, not inappropriately, the staircase, or *treppe*. The treppe signifies that in the early stages of muscular activity the working power of the muscle is progressively augmented—there is a temporary improvement in the power to work. This in turn means that what physiologists call the irritability of the muscle, or, in other words, its power of responding to a stimulus, has become greater; hence the same stimulus is followed by a greater contraction. A progressive improvement in the power to work in the early portion of a task, I may say, is not peculiar to muscle. We all must have noticed it in our own experience, with both physical and mental labor. It has also been demonstrated by laboratory methods in nerves, the central nervous system, and other animal and plant tissues; and it is probably a characteristic of all living substance. An analogous phenomenon is observed when living substance is put under the influence of certain drugs—a small quantity of alcohol, for example, often effects a temporary improvement in the individual's power of performing work.

Following the treppe, the muscle may perform maximal contractions for a considerable time; it is in its best working condition; its irritability is such that a given stimulus calls forth the greatest contraction of which it is capable. But sooner or later the contractions begin to diminish in extent; they sink to the level of the original amount and below it; the muscle becomes gradually weaker and weaker, until, with long-continued effort, it may finally cease altogether to lift the weight. This decrease in working power from the maximum characterizes the stage of fatigue proper. Decrease in working power may, in fact, be said to be the universal physical phenomenon of fatigue, whatever form of protoplasm we may be considering. Decrease in working power is accompanied by a decrease in irritability. The stimulus remaining the same, the work is diminished: but if the stimulus be increased in intensity, the protoplasm may again perform more work for a brief time. Sooner or later, however, all stimuli cease to be effective, and the living substance is then either exhausted or dead.

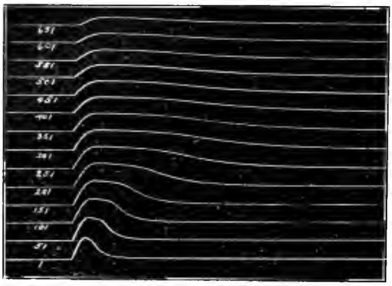


Fig. 2. Series of contractions of the frog's gastrocnemius muscle, excised and stimulated at intervals of two seconds. Every fiftieth contraction is recorded. The increase in the duration of the process of relaxation as fatigue proceeds is shown in the progressive lengthening of the descending limb of the curves.

If, in our graphic record of muscular fatigue, we are employing a favorite subject of physiological study, the muscle of the frog, we observe another striking physical change. Early in the series, even before the treppe has reached its maximum, the duration of each contraction begins to increase, mainly by a slowing of the process of relaxation (Figs. 2 and 3). This may reach great proportions before exhaustion sets in. This slowing of relaxation appears to be wholly absent in the fatigue of warm-blooded, and presumably of human muscle (Fig. 4).

The fatigue of muscle tissue is thus characterized by marked physical peculiarities. It is only natural to ask what are the causes of these.

Happily it is becoming the fashion in physiology, if only slowly and following long after, it is true, the usage of John Stuart Mill, to speak less of causes than of conditions. The cause of a phenomenon is the sum total of its conditions. All conditions are causes, and it is illogical to select one or two conditions and dignify them by the seemingly superior designation. In speaking of the causes of fatigue, as is often done, one usually means its chemical conditions; for within protoplasm, when in activity, there occur certain chemical or metabolic changes, with which the phenomenon of fatigue is closely associated. These chemical changes involve two general processes, namely, the consumption of certain existing substances which are essential to the activity of the protoplasm, and the production and accumulation within it of certain waste substances. Here again the muscle has yielded us our chief knowledge. Of the substances that are consumed in protoplasmic activity, we know most about two, oxygen and carbohydrate. For all aerobic tissues or organisms a continual supply of oxygen is essential to the continuance of working power—in fact, one way of bringing on the main phenomena of fatigue seems to be by eliminating oxygen. On the other hand, recent work suggests that one of the means of increasing working power or temporarily, at least, delaying its loss, is by artificially supplying oxygen to the body. It has been known for some time that with the usual conditions under which we live, the main source of the energy of muscles and probably of other organs is carbohydrate material, glycogen or its near

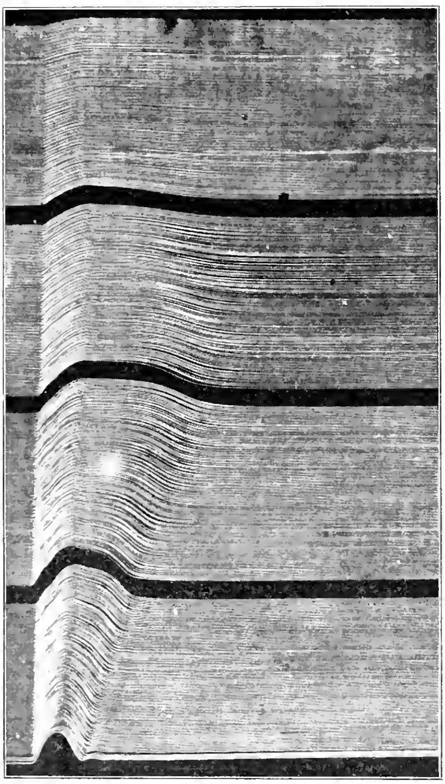


Fig. 3. Series of 550 contractions of a frog's gastrocnemius muscle, excised and stimulated at intervals of two seconds. Every contraction is recorded, except at the places indicated by the black bands, at each of which the records of fourteen contractions are omitted. The record of the first contraction is at the bottom of the figure: that of the last one at the top. Fatigue is shown in the progressive decrease in height and the increase in length of the curves.

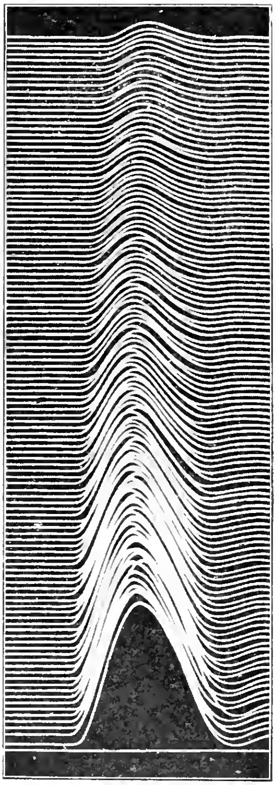


Fig. 4. Series of contractions of a rat's gastrocnemius muscle, excised and stimulated at intervals of two and one half seconds. Fatigue is shown in the progressive decrease in height of the curves.

relative, sugar. In the burning of carbohydrate in the tissues its potential energy becomes the actual energy of heat and muscle work. This fact would suggest the loss of carbohydrate as one of the factors in the oncoming of fatigue, especially in its later stages. Exact laboratory investigation, moreover, shows that if most of the carbohydrate be removed from an animal's body, he presents the symptoms of pronounced fatigue; and the same is true of his individual muscles, which are incapable of performing as many contractions as the muscles of a normal animal. Feeding such an animal with sugar restores his energy and makes his muscles capable of greater labor. This latter experiment has its counterpart in the common practise, by soldiers, guides and explorers, of consuming sweets, such as maple sugar, chocolate and raisins, when on long marches; while for the farmer in the hayfield nothing is more gratifying than a sweetened drink. It is quite possible that future research will discover other substances, besides oxygen and carbohydrate, the loss of which to the tissues is conducive to the production of fatigue.

Oxidation and destruction of carbohydrate result in the formation of at least two waste substances, both of an acid character, namely, carbon dioxide and lactic acid. Now it is an interesting fact, derived from laboratory investigation, that both of these substances, when in any but small quantity, are inimical to protoplasmic activity, and, furthermore, that a muscle under their influence shows the very same physical symptoms that are shown by a muscle fatigued through work. A fresh muscle to which has been given a moderate or considerable quantity of either one of these substances is a muscle already fatigued, although it may have performed no work (Fig. 5). These two metabolic products are thus believed to be important factors in the causation of fatigue, and to them has been given the name, "fatigue substances."

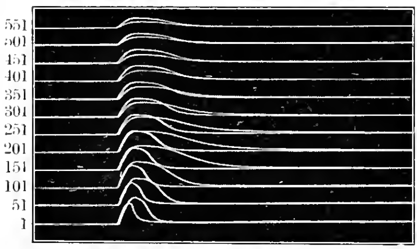


Fig. 5. Series of contractions of the two gastrocnemius muscles of a frog, excised and stimulated at intervals of two seconds; the one muscle normal, the other under the influence of carbon dioxide. The longer, or, in the later contractions, the lower curves are those of the poisoned muscle. Every fiftieth contraction of the two muscles is recorded from the same base line. The augmenting action of the fatigue substance is visible in the first two hundred contractions; its fatiguing action in the subsequent ones.

Fatigue substances are poisonous, or toxic, to protoplasm; they diminish its irritability, so that a given stimulus calls out a less response than before. Certain other substances, besides carbon dioxide and lactic acid, are thought to belong to the class of fatigue substances, some of which are probably produced normally, while others occur only in diseased conditions. Among these pathological fatigue substances may be mentioned β-oxybutyric acid, which is present often in large quantities in a body suffering from diabetes—and it is a well-known fact that a person afflicted with diabetes is incapable of any considerable labor without extreme fatigue. β-oxybutyric acid occurs also in a starving body. The weakness of a person in starvation is associated partly with the absence of the essential carbohydrate or other food stuff, and partly with the presence of β-oxybutyric acid. It is probable that future research will add still others to the class of fatigue substances, especially to those which are accompaniments of disease. Fatigue is one of the most common features of disease, and especially of diseases that are characterized by an upset of the chemical balance of the body. In such cases a considerable increase in the quantity of some intermediate metabolic product may conceivably lead to fatigue phenomena.

A few years ago, in studying experimentally the action of fatigue substances on muscle, I came upon an unexpected result. Fatigue substances in small quantity have a physiological action which is exactly the reverse of that of the same substances in larger quantity—instead of depressing or fatiguing protoplasm, they act so as to augment its activity. In other words, they increase its irritability, so that a given stimulus is capable of eliciting a greater response than it could elicit without the aid of the fatigue substances. Graphic records of the contractions of muscles under the influence of very small quantities of carbon dioxide, lactic acid or other fatigue substances, show how potent this augmenting action may be (Fig. 5). I believe that in this action we have the long-sought explanation of the treppe. In the early stages of muscular work the fatigue substances are present in small quantity, in later stages in large quantity. Correspondingly in the early stages there is augmentation or treppe; in the later stages there is depression or fatigue.

Thus far I have confined myself largely to a consideration of fatigue as exhibited by muscles, where the phenomena are best known and can be studied most accurately. There is every reason to believe, however, that the main principles of muscular fatigue are demonstrable in the other tissues and organs of the body—that in them also fatigue is characterized, physically, by a diminution in working power and, chemically, by both the destruction of energy-yielding substances and the appearance of toxic metabolic products. Diminution of working power is manifested in very different ways by diverse tissues. Glands in fatigue seem to secrete less than when fresh, and it may be that the action of digestive juices is diminished. The kidneys may be deranged, so that their epithelium is unable wholly to prevent the passage of albumin from the blood to the urine. A fatigued heart is dilated, its beats are quickened and may become irregular, and its diastole, or resting period, may become abbreviated. Fatigue often results in an abnormally high bodily temperature, constituting a fatigue fever. The chemical phenomena of fatigue in the various organs and tissues, apart from the muscles, is almost wholly unstudied, and there is great need of a careful analysis of the entire subject.

The fatigue of the nervous system is of great general interest, yet there are few subjects in experimental physiology that are more difficult of study. Notwithstanding that most of us doubtless believe that we know the symptoms of nervous fatigue well, physiologists have been able to discover only scraps of fact in this field. The isolated nerve of a cold-blooded animal, when artificially stimulated in the laboratory, can perform its work for many hours without showing the least sign of a diminution of power. Only when placed under unfavorable conditions, such as in light anesthesia, or when deprived of oxygen, does the nerve exhibit with continued stimulation a gradual loss of conductivity. From this it is inferred that the nerve fiber itself under normal circumstances is highly resistant to fatigue, and that any unfavorable dissimilative changes which it undergoes in activity are compensated for at once by an equal assimilation. This highly interesting and suggestive conclusion is perhaps equally true of nerve centers. Hodge and others, it is true, have demonstrated morphological changes in nerve cells as the result of artificial stimulation and of normal daily activity. Thus the nuclei of the brain cells of a honey bee may show a diminution in volume of 75 per cent., at the end of a day's labor; and the English sparrow, though popularly regarded as less typical of industry, reveals almost as much cerebral activity. Notwithstanding these evidences of metabolism, no one has yet succeeded in obtaining, by direct or reflex artificial stimulation of the nerve ganglia, the spinal cord or the brain of animals, indisputable physiological evidence of the genuine fatigue of the nerve structures involved. Many attempts have been made to detect fatigue in the nervous system by testing the muscular power, as by the employment of the ergograph, the instrument in which a muscle or set of muscles is made to perform a series of voluntary contractions and lift a given weight, the progress of fatigue being indicated by the rate at which the lift diminishes. But endeavors to arrive at an exact analysis of the result of such an apparently simple experiment have given rise to a controversy as to the location of the fatigue, some investigators claiming it for the muscles, others for the brain.

A still further attempt at the investigation of brain fatigue is through the study of certain mental processes during or following long-continued effort. Mental fatigue is characterized by a diminution of attention, a difficulty in concentrating one's thoughts, slowness in reacting to sensory stimuli, in memorizing or in reasoning, difficulty in recalling memorized passages, errors or slowness in mathematical calculations, and other phenomena. While these are obvious in the fatigued individual, all attempts at exact measurement of them and the deduction therefrom of the degree of psychical or physical fatigue have failed.

Thus, while some of the characteristics of nervous fatigue are known, all methods heretofore adopted to study the fatigue of the central nervous system exactly with a view of determining its relative susceptibility to fatigue are unsatisfactory. The preponderance of evidence at present seems to me to be in favor of a high degree of resistance to fatigue on the part of the brain and spinal cord, as of the nerve fiber itself. In fact, such a condition is what we should expect *a priori*. The nervous system is the administrative instrument of the individual; it directs, controls and harmonizes the work of the parts of the organic machine, and gives unity to the whole. It is not the frail, delicate thing, easily put out of gear, that we at times believe it to be. It is capable of enormous demands on its powers and of enormous resistance. It is the last system to succumb in many diseases and in such a dire condition as starvation. It would seem to be only highly advantageous to the organism that its nervous system should be able to resist the oncoming of fatigue, with all the direful consequences that might follow its advent.

After thus analyzing the phenomena of fatigue in their manifestations in the various organs and tissues of a complex body, let us briefly consider fatigue as we feel it in ourselves. When we perform a long-continued and ultimately fatiguing task, either physical or mental, we can recognize, with little difficulty, three successive stages of working power, although these are not sharply separated from one another. During the first stage our working power gradually increases; during the second it remains approximately stationary at a high level; during the third it gradually decreases. During the first stage our performance is at first distinctly up-hill work; we find it difficult to concentrate our attention; we feel already fatigued; we could easily give up and do no more. But, surprisingly enough, if we keep on we find the work getting easier; we can accomplish more and more, seemingly without greater effort; we seem to be breaking through barriers that have hindered us; our sensations are agreeable; we say that we are getting our second wind; we feel new courage and no longer care to give up. Before we realize it we have gotten our second wind and have passed into the second stage; our working power is at its best, and we continue to labor, heedless of time; if we attempt to philosophize, we are only conscious of the fact that our labor is easy and our burden light. But this stage, though it may be long continued, ultimately gives place to the third stage when we realize that our powers, after all, are limited, that work is hard, that either we must put forth greater efforts or our output diminishes, and that we are really tired. Now these three stages of individual labor are but the three stages which we have already seen epitomized in the isolated muscle—the treppe, the period of maximum contractions, and the fatigue—and I do not doubt that they are associated with the same chemical phenomena. The stage of getting our second wind is when our fatigue substances are in minute quantity, and they gradually augment our physiological irritability and our output of energy. The stage of our best work is when irritability is at its highest, we have a store of oxidizable fuel, and toxic products have not yet begun to exert their deleterious action. The stage of fatigue is when our fuel is becoming exhausted, its waste products are clogging the furnaces, and physiological irritability is low.

Fatigue, as we feel it after excessive work, is often spoken of as a sensation. Really it is a great complex of sensations. These sensations differ in some degree according to the character of the work, whether it is mental or physical, and if physical, according to the particular groups of muscles employed. But in extreme fatigue such differences are comparatively slight. There may be a "tired" feeling in the head of obscure origin; pain and soreness in the muscles, resulting from an excessive accumulation of blood or lymph, or perhaps from an actual rupture of muscle fibers; stiffness in the joints, resulting from lymph accumulation; swelling of hands and feet, from the same cause; sleepiness, which is accompanied by cerebral anemia; even a feverish temperature because of derangement of the temperature-regulating mechanism; and many other sensations, but, most general of all, a disinclination to perform either mental or physical labor, which may be due in part to general depression of the nervous system, in part to the presence of the unusual sensations, and in part to the mental recognition of the fact that the irritability of our tissues has become diminished and a greater stimulus than before is now required to induce a given action. It is not often possible for the individual to make a satisfactory analysis of the excessively complicated compound of sensations, which he may possess when his body is in a fatigued state. But it has come now to be generally accepted that the sensations

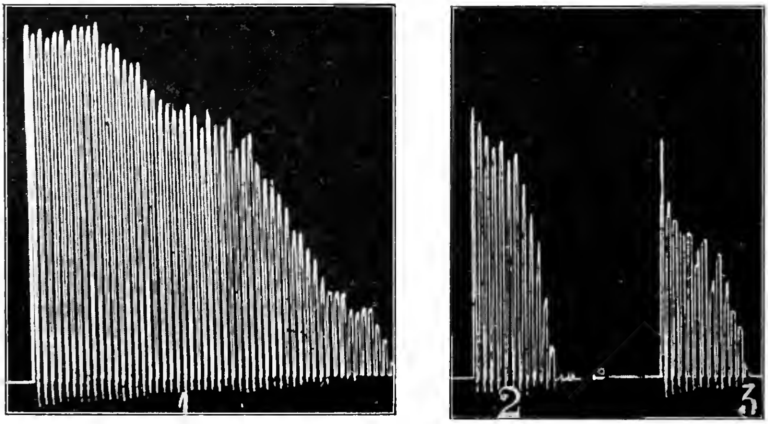


FIG. 6. Series of contractions of the flexor muscles of a human finger. The muscle was stimulated electrically every two seconds, and the resulting contractions were therefore involuntary. Record 1 was made when the muscle was fresh; record 2 immediately after three and one half hours had been spent in the oral examination of students; record 3 two hours after the completion of the examination. (From Mosso's "Fatigue.")

of fatigue result largely from events happening outside of the brain and spinal cord, events of which I have been speaking under the head of physical and chemical phenomena. Such events are not, however, confined to the particular tissues that have performed the fatiguing work, for fatigue substances, though produced in one tissue and fatiguing it, may be carried by the blood to others and there also exert their characteristic action. This fact, that the excessive work of one tissue may cause the fatigue of other tissues, is of great practical importance to us in our daily life. We all believe that excessive muscular work may cause mental weariness. It has been shown by laboratory experimentation that the reverse is true, that excessive mental work may cause muscular weariness. In an experiment upon himself Dr. Maggiora, of Turin, found that the flexor muscles of his middle finger, upon being stimulated by an electric current applied directly to them, were capable of lifting a certain weight fifty-three times before temporary exhaustion set in (Fig. 6). Soon after the completion of the test he entered the class room and devoted the subsequent three and one half hours to the oral examination of students, a task which, he being then a teacher of little experience, was excessively difficult. Immediately after the end of the examination he tested his lifting power again and found his muscles capable of making only twelve contractions. It is often thought that the best means of recuperating after a day's hard mental labor is through the performance of physical exercise. A temporary change of occupation may, indeed, be of great benefit, by relieving an exhausted organ and an exhausted focus of attention. But physiology tells us that a tired brain means a tired body, and that with the brain fagged there is nothing culpable in a desire for not only mental but physical rest.

But there is another aspect of personal fatigue which we can not neglect. Our sensations become our servants or our masters, according as we will. Either we control them, or they control us. Is it legitimate, is it moral, to yield to every sign of weariness? Here we meet at once the problem of the formation of habits. Fatigue may easily become with us a habit, a habit which is destructive to legitimate effort. We have all known the perpetually tired man, the chronically fatigued, to whom both initiative and performance alike are distasteful and to be avoided, when possible. This condition may at times be so pronounced as to be positively pathological, demanding special curative treatment. Fortunately such a condition is rare. Most of us may live on a high or a low plane of activity at will; we may do much or little; we may yield early to fatigue or we may successfully resist it for a time with impunity.

The more one studies physiology the more one appreciates the fact that protoplasm possesses an enormous power of work, and that the human body is endowed with marvelous capacity. Whether we shall get our second wind, or, having gotten it, whether we shall utilize to the full our powers of work, is a matter of our own will. I believe that few of us live up to our opportunities for accomplishing things. We are too inclined to yield to the early demands of fatigue. Even without exceptional hereditary endowment more of us might have, if we would, the endurance of a Weston, the discernment of a Darwin, the shrewdness of a Harriman, the determination of a Peary, or the insatiate desire to be on top which distinguished our late president. In his very sensible and characteristically delightful essay on "The Energies of Men," William James says:

> The human individual lives usually far within his limits; he possesses powers of various sorts which he habitually fails to use. He energizes below his *maximum*, and he behaves below his *optimum*. In elementary faculty, in coordination, in power of *inhibition* and control, in every conceivable way, his life is contracted like the field of vision of an hysteric subject—but with less excuse, for the poor hysteric is diseased, while in the rest of us it is only an inveterate *habit*—the habit of inferiority to our full self—that is bad. . . . We live subject to arrest by degrees of fatigue which we have come only from habit to obey. Most of us may learn to push the barriers farther off, and to live in perfect comfort on much higher levels of power.

Herein lies the value of training. Training, whether of the child or the adult, the athlete or the thinker, consists largely in the development of a power of resistance to the toxic fatigue substances, and is not unlike the production of a condition of tolerance to a poisonous drug by the administration of successively increasing doses of it. Physical training is not fundamentally different from general educational training. Habits of industry, which every educational system strives to develop in the child, are the converse of habits of fatigue, and in the last analysis habits of industry mean, in very large part, an acquired power of resistance to fatigue substances.

One difficulty which we all recognize is that of distinguishing between real and pseudo-fatigue in ourselves or others, and knowing when a rational degree of real fatigue has been reached. The matter is a vital one to teachers, for a knowledge of the rate at which working power diminishes, of the presence or absence of a fatigue state at a given moment, might be of material help in directing the pupil's work. Various studies have been made of the fatigue of school children, but the results of all of them are unsatisfactory because of the lack of a satisfactory method of investigation. Even the physiologist in his laboratory, however exact he may be with the muscles of animals, has no method of measuring accurately the degree of fatigue in the intact body of a human being. Our sensations are not altogether a safe guide. We often interpret a temporary sleepiness, a temporary lack of power of attention, and uneasiness to be free from our task, as signs of real weariness and evidence that we should stop our labors. Yet we know that often a slight change of conditions will seem to give us renewed energy, the feeling of fatigue is gone and we turn with freshness to our task; our supposed fatigue was only an illusion. Even with our imperfect experimental methods, however, enough has been discovered to show, among other things, that human beings differ greatly in the rate at which fatigue develops. Mosso demonstrated this many years ago, though his methods are not now regarded as the best.

I have thus far confined myself to a consideration of the nature of fatigue and the conditions under which it develops. Recovery from fatigue is perhaps of even greater interest. Both in the isolated muscle and in the intact organism, fatigue may be carried so far that recovery is difficult or even impossible. The later stages of fatigue are often spoken of as exhaustion, but obviously no sharp line can be drawn between fatigue and exhaustion. Exhaustion is probably most common when labor is continued for years without adequate resting periods. Exhaustion from a temporary effort is of rare occurrence, observable occasionally in athletes and in persons upon whom there is made a sudden and unexpected demand for enormous physical or mental exertion. Usually, however, when a fatiguing expenditure of energy by a living tissue ceases, recovery begins at once. Even in the excised muscle, with all supply of blood cut off, a few minutes' rest allows for a certain degree of recuperation, due possibly to the absorption of oxygen. If a weak solution of common salt, or, better, a suitable mixture of various salts, be passed through the blood vessels of the muscle for a few minutes and thus the accumulated fatigue substances be, at least partially, washed out, the recuperation is greater. If a small quantity of glucose be added to the solution, or if nutritive oxygenated blood be introduced, there is still greater recovery, and the power of further work is much enhanced (Fig. 7). All of these methods are

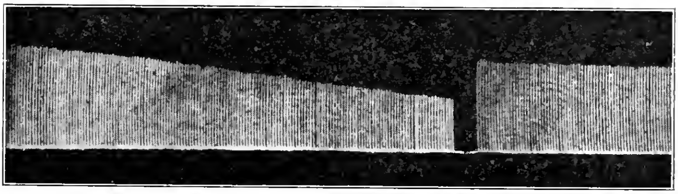


FIG. 7. Series of contractions of a frog's gastrocnemius muscle *in situ* and stimulated at intervals of two seconds. The flow of blood through the muscle was stopped by ligating the artery, and the record of fatigue was made. At the break in the series, the muscle rested five minutes, during which time the ligature was removed and the blood was allowed to circulate through the muscle. The record of contractions at the right of the break was made immediately after the resting period, and while the blood was still circulating.

physiological—in them the chemical conditions conducing to fatigue are replaced by reverse conditions and the result is reversed—oxygen and food are introduced, carbon dioxide and lactic acid are removed, and there is a restoration of working power. In the living human body the same processes and the same result are best brought about through the combined agencies of food and rest, with sleep. Sleep is here of value since, by its complete inhibition of the more obvious corporeal activities, it makes rest more complete and thus allows the more complete elimination of fatigue substances and restoration of those things that are essential to future activity.

Equally difficult with the problem of the extent to which labor may safely be carried is the problem of how much food, rest and sleep are required for healthful recuperation. How much we think we require is another question, for here again our sensations are misleading and it is easy to acquire habits which bear little relation to nature's demands. We here assembled, being in the shadow of Professor Chittenden's laboratory, are in the very center of the low-protein camp, and with appetites bridled we can safely defy those who tell us to eat what we please, when we please, and all that we please. There is, indeed, little doubt of the correctness of the main contention of Chittenden, Fletcher, Fisher and their followers, that it is physiologically advantageous to consume less protein than most of the civilized races consume, and it is impossible to avoid a strong suspicion that the presence of a superfluity of food stuffs within the body leads to an accumulation of intermediate metabolic products which in themselves act on the tissues as fatigue substances. The physiological optimum in the matter of quantity of food probably differs with each individual and, with our customarily unscientific habits of judging ourselves, is probably rarely known. This is equally true of the amount of rest and sleep required for recuperation. Our fathers told us "eight hours' work, eight hours' rest and eight hours' sleep"—yet did our fathers, more than we, literally observe the adage? As I believe that most of us eat too much, so I believe that most of us work too briefly and rest too long. Yet more significant than duration is intensity. "Work when we work, and play when we play," is not a meaningless nursery jingle, but a wise physiological dictum. Application, concentration, putting our whole selves into our task, with a wholesome disregard of fancied fatigue—that is the method of accomplishment. But when fatigue really comes, then should the task be laid completely aside for restoration. Play is one of the surest agencies for mental relaxation in the waking state. Pathetic was the confession of one of the world's most busy workers a few years before his death, at the age of forty-five, that he had "almost forgotten how to play." Effective sleep should be dreamless, and if it is of the right sort, it need not occupy one third of all our life. For most persons eight hours of actual sleep would mean nine hours in bed—and only a sluggard would demand that.

Food, rest, play and sleep may be regarded as the effective physiological antidotes to fatigue. One ingenious German investigator would add to these another. In an experimental study he believes that he has demonstrated in fatigued animals the existence of a fatigue toxin, different from simple carbon dioxide and lactic acid and allied to the toxins produced by bacteria. He claims to have extracted this in a pure form, and upon successive injections of it for a period of time into the bodies of other animals their tissues have produced, he claims, an antidote to it in the form of a real antitoxin. This antitoxin of fatigue, if administered to fatigued animals or even human beings, is said to bring about prompt recovery; if administered to fresh organisms it is said to greatly prolong their working period. I am not prepared to deny the truth of these claims, but such striking discoveries should be confirmed by other investigators before one can fully believe in their reality. It may be said that present science knows no safe, quickly acting, effective antidote to the toxic action of fatigue substances. There can be no doubt, however, about the temporary anti-fatiguing power of certain drugs. The caffeine of coffee and tea is one of these, and the theobromine of cocoa is another. Alcohol, too, may act as a temporary whip. When administered to even an isolated muscle, in small quantity, it augments activity, quickens contraction and delays fatigue; in large quantity it is depressing and hastens fatigue. In these respects alcohol is not unlike the physiological fatigue substances. It is undoubtedly useful in very brief emergencies involving fatiguing effort, but like other drugs its usefulness lies outside the normal physiological life of the individual.

Besides the more purely physiological and psychological aspects of fatigue, it has an important relation to many sociological problems. In its milder form it may be regarded as a blessing, since it leads to healthy rest. But if its warnings are not heeded, it may prove a serious affliction. By reason of its inhibition of activity it is a potent sociological force. It is one of the causes of misery and poverty and disease; it is an inciter of crime; it has helped to lose battles; it has limited industrial expansion. Professor Irving Fisher has recently estimated the minimum annual cost of serious illness in this country as one and a half billion dollars, and says: "The economic waste from undue fatigue is probably much greater than the waste from serious illness." Fatigue must be reckoned with in all human activities, and its toll must be rigidly paid. Happy is he who has the power so to direct his bodily machine as to obtain from it its highest efficiency.

A GREAT MARINE MUSEUM

By Professor CHARLES ATWOOD KOFOID
UNIVERSITY OF CALIFORNIA

A LOGICAL and characteristic expression of the national spirit of modern Germany is to be found in the Institut für Meereskunde which was established in 1900 in connection with the Königliche Friedrich-Wilhelms Universität at Berlin. The rise of Germany as a maritime power has found popular demonstration in the Marine Expositions at Berlin in the winter of 1897–1898 and again in the summer of 1908. The first exposition led to the beginning of a permanent marine museum and the second contributed greatly to its expansion. In 1898 the German Naval Bureau together with the Prussian Cultus Ministerium undertook the establishment of an oceanographical institute in conjunction with some Prussian university, plans for which were drawn up by Professors E. v. Drygalski and E. v. Halle with the later assistance of Freiherr v. Richthofen. The enterprise had from the beginning the deep personal interest and cooperation of the German Emperor. It finally took the form of the Institut für Meereskunde of which Professor Albrecht Penck is director.

In 1906 the Museum für Meereskunde connected with the Institut für Meereskunde was opened in the building on Georgenstrasse, formerly occupied by the chemical laboratory of the university. The purpose of the museum has been stated by its director to be "to inspire and to diffuse far and wide in the German nation by means of its exhibits a conception and understanding of the sea and its phenomena, the means employed in its exploration, the wealth of its life, and its economic value, as well as the social and national significance of navigation, marine commerce and sea power." "Deutschland zur See" is its motto!

This end has been sought by the almost lavish installation of exhibits which reveal everywhere the combination of technical skill and broad scientific knowledge and direction, together with a remarkable freedom from conventional methods in design and execution of the displays.

The exhibits are found on the two lower floors of the building and offices, library and laboratories are on the third floor. The whole of the first floor and part of the basement are given up to a most varied and elaborate display of the German naval and marine interests along historical, structural and mechanical lines. The second floor contains

FIG. 1. EXHIBIT OF APPARATUS FOR DEEP-SEA EXPLORATION, sounding machines and bottom samplers.

the exhibits of harbor construction, light houses and life-saving equipment, and the scientific departments of special interest to those concerned in marine investigations.

The first of these is the collection of nautical and oceanographic instruments and the oceanographic exhibit. The collection of charts, compasses, sextants, chronometers, clinometers and ship's logs is extensive. In adjacent rooms, 3 to 6, are to be found a most excellent and an almost historically complete collection of the instruments devised for deep-sea exploration. Sounding leads, pressure tubes and bottom samplers from the time of the expeditions of the *Challenger* (1873-

FIG. 2. OCEANOGRAPHICAL EXHIBIT.

1874) and the *Gazelle* (1874–1876) down to all the varied patterns from the ships of the cable construction companies and recent deep-sea expeditions, are here displayed together with sounding wires, cables and weights, sounding machines of various types—Thomson, Lucas, Sigsbee, LeBlanc and others—exhibited either by photographs and diagrams, or as actual instruments. There is also a display of typical bottom samples as collected by the merchant marine.

The study of the physical and chemical conditions in the sea is elucidated by a unique collection of instruments. Pressure and reversing thermometers of the Six, Chabaud, Miller-Casella, Negretti-Zambra, Knudsen, Richter and other types are shown, together with instructive exhibits of the effects of pressure at great depths in the sea in crushing thermometers. Scales for recording the color of the sea water and apparatus for determining its transparency are exhibited near the windows of the room. The apparatus used in determining specific gravity and salinity is also found here; self-closing water-samplers of the Meyer, Sigsbee and Petterssen-Nansen patterns for bringing up water from any desired depth without contamination from other levels, areometers, pycnometers and apparatus for chlorine (Knudsen) and gas (Fox) analysis.

In an adjacent room are meteorological instruments together with an exhibit of hydrographical instruments such as drift bottles, wave meters, tidal registers and current meters of Aime-Irminger, Massee, Arwidson, Nansen, Ekman, Petterssen bifilar and other patterns for submarine exploration.

The collection of biological gear and tackle is much less complete and less advantageously displayed. There are samples of dredges, tangles, trawls, tow-nets, plankton nets, plankton nets of the Hensen, closing-net of Nansen and young-fish net of the Helgoland pattern.

The oceanographical exhibit in rooms 8 and 9 is original in design and execution and contains unique and instructive displays designed to facilitate by comparative methods the quick and easy comprehension of the fundamental facts of oceanography. Marble blocks are used to represent the relative volumes of the globe, the sea, the land above sea-level, and in the continental blocks (above 2,300 m. below sea-level). In a similar way their relative weights and those of the atmosphere and of the dissolved salt in the sea are shown, as are also the quantity of salt and the proportions of the various substances dissolved in sea water. A very striking illustration of the quantity of salt in the sea is shown by a comparison, to scale, of the thickness of the crust left on the sea bottom on evaporation of the sea, with a model of the royal castle at Berlin to the same scale. The relative elevation of the continents and depths of the seas are shown by plastic reliefs. Models of a transatlantic liner on columns of blue glass bring in vivid contrast the conditions as to depth in the North Sea, the Atlantic and the greatest known ocean depths. Movable mechanisms illustrate wave motion, while the effect of breakers on steep and flat coast line is shown by photographs and examples of erosion.

The biological exhibits are striking in their design and educative in purpose. There is little attempt at a systematic exhibit of marine

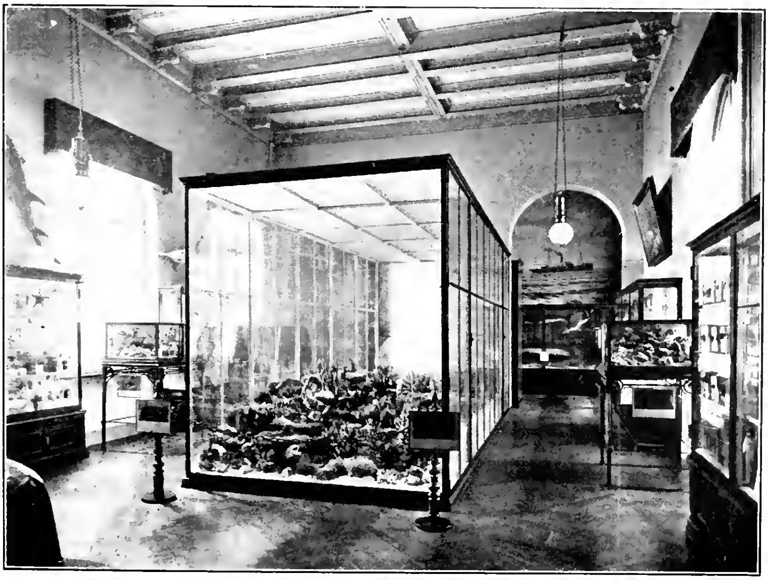


FIG. 3. BIOLOGICAL EXHIBIT. Coral reef from the Red Sea.

forms, the whole of the selection and grouping of the collections being subordinated entirely to securing a representation, as nearly normal as possible, under the limitation of space and conditions of the material, of the characteristic assemblages of marine animals and plants. Numerous tanks of considerable size contain displays of faunal types, in alcohol or formalin, in natural groupings and environmental effects. Dried collections and the taxidermist's art are also used in larger exhibits, as, for example, in a most excellent portrayal of a coral reef from the Red Sea. Ten small "alcoholaria" give vivid pictures with much of the original color preserved, of the minor types of faunal assemblages about a coral reef, such as the sea urchins and sea roses (*Crambactis*) with symbiotic fish (*Amphiprion*); giant mussels (*Tridacna*), corals and parrot fish; the madrepore area; the rock fauna; the regions of dying and of dead corals and the plant life of coral reefs. In like spirit and perfection of technique are displayed the fauna of the Antarctic icebergs, the sponge beds of the Ægean Sea, the fishing grounds off Helgoland, the pelagic world, the sandy grounds, the rock pools, oyster beds, limestone cliffs and the fishing banks of the North Sea.

The ecological interrelations of the marine fauna are suggested by exhibits of the food of well-known fish. The economic values and uses of the products of the sea are concretely illustrated in striking manner by transparencies, and by exhibits of the crude materials and various

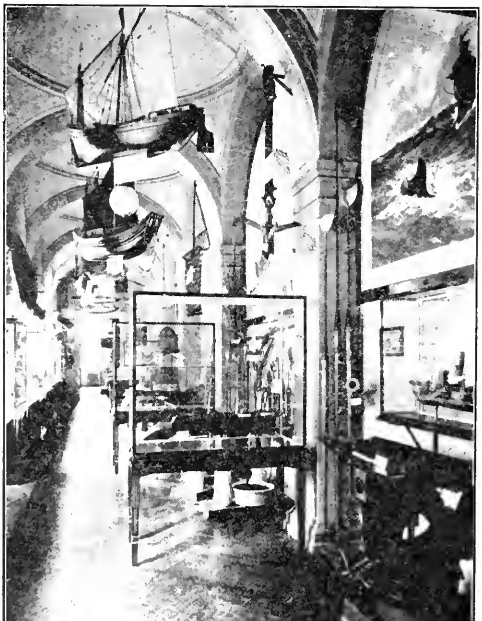


FIG. 4. ECONOMIC EXHIBIT. Whale fisheries and their products.

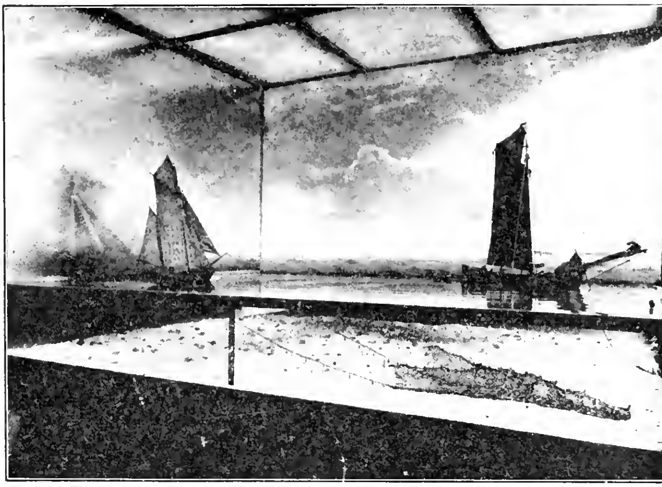


FIG. 5. MODEL OF NORTH SEA TRAWLER AT WORK ON FISHING GROUNDS.

stages in their manufacture into the finished products of art or industry.

The fisheries section is rich in well-displayed exhibits of most of devices known to man from the earliest times to the present, for the winning from the sea its rich booty; examples of gear and tackle, photographs, transparencies and oil paintings of their use, models showing boats and fishery gear in action, and the homes of fisher folk.

The wonderfully rich and exceedingly varied exhibits of this museum, centered as they are around the idea of the utilization of the sea, that least-known and last-to-be-conquered part of the globe, give even to the museum-weary traveler a new and inspiring conception of the magnitude and diversity of the resources of the sea and the complexity and attractiveness of the national, commercial, industrial and scientific problems connected therewith.

That the museum has accomplished its purpose in stimulating popular interest and enthusiasm in marine matters is attested not only by recent German political history but also by the 100,000 persons who thronged its rooms in the first year it was opened to the public and in the interested groups of visitors who still frequent its halls. The exhibits are free to the public, special days are reserved for classes, photographing and sketching are encouraged, and popular lectures are given on subjects allied to the purposes of the museum, for which a very extensive collection of lantern slides has been made.

The publications of the museum include, in addition to the illustrated guides, a popular series of "Meereskunde, Sammlung volkstümlicher Vorträge zum Verstandnis der nationalen Bedeutung von Meer und Seewesen," twelve parts yearly from 1897 and a more formally scientific series "Veröffentlichungen des Instituts für Meereskunde und des Geographischen Instituts an der Universität Berlin."

Professor A. A. Michelson.

Head of the Department of Physics in the University of Chicago. President elect of the American Association for the Advancement of Science.

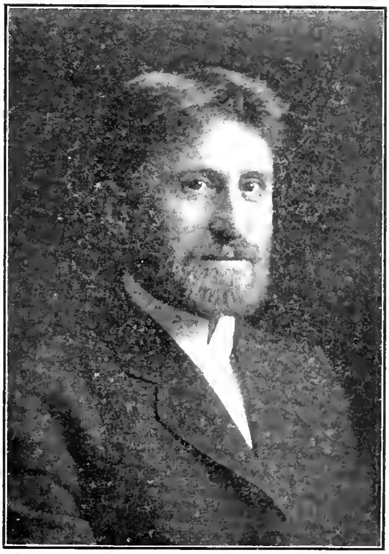
THE PROGRESS OF SCIENCE

THE CONVOCATION WEEK MEETING AT BOSTON

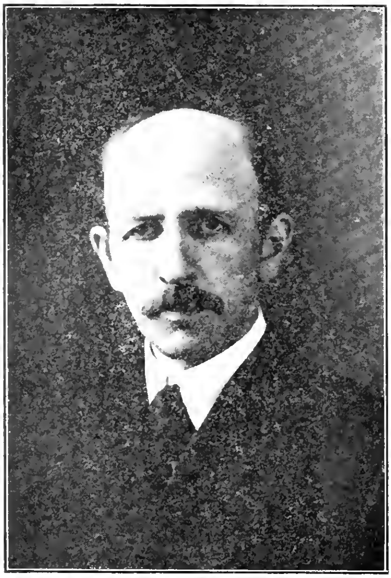
The meeting of the American Association for the Advancement of Science and the national scientific societies affiliated with it held at Boston during the week following Christmas was as large and important as any gathering of scientific men that has hitherto taken place in this country. The registration of members of the association was 1,140 as compared with 975 in Washington in 1902, 890 in Philadelphia in 1904, 934 in New York in 1906, 725 in Chicago in 1907 and 1,088 in Baltimore in 1908. From this voluntary registration it is difficult to estimate the attendance of scientific men. 200 chemists registered as members of the association and 558 as members of the American Chemical Society. Should a similar proportion have obtained in the other sciences, the number of scientific men would have been in the neighborhood of 3,000. It was probably not so great as this, but well above 2,000.

Although Boston is at the northeast corner of the field of scientific activity of the United States, it is still central, through the magnitude of its educational and scientific work and on account of its easy accessibility from other centers. Harvard remains our leading university and the Massachusetts Institute our leading school of technology, although the gap between them and other institutions is closing, and their supremacy may not be unchallenged when the association next

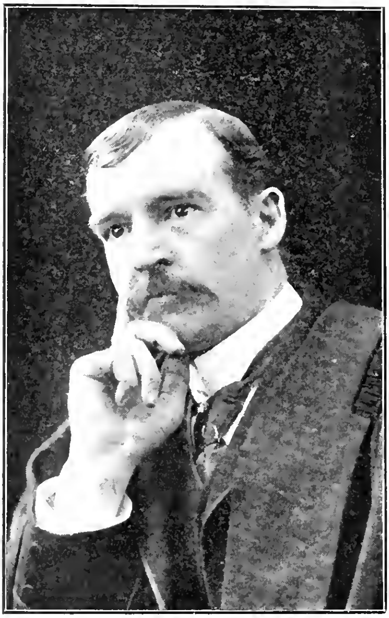
DR. ERNEST W. BROWN,
Professor of Mathematics in Yale University, Vice-president for Astronomy and Mathematics.



DR. L. A. BAUER,
Director of the Department of Research in Terrestrial Magnetism, Carnegie Institution, Vice-president for Physics.



Dr. William McPherson,
Professor of Chemistry in Ohio State University, Vice-president for Chemistry.



Dr. D. P. Penhallow,
Professor of Botany, McGill University, Vice-president for Botany.

meets in Boston. All arrangements were admirably made, though it was in some respects unfortunate that it was necessary for the sections of the association and the different societies to meet at widely separated places. The hotel selected for headquarters was somewhat small for a general meeting place, and the office of registration in the Technology Union, while a pleasant meeting place, was too isolated. In-

R. W. Brock,
Professor of Mining, School of Mines, Kingston, Can., Vice-president for Geology.

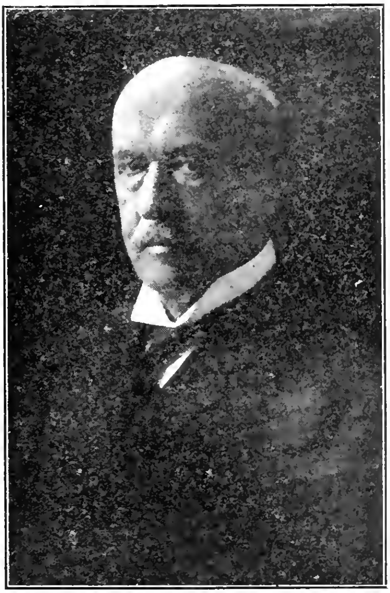
deed it may be said that while the meetings of the special societies were admirable, the efforts made by the general association to provide meetings of general interest and to bring together men of science working in different departments were only partly rewarded. The addresses and programs were in most cases excellent, but the scientific men in attendance were occupied in their special societies, very few members of the association not engaged in scientific work attended the meeting and the citizens of Boston probably find the city already saturated with lectures and addresses. At the meetings of the British Association there are usually a thousand or more local members elected for the meeting who provide large audiences. The difference is doubtless largely in the social organization of society; but it is unfortunate that the American Association is able to do so little to give science the dominant place it should have in the life

W. H. Holmes.
Head Curator of Anthropology, U. S. National Museum, Vice-president for Anthropology.

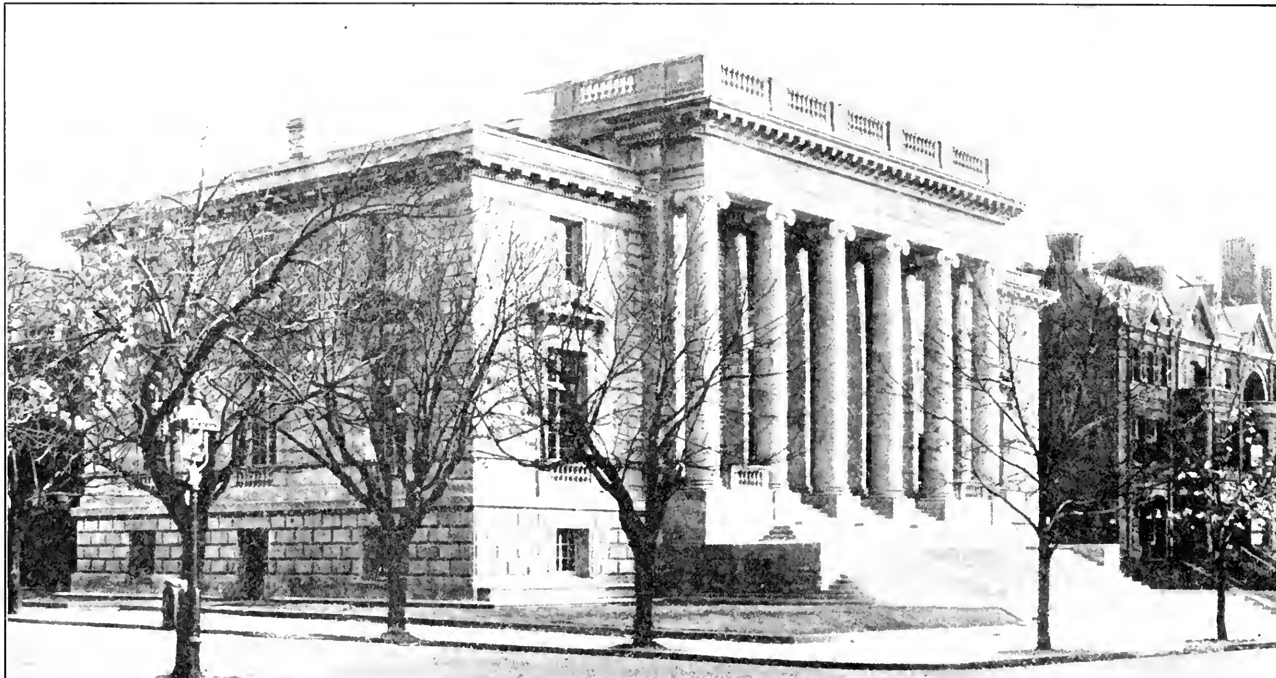
of the people. All those who realize the importance of this problem should unite to do what they can to keep the larger public in touch with the advance of science.

It is almost bewildering to consider that the titles of more than a thousand scientific papers were printed on the preliminary program. They were distributed among the sciences included in the association, as follows: astronomy and mathematics, 37; physics, 54; chemistry, 254; mechanical science and engineering, 17; geology and geography, 141; zoology, 124; botany, 122; anthropology and psychology, 63; social and economic science, 17; physiol-

Dr. James E. Russell.
Dean of Teachers College, Columbia University, Vice-president for Education.



Dr. W. G. Sumner.
Professor of Political and Social Science, Yale University, Vice-president for Economic and Social Science.



Administration Building of the Carnegie Institution of Washington.

ogy and experimental medicine, 166; education, 30. Chemistry is thus by far the best represented of the sciences, and social and economic science the weakest. The former fact is in part accounted for by the industrial applications of chemistry, but it also represents efficient organization and close affiliation between pure and applied science. There must be nearly as many men engaged in physics and its applications, but the number of papers was only a fifth as large. Economics and sociology are not adequately represented at the meetings of the association because the national societies concerned with these subjects are meeting elsewhere.

Dr. T. C. Chamberlin, the retiring president, in his address given in Sanders Theater of Harvard University on the first day of the meeting was able to select a topic on which he is the leading expert authority and which is of broad human interest. The address was entitled "A Geologic Forecast of the Future Opportunities of our Race" and reviewed the relations of the nebular hypothesis and his own planetesimal hypothesis of the origin of the solar system and the earth to the geological history of the earth and the life on it. The newer theories give the earth a long past in which life has been supported and a long future in which it can be supported not seriously threatened by catastrophies. The highest development and the greatest longevity of the race depend mainly on moral purpose and the resources of research which now for the first time are being clearly manifested.

The president of the meeting, President David Starr Jordan, of Stanford University, eminent equally as a zoologist and for his services to education, handed on the office to Professor A. A. Michelson, of the University of Chicago, one of the world's great physicists, according to the awards of the Nobel prizes the most eminent scientific man of America. He will preside at the meeting to be held next year at Minneapolis and will give the annual address at the meeting to be held the following year at Baltimore. We are able to reproduce his portrait and the portraits of the vice-presidents of the Baltimore meetings, as it is worth while to make the acquaintance even through a picture of those who hold an office which indicates both activity in research and leadership in scientific organization.

DEDICATION OF THE ADMINISTRATION BUILDING OF THE CARNEGIE INSTITUTION OF WASHINGTON

The Administration Building of the Carnegie Institution of Washington, situated on the southeast corner of Sixteenth and P Streets, Washington, D. C., was dedicated December 13, 1909. The brief ceremonies of the occasion were conducted in the assembly room of the building. Dr. John S. Billings, chairman of the board of trustees, presided; an account of the origin and development of the institution was given by Hon. Elihu Root, vice-chairman; and remarks in appreciation of the work already accomplished by the institution were made by Mr. Andrew Carnegie, the founder. Professor George E. Hale, director of the Solar Observatory of the institution, then gave a lecture by aid of lantern illustrations of the work already done in his department of investigation.

At the close of these exercises the trustees and guests were invited to inspect exhibits of the ten departments of investigation and of the divisions of publication and administration, installed in the rooms on the uppermost floor of the building. During the conversazione which followed refreshments were served on the main floor of the building. Since the assembly room will seat only about two hundred people, the lecture of Professor Hale was repeated during the afternoon of the following day for the benefit especially of the members of the departments of investigation quartered in Washington and for the benefit of interested guests from government bureaus.

During the afternoons of the three following days the building and the exhibits above referred to were open to inspection by the public. About two thousand people availed themselves of these opportunities. For the benefit of friends and guests of the institution, a souvenir pamphlet giving in brief the plan and scope of the institution and some indications of its development up to date had been prepared, and a copy of this was furnished to each visitor.

SCIENTIFIC ITEMS

We regret to record the deaths of Dr. Charles B. Dudley, chief chemist of the Pennsylvania Railroad Company, and Dr. Ludwig Mond, F.R.S., the distinguished industrial chemist.

It is proposed to add to the collection of portraits of deceased members of the American Philosophical Society that of Professor Simon Newcomb. The formal presentation of the portrait is expected to take place in connection with the annual meeting in April.

Mr. William H. Holmes, chief of the Bureau of American Ethnology, on January 1 severed his official connection with the bureau and resumed his place as head curator of anthropology in the U. S. National Museum, and in this connection also became curator of the National Gallery of Art. Mr. F. W. Hodge took charge of the Bureau of American Ethnology with the title ethnologist in charge.—Dr. C. F. Chandler, since 1864 professor of chemistry in Columbia University, will retire from active service at the close of the present academic year.

The Chicago Geographical Society has awarded the Helen Culver gold medal to Commander Robert E. Peary, for distinguished services in exploration, and to Professor Thomas C. Chamberlin, of the University of Chicago, for distinguished services in geographical research.

Mrs. Russell Sage has given Yale University $650 000 to pay for the Hillhouse property.—Mr. Henry Phipps, founder of the Phipps Institute in Philadelphia, has presented to the University of Pennsylvania $500,000, to be used in the campaign against tuberculosis. The management of the Phipps Institute will be placed in the hands of the university.—Mr. Otto Beit has given to the University of London £215,000 to endow fellowships for medical research.

THE POPULAR SCIENCE MONTHLY.

MARCH, 1910

INSECTS AND ENTOMOLOGISTS: THEIR RELATIONS TO THE COMMUNITY AT LARGE[1]

By Professor JOHN B. SMITH, Sc.D.

RUTGERS COLLEGE

WHEN your president first wrote me, suggesting that I should deliver the popular lecture required by the constitution of this society, he also suggested a subject: "What entomology has done for the world, and its future." The subject is an attractive one; but it required little consideration to decide that within the time at my disposal for preparation and presentation it was impossible for me to do justice to it. The mere compilation of what has been accomplished would require all the time, and I am distinctly doubtful concerning my ability as a prophet. There are no records of any successful ones in my family history and I have never observed any suggestive symptoms in my own case. I therefore secured a compromise on a much less ambitious topic, and find that quite large enough, for, until systematically set down, the importance of insects in their relation to man, direct and indirect, is scarcely appreciated. It is only within the last decade that our conceptions in this matter have become at all clear, and among the public at large extreme haziness is still the dominant condition.

And it was not even easy to determine just what constitutes an entomologist under our present-day methods of specialization, for while not so long ago any person interested in the study of insects at all might be called an entomologist, there are now many students of insects who know nothing at all about them as a whole, but a very great deal about some small, almost or quite invisible part of a single species or group.

[1] Popular lecture delivered at Boston, December 30, 1909, before the Entomological Society of America, its friends and guests.

So we must at the outset classify our students and determine what is really meant by an entomologist:

First of all, we have those individuals who devote their energies to the study of adult specimens only; describing species and genera, revising and monographing groups and, in short, devoting themselves altogether to systematic work. This is essential work, for until species are made known and tagged there is nothing to speak or write about and, no matter how interesting their structure or habits, the information is absolutely useless or unavailable to others, until it can be applied by some definite term to some definite concept.

The systematist then, no matter how little he may know of the insects outside of the dry specimens with which he works, is entitled to be called an entomologist and to have his good deeds recorded here.

Then we have, secondly, those students to whom the systematic position of an insect is a matter of little account; but who are interested in its life history, in its development, in its relation to its surroundings and more or less, perhaps, in its economic importance to man or to some set of men. Without question, these students also are eminently entitled to be considered as entomologists and there is no body of men whose work is of greater importance to the community than those falling under this heading.

In a third category come those who see in the specimen before them a combination of structures of greater or less interest or importance; who care little or nothing for its life history or economic importance, and nothing at all for its systematic position. They need the name of the species only to designate the particular organism that was studied. The work of these students is of the highest possible importance; but they are not entomologists, though their studies may be confined to insect structures. They are anatomists or histologists, depending upon whether they study it grossly, with dissecting needles and low power lenses, or whether they first slice it into sections and then use the high power microscope to look through them. It goes without saying that any member of the first and second division may be a member of the third as well, and I would not be understood as in any way belittling the importance of the work done by these men.

A fourth class is interested in certain species of insects only because of their relation to some other animal or to man, and only in so far as that relation exists. Such are they who study mosquitoes only as intermediate hosts of diseases of man, or bot flies only as parasites of animals. The work done by these students is of intense scientific and practical interest and of the utmost importance to the community, but they are not entomologists, although some of those carrying on this kind of work are entitled to rank as such because of other work done.

And now, what about him who falls under none of my classifications; the man who uses all his leisure in scouring woods and fields, swamps and running waters, for its wealth of insect life; who works in good weather and bad, for whom the woods at night hold no terrors when in pursuit of specimens? What about the collector? Of a surety he is entitled to rank among the elect, for without him the systematist would have little to work with and the student of insect ecology but a poor basis for his branch of the science. It is the collector who in the past has formed the body of all our entomological societies, and now forms the working majority of most of them. It is the collector upon whom the science rests as a foundation and he is entitled to rank by himself, although aside from this he may and often does belong to one of the other divisions as well.

Now, dropping the entomologist for the moment, let us consider the insects themselves, and here we find their influence extending in every direction: sometimes to our benefit, more often to our injury. Those that affect us injuriously we are able to subdivide into those that attack us directly either as parasites or merely as a source of food supply, and those that prey upon our crops, supplies or farm stock. And even the list of directly injurious forms is not a small one for, to begin with, there are no less than three species of sucking lice that attack the human animal and are confined to him, favoring his head, and other hairy regions, and his clothing when he wears any. It is an interesting matter for reflection that the egg-laying habit of the body-louse is an adaptation that must have required ages to develop and that could not even begin to develop until man wore clothing of some kind.

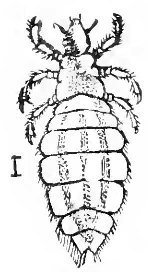


FIG. 1. A head louse.

And wherever man goes wholly or partly unclothed, he shares with other animals the danger of becoming infested with creatures like bots, screw worms and other dipterous maggots, or penetrating insects like jigger fleas and their allies. Man, then, stands in the relation of host to a not inconsiderable number of insects species, only a few of which, however, are really dependent upon him.

But as prey, his usefulness to insects is infinitely greater. In his home a variety of bloodsuckers have established themselves; even in his bed they may be found, and they range from the reasonably sized creatures found in the temperate regions to the infinitely more formidable creatures found in the tropical countries, where the bites often produce unpleasant and even dangerous results.

Where man has hairy pets, like cats and dogs, the fleas that infest them primarily often attack him as a compliment, and in some sections of the world and of own country fleas are not insignificant either in numbers or effects.

Outdoors, Tabanids or horse and other flies in great variety make life miserable in the woods or on the sea-shore, while even in New Jersey an occasional mosquito may yet be met with, ready to demonstrate that he likes you none the less because of any campaigns waged against him—or her.

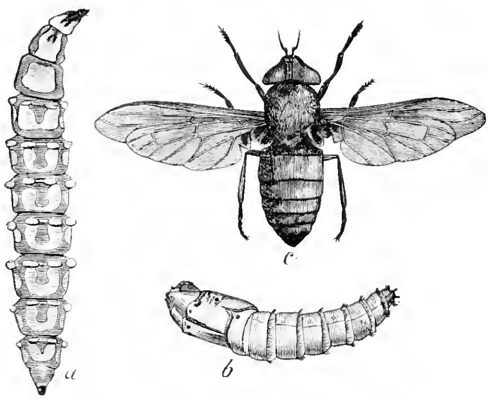


FIG. 2. A horse-fly—*Tabanus atratus*: *a*, larva; *b*, pupa; *c*, adult; after Riley.

Gnats and midges of various kinds, whether we call them black-flies, punkies or other names, all manifest an affectionate interest in the human visitor to their homes, and I do not mind saying that there have been occasions when I abandoned the field to them and admitted defeat. It is wonderful how well fitted these insects are for their work and how well they understand the use of the tools with which kind nature has provided them!

Some kinds of insects have no grudge against man and as such never bother unless interfered with, but they are quite ready to manifest their displeasure if they are wasps or hornets, or to make it unpleasant in other ways to the ignorant meddler, as in the case of many of our Limacodid larvæ or nettling caterpillars. Sometimes an insect becomes a nuisance quite without intent, as in the case of the caterpillar of the brown-tail, which distributes its hair so liberally that it produces severe irritations and inflammations, as those residents of Massachusetts that have suffered from "brown-tail rash," know to their sorrow.

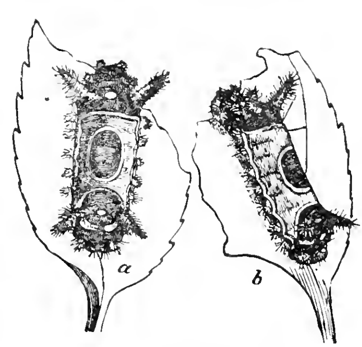


FIG. 3. The saddle-back caterpillar, *a*, from above, and *b*, from side; after Riley.

And this brings me, naturally, to the consideration of those forms that are troublesome or even dangerous to man because they are agencies in the transmission of diseases, either as carriers or as intermediate hosts. Note that I use two terms: *carriers* and *intermediate* hosts, because there is a vast difference between them. Carriers are such insects as merely pick up by accident disease "germs"—to use a current expression—and transport them to another place where they may or may not find a suitable medium to propagate, and where they may or may not be in position to get into the proper portion of the human animal. Almost any sort of insect may be a carrier, although there are some few peculiarly adapted for the purpose, and such a carrier may be the transmitting agent for a variety of diseases: it is not itself affected by any, and is in no sense a fellow sufferer.

It is different in the case of intermediate hosts; here the insect itself harbors one stage of the morbific organism and is itself a sufferer from one form of the disease. Its power of transmission is strictly limited and is restricted to one disease alone.

The best known and most abundant of the germ carriers is the common house-fly more recently called "typhoid fly." Now it un-

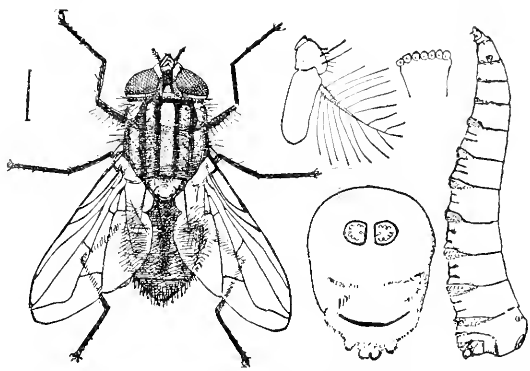


FIG. 4. The house-fly, with its larva and details of structure; after Howard, U. S. Department of Agriculture.

doubtedly is *a* typhoid fly, but it is only one of several species that may be equally effective, and it is by no means a carrier of typhoid germs only. Its habits are such that it may be a transmitting agent for any intestinal disease and for many of the pulmonary and bronchial troubles as well. In a typhus or cholera epidemic it is a "cholera" or "typhus fly" and to call it the "typhoid fly" gives an unfounded suggestion of definite relationship between disease and insect.

But it certainly is marvelously well adapted as a carrying agent. Its omnivorous feeding habits, its persistence in seeking entrance at places where savory or other pungent odors attract it, and its foot and mouth structure make a combination difficult to equal. The pulvilli of the feet with their numerous minute hooked hairs are ideal collectors of microorganisms, and the lobed, lip-like mouth structure, with its array of pseudo-trachea for surface scraping, can hardly be surpassed in effectiveness. No doubt the house-fly is a danger of the first order, and there is no economic problem now before the sanitarian, of more importance than the elimination of this pest. That it can be done there is no doubt, and that in time it will be done is equally certain.

There are numerous other flies and insects that serve as carriers, and there are numerous diseases due to more or less uncleanly habits, that are carried by insects; but the process is so simple and direct that it offers little of scientific interest.

Much more complicated is that transmission of disease in which the insects act as intermediate hosts, and here again the members of the order Diptera lead the way. We assume that man is highest in the scale of vertebrate development, and it is no part of my thesis to dispute this. It is equally assumed that the Diptera are most highly specialized in their development among the insects, and it is significant that the association of humanity with these flies has been so close and

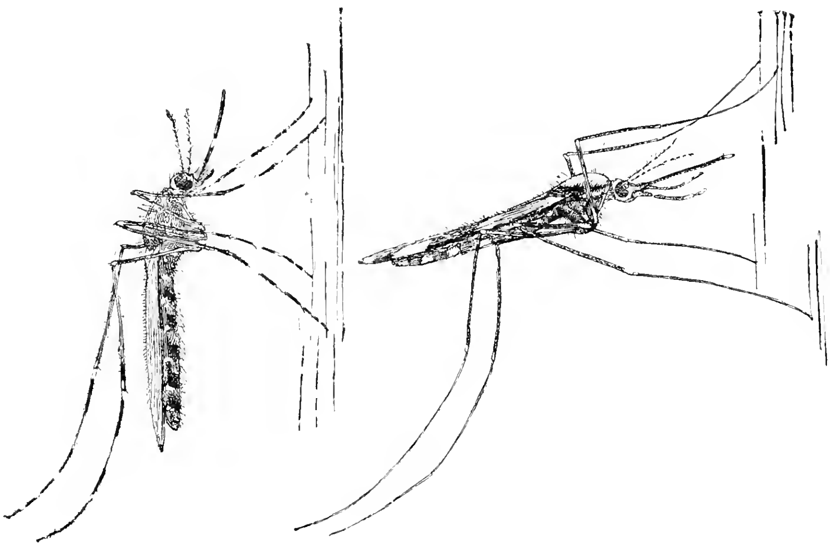


Fig. 5. Resting position of *Culex*—at left; of *Anopheles*—at right; after Howard, U. S. Department of Agriculture.

so long continued that it has been possible for a common parasite to develop whose continuance depends absolutely upon the intimate association of the two.

If all insects were eliminated absolutely, typhoid, cholera and associated diseases might still continue to plague mankind; but eliminate *Stegomyia calopus* and yellow fever would be equally eliminated, because without that particular species the parasite causing the disease would find it impossible to continue its existence. Not that we know very much about the "germ" of yellow fever, and its life-cycle is largely guess-work; but we do know enough, from direct observation and experiment, to warrant the statements that I have just made.

It is different in the case of malerial fevers and their association with certain species of Anopheles. Here we do know from direct observation the entire life-cycle of the parastic organism from the time it enters the circulation through the beak of the mosquito until it reaches its limit of growth in the human body. We have observed the blasts and sporozoits entering a red blood corpuscle; we have observed the gradual growth in this corpuscle; we have followed the gradual breaking down of the cells and have observed their rupture and the discharging spores. The development of the gametes has been observed; the flagellation and conjugation of the micro- and macro-gamete and the development in the Anopheline stomach from vermicule to zygote. All this has been demonstrated, and so little guess-work is there about it that the elimination of Anopheles breeding places is now the first step in dealing with an outbreak of real malarial trouble.

The relationship between rats, fleas and plague has also been practically established, and elimination of the disease in man is sought by the destruction of rats. I have already mentioned, in another connection, that the cat and dog flea would, when opportunity served,

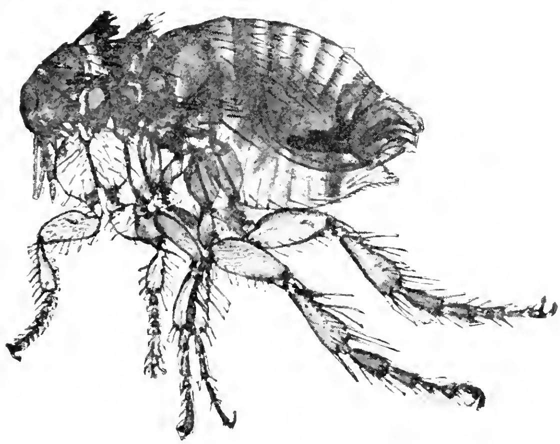


Fig. 6. A rabbit flea.

bite human beings; the statement may be made more generally that almost any flea will, when there is occasion, bite almost any warm-blooded animal upon which it finds its way. So the fleas upon plague-stricken rats, leaving their natural hosts, may and do infest men instead of other rats when men herd where rats abound.

In more torrid or tropical countries insect-borne diseases are more numerous than in our more temperate clime, and there the mosquitoes, bearing a much greater variety of fevers, also transmit organisms of much higher character than "germs." Filariasis is a disease caused by minute thread-worms or *filaria*, and these also require the mosquito as an intermediate host to complete their development.

In recent years the records of studies made of certain tropical diseases have been largely records of studies in insect transmission of disease; and the studies made on insects, by physicians, have been as important as those made on the afflicted patient.

The identification of a species of Glossina or tsetse fly as an agent in the spread and transmission of the "sleeping sickness" is one of the more recent accomplishments in this direction, and opens a way for dealing with this plague that has practically depopulated great areas in Africa.

This seems like a series of heavy indictments against a lot of insignificant creatures whom, heretofore, we have deemed ourselves justified in ignoring. But the case has been understated rather than otherwise, and it is time that we recognized insects as among the most dangerous enemies to man from the sanitary standpoint.

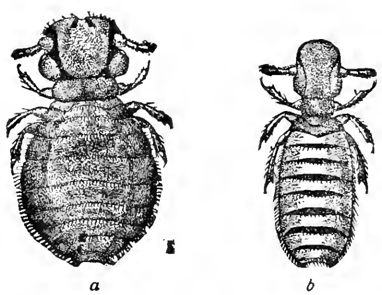


FIG. 7. Types of Mallophaga or biting lice.

Let me put it in a somewhat different way: could we at a blow eliminate all the members of the single order Diptera—including the fleas—we should at the same time absolutely eliminate malaria, yellow fever, dengue, jungle and several other kinds of tropical fevers, the bubonic plague, sleeping sickness, filariasis, several forms of eye diseases, certain ulcerating sores in tropical countries, and we should reduce to a minimum enteric fevers of all kinds, lessen the death rate from tuberculosis and pulmonary troubles, and probably modify or lessen leprosy and kindred diseases.

But this is not all our plaint; for besides attacking man directly in his bodily health and comfort, they attack his domestic and other animals and lessen their value if they do not absolutely destroy them.

Every one of our domestic animals and all our feathered friends of the barnyard are infested by lice—biting and sucking and some of them harbor several species. All of them are well adapted in form to the conditions under which they live; and even the hog, which is not usually thought of as a hairy animal, has a species that manages to move about as freely as need be among the bristles. Naturally, animals so infested can not do their best for their masters; they become mangy in appearance, do not grow well, the fowls lessen in egg production and the cows in milk.

To the dairyman, flies—comprehensively speaking—are nuisances from all points of view. In the pasture Tabanids in great variety get after them; in the stable Stomoxys is always on hand. Occasionally the fauna of one country contributes a pest to that of another, as was the case when the so-called horn-fly was introduced about twenty years ago from Mediterranean Europe and rapidly spread throughout the United States and Canada.

Buffalo gnats and similar species make certain sections of the Mississippi Valley region almost uninhabitable for cattle at times, and dairying in some places is barred because of the abundance of mosquitoes. These are all external attacks which reduce the condition of the creature attacked because of the irritation, pain or actual loss of blood.

There are others that are more truly parasitic, like the bots. Whereever sheep are raised in numbers the herders have their troubles with the species that gets into the nasal passages, causing blind staggers and often death. Cattle are infested by species that lodge under the skin,

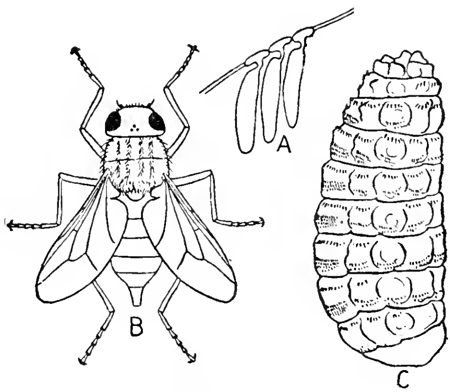


FIG. 8. The ox bot, *Hypoderma lineata*; *a*, eggs; *b*, fly; *c*, larva.

forming suppurating sores along the back. These reduce the condition of the animal and materially lessen the value of the skin. Horsemen know to their sorrow the species that fixes on the walls of the stomach, often in such numbers as to kill the animal. To realize the amount of suffering caused to their hosts by these insects and others with similar habits is almost impossible. To estimate the money loss caused to man has been attempted and the figures run to astounding sums.

But the end is not even yet, for these same animals often suffer from diseases similar to those of man and like them transmissible through or carried by insects. Ticks are not insects, but the economic entomologist is often expected to deal with them, hence we may just mention the cattle tick in connection with Texas fever, which has destroyed and still destroys its thousands and causes enormous money losses.

Many of our birds suffer from maladies similar to malaria, caused by a Proteosoma, and even the common and ever vociferous sparrow is not exempt. These species of Proteosoma find their intermediate hosts in certain species of *Culex* or whatever the present equivalent of that generic term may be. Some of these diseases have been carefully worked out, but how many more remain of which we know nothing as yet, I would not even dare to guess.

The effect of the tsetse fly or its bite on horses in South Africa has been long known, but just how that effect is produced is a matter of more recent knowledge. We know now that the disease is produced by Trypanosomes carried by the flies, and this information has opened the way to intelligent treatment.

Here again, be it noted, the order Diptera contributes the bulk of the dangerous species to the mammalian types, and to our horses,

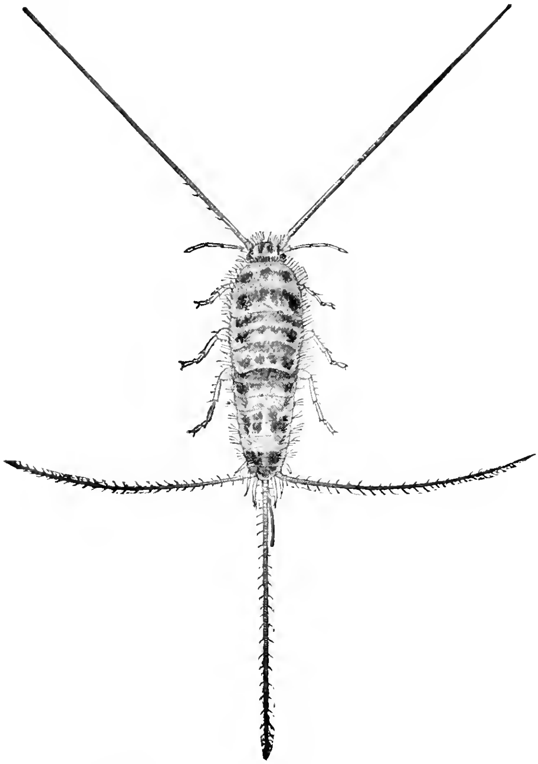


Fig. 9. A silver-fish, *Lepisma* sp.; from Howard, U. S. Department of Agriculture.

cattle and sheep, the elimination of all flies would be as great a boon as to man himself.

Heretofore I have spoken only of insects that either attack or influence the health of man or other animals. But there are numerous others that live with him and are messmates, sharing in the produce that he has stored for his own use, and in this work members of almost every insect order are concerned.

The Thysanura are represented by various species of Lepisma or silver-fishes, and sometimes by spring-tails and bristle-tails where produce is stored in damp places.

The Neuroptera have quite a variety of forms, ranging from the Psocidæ which the housewife usually regards with a disgust intended for parasites of similar form, to the Termites or white ants whose work is noted more frequently than the insects themselves.

Among the Orthoptera, the voice of the cricket on the hearth calls up only pleasant association; but the appearance of roaches in kitchen and pantries arouses feelings of quite a different character. And roaches of many varieties are found in human habitations throughout the world.

As to the Hemiptera or true bugs, they have been already referred to as direct feeders or parasites upon man himself or his domestic animals. They do not add to their sins attacks on his supplies.

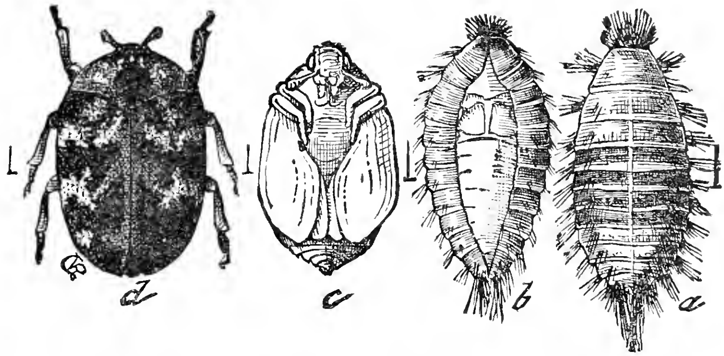


FIG. 10. The carpet beetle or "buffalo moth," *Anthrenus scrophulariæ; a*, larva; *b*, pupa forming in larval skin; *c*, pupa; *d*, adult; after Riley.

The Coleoptera or beetles contain numerous messmates and some that do not even confine themselves to his stores. The carpet beetles feed upon his supplies of woolens, whether on the floors or on the shelves, and occasionally they get into the feathers of his pillow. But these are minor troubles compared with those that arise when the feeding is on the feathers of the madam's hat or the fur of her winter coat. Similar species get into our closets and pantries to feed upon the meat supplies, and occasionally we find them already established in provisions received from the packing houses, so that similar species occur the world around. Our grain, flour and meal supplies furnish homes to more kinds of species than the ordinary householder cares to consider, and nowhere does neglect or lack of cleanliness produce quicker infestation than in the pantry where our grain products are stored. Our lentils, peas, beans and other legumes are attractive to a variety of "weevils," especially in barns and granaries.

Even the den of the master of the house is invaded—if he is master and has a den—and in his supply of cigars and cigarettes the cigarette beetle and its larvæ hold forth—scarcely improving the flavor of the tobacco for smoking.

Among the Lepidoptera we find valiant aids to the beetles in destructive work on stored products. There are various kinds of meal-

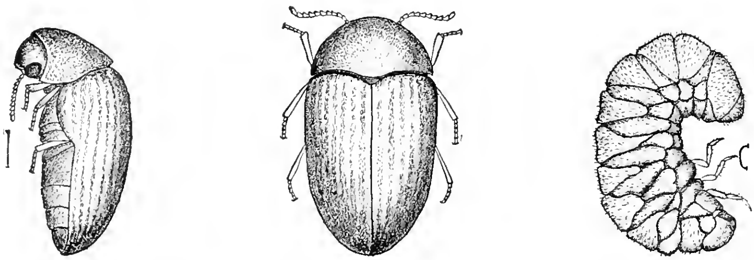


FIG. 11. The cigarette beetle; *a*, from side; *b*, from above; *c*, larva.

moths, feeding on whole or prepared grains, and some of these, like the Mediterranean flour moth, cause serious troubles in mills. The well-known "Angoumois grain moth" not infrequently ruins entire crops of wheat for milling purposes, and in barns and granaries breeds continuously. Dried fruits are attacked by similar species and indeed scarcely anything in the pantry is exempt from the small caterpillars which usually live in silken tubes of their own construction.

And then there are the clothes and carpet moths which cause troubles of their own and are sources of much worry and expense to a part of the population not ordinarily interested in entomological matters. Incidentally they are sources of income to others who thrive on

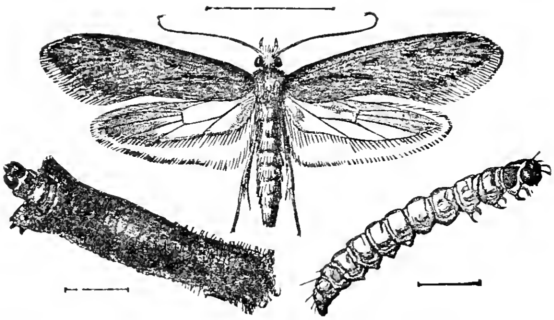


FIG. 12. A clothes-moth, with its larva free and in a case; from the Division of Entomology, U. S. Department of Agriculture.

selling compounds more or less effective in protecting fabrics against the ravages of the "moths."

In the order Hymenoptera there are comparatively few species, confined practically to one series of families—the ants—that cause trouble in our households. But these, where they do occur, may exceed a combination of all the others in the annoyance and positive injury that they cause. There are several native forms, large and small, red and black, that are frequently pestiferous, and within the few years last past we have acquired another, the "Argentine Ant," which, as is customary with introduced pests, does more harm within its present range than all the native kinds combined.

Again we have reached the Diptera or flies; but this time there is very little fault to find, for those species, other than the pests already mentioned, that do come into our houses, do so mostly as scavengers.

And there is yet another heading under which we have to consider insects in their effect upon man, and that is in the light of pests on the crops which are grown by him. A very large percentage of all insects are vegetable feeders and, naturally enough, when large areas are planted to one crop, so as to eliminate for the insect the problem of food supply, and cultural methods lessen their natural enemies, these vegetable feeders flourish out of all proportion to their normal natural limitations. The result is that a considerable percentage of the crop is destroyed, and most of the destroyed percentage represents the farmers' profit. That is to say, suppose it costs $5.00 to cultivate, plant, harvest and thresh an acre of wheat, and the harvest sets for a 15 bushel crop. With wheat at $1.00 per bushel at the station, the farmer might count on a profit of $10.00 per acre. But if in spring chinch-bug attack reduces the yield by 5 bushels, and the wheat-head army worm destroys 3 bushels more, the net return is reduced to $2.00 per acre, which is not living wage to the owner.

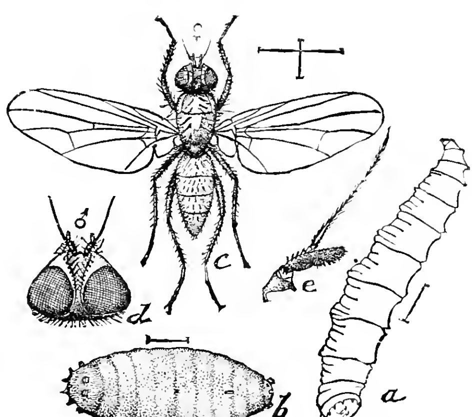


FIG. 13. A root-maggot, *a*; its pupa, *b*; and the adult fly, *c*.

That this sort of reduction occurs with discouraging frequency on many sorts of crops throughout our country, is within the experience of every economic entomologist, and the total calculated loss per annum from insect attack in the United States alone amounts to $1,500,000,000. Surely a terrific tax to pay and one which is not paid without protest.

Not only is practically every crop attacked, but every portion of the plants may be infested. There are maggots that burrow into the roots of vegetables; borers that live in the roots of trees, shrubs and even meadow plants, and wire-worms and grubs that eat off the rootlets of grasses, strawberries and the like. Potatoes are gnawed underground by a variety of insects, and not a tuber nor a bulb escapes infestation.

The stems of herbaceous plants and shrubs and the trunks and branches of trees harbor borers without number and belonging to several orders. Vigorous growing vines like those of cucurbits may harbor several borers in a single stem, while even a wheat straw affords ample accommodation for several species, from the minute joint-worms to the caterpillars of owlet moths.

Fruit and other trees are attacked even in the nursery, and many a seedling never gets beyond the earliest stage of development. The temptation is great to enlarge on these points; but the difficulty would then be to find a stopping place. It must suffice to say that there is no part of a plant from the tip above to the rootlet below ground that

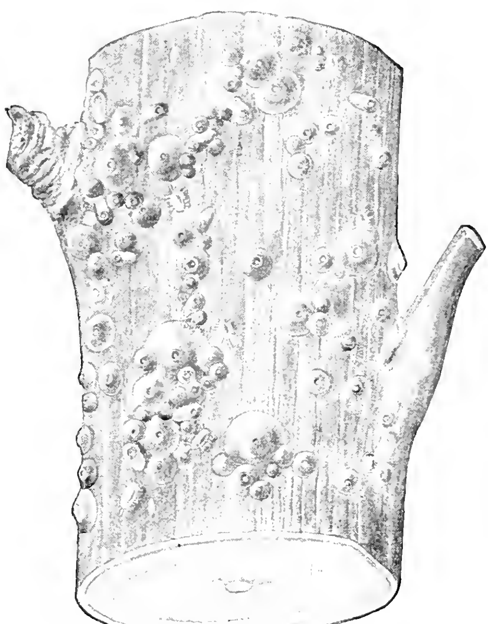


Fig. 14. The San José Scale as it appears on an infested shoot; from the Virginia Experiment Station.

may not be inhabited by a borer. Nor, on the other hand, is there a part of the outside of the plant above ground that may not be infested by scales or plant-lice.

Not so many years ago the Pacific Coast feared for its fruit industry because of the Cottony Cushion Scale, an imported pest. Still more recently the eastern United States was invaded by the San José Scale, another imported species which is responsible for more legislation, more organization, more expenditure of money and a greater revolution in methods of fruit growing, than any insect in history. No one who has not been in this fight from the beginning and who has not seen the changes in development, can really appreciate what has happened in the last decade. Incidentally, this insect has made more positions for entomologists and has stimulated more interest in entomological work than all other species combined; in which respects it may not be considered an unmitigated pest.

As for plant-lice, their name is literally legion and their study is only begun. We find their eggs in winter and the insects themselves throughout the year. With the beginning of plant-growth the Aphids also begin development and the character of the infestation is as various as the plants or parts of plants attacked. They are not even confined to the overground parts of the plant, but may be on the roots as well: either permanently or in an alternate stage. It is just allowable to mention the grape Phylloxera as a species that does all its real injury in the subterranean stage, and to record that this is one of the few contributions that America has made to European agriculture, in return for the many that we have received.

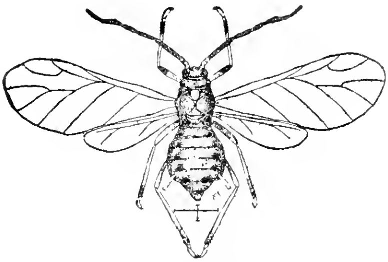


FIG. 15. A winged plant-louse.

The host of other plant bugs that suck the juices of vegetation can only be hinted at. Mention must be made, however, of the chinch-bug, which in the middle west has been the subject of more careful study and experiment, and has done, perhaps, more wide-spread damage than any other of its ordinal allies.

As to feeders on foliage, there seems no end to them and they are of all orders. Nor are their injuries of recent notice. The plague of locusts which devoured all crops was one of those visited upon Egypt in the days of Moses, and similar plagues of locusts exist to this day in African countries. They have not been unknown in the United States in years past and it is not yet safe to say that there will be no more.

Gypsy and brown-tail moths afford excellent illustrations of the expense that caterpillars may impose on a community, for they have cost Massachusetts alone not less than $2,000,000 directly and indirectly, while the general government has already spent more than half a million.

No part of a plant being free from insect attack, the fruit and seeds should also be infested, and so we find it. Codling Moth and Plum Curculio are terms known to horticulturists throughout the country, while cotton-boll weevils have more recently taken a prominent position in our southern states.

I trust that I have succeeded in convincing my audience of the important part that insects play in the community, and how vitally they affect man in his life, his health and his pocket. I might add to emphasize this still more, that were all natural checks removed from plant-feeding insects for two successive years, not a green thing would be left on the face of the earth; and that with the same checks removed from the forms parasitic and predatory on the higher animals, the third year would probably see the end of all vertebrate terrestrial life.

The questions will naturally arise—is there no brighter side to this subject? Are not insects of some use, and do we not derive some benefit or advantage from them?

Both of these questions are answerable in the affirmative, for insects are distinctly and importantly useful to man both directly and indirectly, altogether aside from the fact that parasitic and predatory species materially reduce the amount of injury that would otherwise be caused by those already mentioned.

Leaders among the directly beneficial species are the honey-bees and silk worms. Bee products, wax and honey, amount to millions of dol-

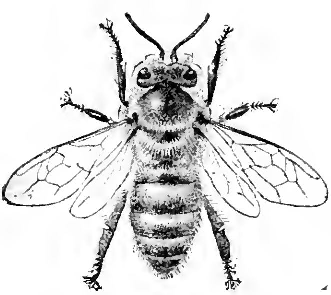


FIG. 16. Honey bee.

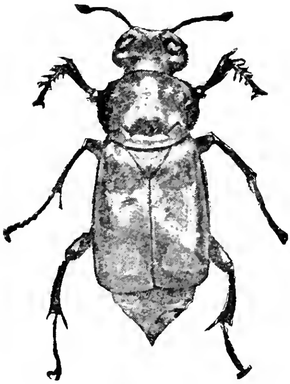


FIG. 17. A burying beetle, *Necrophorus* sp.

lars annually, and there is no more attractive food than good honey —a matter that is much more appreciated in continental Europe, where honey is a usual part of breakfast, than in the United States, where it is rarely seen on our tables at any meal. Bees-wax is, of course, an important commercial product, although its place for many purposes has been usurped by the cheaper paraffin.

As for silks, I would not dare to estimate the amount of money invested in them annually. The silk worm makes up in value for much of the injury caused by other caterpillars, and it would be well sometimes for our grand ladies in rustling garments to realize that they owe a large percentage of their exterior magnificence to a nasty, inconspicuous caterpillar.

Before the development of the aniline dyes there was no more beautiful scarlet than that obtained from the cochineal insect, a miserable coccid, allied to some of our destructive mealy bugs. As a pigment it produced a beautiful carmine, and this may make us look more leniently upon creatures like the cottony cushion and San José scales. Several of our common soft scales, notably that huge creature that infests the tulip tree, give a purplish extract in alcohol, and so do some of the Lachnid plant lice; but they will hardly be considered now-a-days as a source of coloring materials.

Insects figure to some extent in the pharmacopœia, although not so much now as they did in days gone by. That powdered roaches had medicinal qualities was known to the ancients, and I believe that tinctures and extracts of these insects are still obtainable. Spanish flies or cantharides have a well deserved reputation for blistering properties and have been used to promote the growth of hair. They have also been made into extracts and tinctures, and used internally for a variety of troubles.

Bees produce an acid that is useful in some rheumatic affections, and it is asserted that the simplest effective method of application is to allow the bee itself to administer the remedy directly to the affected part. Incidentally, by this method the patient gets back at the operating physician, for whether the patient is benefited or not, the administrator dies as the result of the application.

But decoctions and other preparations of insect species are no longer so much thought of as in days gone by, and we now run to sanitation and other preventive measures, to serums and antitoxins, to antiseptics and to coal-tar products, so I need hardly claim very much more for insects under this head.

I might mention that insects as food material are not unknown, and while I have already mentioned locusts as a plague, I might add in mitigation that they also serve as an important article of food for the natives in the countries where they occur in such numbers. Wood-boring larvæ and even insect eggs have been and are even yet eaten; but their value in these respects can hardly be deemed sufficiently great to give them a favorable standing in our present communities.

Indirectly valuable to man are a long series of species that act as scavengers, reducing dead animal and vegetable matter to its inorganic compounds, and another series that serves as an aid to plant propagation. The former need little attention because man can do scavenger work much better and quicker himself; but in the work of plant pollination the importance of insect work is scarcely appreciated by the public at large.

Numerous plants depend absolutely upon insects for continued existence, and there are all stages of dependence from those where the plant depends on one species only to those for whom any insect that can carry pollen at all will serve. An illustration of a dependent plant is the Yucca which is visited by a little white moth, a Pronuba, which proceeds in its work as deliberately and purposefully as if it realized the importance of every step in the process. Another of still greater interest is that of the edible Smyrna fig, which depends upon Blastophaga for its fruit development. It is a case where the establishment of a horticultural interest depended upon the possibility of introducing with the fruit its specific pollinator as well.

The relation of bumble-bees to red clover is so well understood now that it is not really necessary to do more than mention it, and in general, the most effective pollinators are found among the bees, because they, more than any other insects, are structurally adapted for the gathering and transportation of pollen. Not only are the mouth structures adapted for getting deep into the flower cups but the hairy covering itself is modified so that it holds the grains dislodged as the insect moves among them.

To be sure butterflies and moths are also of use, and the butterfly tongue is well adapted for its purpose of reaching down and lapping nectar from concealed nectaries. Some of these tongues indeed are so developed as to permit the insects to feed while on the wing and to get into depths beyond the reach of less favored species.

(To be concluded)

THE SECOND LAW OF THERMODYNAMICS: ITS BASIS IN INTUITION AND COMMON SENSE[1]

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It is the object of this article to give a simple account of that fundamental principle in physics which is known as the second law of thermodynamics. No generalization of modern physics is of greater importance, not even the principle of the conservation of energy, and no generalization of modern physics is based upon such deeply seated and such widely diffused human intuitions. It is the purpose of this article to give a sharp characterization to this widely diffused intuition.

Thermal Equilibrium

The most important single fact in connection with the study of the phenomena of heat is that a substance settles to a quiescent state in which there is no tendency to further change of any kind when it is left to itself and shielded from all outside disturbing influences. This quiescent state is called a state of thermal equilibrium. For example, the various objects in a closed room settle to thermal equilibrium; when a piece of red-hot iron is thrown into a pail of water, the mixture, at first turbulent, becomes more and more quiet and finally reaches a state of thermal equilibrium. A number of bodies which have settled to a common state of thermal equilibrium are said to have the same temperature. Thus a number of bodies left together in a closed room have the same temperature.

Atomics and Thermodynamics

In nearly every branch of physical science there are two more or less distinct modes of attack, namely, (*a*) a mode of attack in which the effort is made to develop conceptions of the physical processes of nature, and (*b*) a mode of attack in which the attempt is made to correlate phenomena on the basis of sensible things, things that can be seen and measured. In the theory of heat the first mode is represented by the application of the atomic theory to the study of heat phenomena, and the second mode is represented by what is called thermodynamics. In the first case one tries to imagine the nature of such processes as the melting of ice or the burning of coal, and in the second case one is content to measure the amount of heat absorbed or given off and to

[1] The substance of this article will be incorporated in Franklin and MacNutt's "Elementary Theory of Heat," which is now in preparation.

study the physical properties of the substance before and after the change has taken place.

The Atomic Theory of Heat.—The theory of heat properly includes the whole of chemistry, and every student of elementary chemistry is familiar with the use of the atomic theory in enabling one to form clear ideas of chemical processes. For example, the burning of hydrogen is thought of as the joining together of atoms of hydrogen and oxygen to form molecules of water vapor. The atomic theory is also of use in giving one clear ideas of the physical properties of substances. Thus, a gas is supposed to consist of a great number of particles in violent to-and-fro motion, and the gas exerts a pressure against the walls of the containing vessel because of the bombardment of the walls by the rapidly moving molecules of the gas. In addition to these two highly developed branches of the atomic theory (chemistry and the theory of gases), the atomic theory has been applied in a more or less vague but very useful way in the study of a great variety of heat phenomena as exemplified in the following quotation from Tyndall's "Heat a Mode of Motion."

> When a hammer strikes a piece of lead the motion of the hammer appears to be entirely lost. Indeed in the early days it was supposed that what we now call the energy of the hammer was destroyed. But there is no loss. The motion of the massive hammer is transformed into molecular motion in the lead, and here our imagination must help us. In a solid body, although the force of cohesion holds the atoms together, the atoms are supposed, nevertheless, to vibrate within certain limits, and the greater the amount of mechanical action invested in the body by percussion, compression, or friction, the greater will be the rapidity and the wider the amplitude of the atomic oscillations.[2]

Thermodynamics.—To understand the essential features of the science of thermodynamics it is necessary to revert to the discussion of work and energy. Whenever a substance gives up energy which it has in store the substance always undergoes change. Thus, the fuel which supplies the energy to a steam engine and the food which supplies the energy to a horse undergo a chemical change; the steam which carries the energy of the fuel from a boiler to a steam engine cools off or undergoes a thermal change when it gives up its energy to the engine; a clock spring changes its shape as it gives up its energy in driving a clock; an elevated store of water changes its position as it gives its energy to a water wheel; the heavy flywheel of a steam engine does the work of the engine for a few moments after the steam is shut off and the fly-wheel changes its velocity as it gives up its energy.

In mechanics the theory of energy is discussed in connection with mechanical changes only, thermal and chemical changes being carefully ignored, and in taking up the study of thermal and chemical

[2] Tyndall goes on to explain in a general way the difference in the constitution of solids, liquids and gases. See "Heat: A Mode of Motion," pp. 115–119.

changes it is important to understand that our study is not to be concerned with thermal and chemical actions themselves, but with their results. The actions themselves are as a rule extremely complicated. Thus the details of behavior of the coal and air in a furnace are hopelessly complicated! The important practical thing,[3] however, is the amount of steam that can be produced by a pound of coal, and this depends upon (1) the condition of the water from which the steam is made, that is, whether the water is hot or cold to start with, (2) the condition of the air and of the coal which are to combine in the furnace, (3) the pressure and temperature of the steam which is to be produced, and (4) the condition of the flue gases as they enter the chimney. That is to say, the only things which it is necessary to consider are things which relate to quiescent substances. A quiescent substance may be said to be in a standing condition or state and the whole subject of heat (thermodynamics) may be said to refer to changes of state, that is, to changes from one quiescent condition to another quiescent condition without regard to the details of action which lead from one quiescent condition to the other.

Mechanical Energy and Heat Energy

In studying thermal and chemical changes we have to do with a new kind of energy. The gravitational energy of an elevated store of water can be wholly converted into mechanical work, the energy of two electrically charged bodies can be wholly converted into mechanical work (for example, by allowing the charged bodies to move towards each other), the kinetic energy of a moving car can be wholly converted into mechanical work, and so on. On the other hand, the energy of the hot steam which enters a steam engine from a boiler can not be wholly converted into mechanical work. Any store of energy which can be wholly converted into mechanical work may be called mechanical energy. The energy of the hot steam which enters a steam engine from a boiler is called heat energy.[4]

In the attempt to exclude all thermal changes from the purely mechanical discussion of energy one is confronted by the fact that friction (with its accompanying thermal changes) is always in evidence

[3] This practical matter is exactly of the same character as any purely scientific matter involving the application of thermodynamics. It is always a question concerning the correlation of measurable and sensible things.

[4] The important difference between mechanical energy and heat energy, namely, that one can be wholly converted into mechanical work whereas the other can not, may be clearly understood in terms of the atomic theory. Every particle of a moving car travels in the same direction and all of the particles work together to produce mechanical effect when the car is stopped; the molecules of hot steam, however, fly to and fro in every direction, and no method can be devised whereby the whole of the energy of the molecules of hot steam can be used to produce mechanical effect.

everywhere. In every actual case of motion the moving bodies are subject to friction and to collision, their energy is dissipated and they come to rest. This dissipation of energy is always accompanied by the generation of heat, and experience shows that the amount of heat generated is equivalent to the energy dissipated (first law of thermodynamics). It is important to understand that the term dissipation of energy refers to the conversion of mechanical energy into heat by friction or collision.[5] Thus energy is dissipated in the bearing of a rotating shaft, energy is dissipated when a hammer strikes a nail, and so on. The atomic theory enables one to form a clear idea of the dissipation of energy. Thus, the energy of the regular motion of a hammer is converted into energy of irregular molecular motion when the hammer strikes a nail.

It is worth while to give a statement of the first law of thermodynamics reduced to its simplest terms. A given substance is heated by the dissipation of work and brought back to its initial state by being cooled by contact with another (cooler) substance B. Then, if the loss of heat to surrounding bodies is carefully avoided, the thermal effect produced in substance B is exactly the same as would be produced in it if it had been heated directly by the dissipation of the original amount of work. Therefore a substance which is heated by the dissipation of work stores something which is equivalent to the work and which is called heat.

Gay Lussac's Law and the Air Thermometer.—When a number of closed vessels containing different gases at the same pressure are carried from a cool cellar, for example, to a warm room, they all suffer the same rise of temperature, and all of the gases show the same increase of pressure. That is to say, all gases follow the same law of increase of pressure with increase of temperature, the volumes of the containing vessels being constant. This fact was discovered by Gay Lussac and it is called Gay Lussac's Law. This law affords a convenient basis for the definition of temperature ratios, convenient because not dependent upon any particular gas. The ratio of two temperatures (provisionally defined) is the ratio of the pressures of a constant volume of gas at the respective temperatures. That is, if p and p' are pressures of a constant volume of a gas at temperatures T and T', respectively, then we have by definition

$$T/T' = p/p' \qquad (1)$$

The air thermometer is a device for measuring the ratio of two temperatures by observing the pressures of a constant volume of dry air at the respective temperatures.

[5] Energy is also dissipated in a wire in which an electric current flows.

Simple Knowledge Assumed

A great deal of simple every-day knowledge is always taken for granted in a treatise on thermodynamics. It is stated above that the important things in connection with the generation of steam in a boiler by the burning of coal are (*a*) the temperature of the feed water, (*b*) the temperature and pressure of the steam which is produced, (*c*) the character of the coal, (*d*) the temperature and composition of the air, and (*e*) the temperature and composition of the flue gases. In a certain sense this is true, but of course the fundamentally important thing is the knowledge that coal will burn and convert water into steam. Such fundamental knowledge is always taken for granted in the study of thermodynamics. The nature of fire is not an object of study in thermodynamics, but every one knows what fire is in a simple practical way; every one knows that an object becomes hot when it is placed upon a hot stove; and every one knows that steam will squirt out of a hole in a steam boiler under pressure. In the experience of the writer only one case has ever come to notice in which this kind of fundamental knowledge seemed to be lacking. A student was asked to define what is meant by the heat of combustion of coal, and he gave it correctly up to a certain point by saying that it was the number of thermal units generated by one pound of coal; it was, however, impossible to lead the young man by indirect suggestion to add the important qualifying phrase "when the coal is burned," and upon being asked explicitly how one gets heat out of coal, the young man actually replied, with some embarrassment, "Why, Professor, I don't know." Of course, he did know, but apparently he could only think that the study of thermodynamics must refer to unfamiliar and elegant things. No, thermodynamics refers to the things of the kitchen and to the things of the furnace, although the science of thermodynamics is so organized that it talks only of the things that go into and of the things which come out of those mysterious places where maids and furnace-men rule.

Limitations of Mechanics

The science of mechanics applies to the more or less ideal phenomena which are associated with the motion of rigid bodies either singly or in connected machines; with the regular motion of distortion of elastic bodies like the bending of a bow or the oscillation of a string; and with ideally simple motion of flow of liquids and gases like the smooth flow of water from an orifice in a tank. In every actual case of motion, however, we always encounter turbulence more or less marked, and the science of mechanics, which is the science of describing the phenomena of motion, fails utterly if we attempt to consider the minute details of the phenomena of motion which are involved in this turbulence. Let one, for example, watch the movement of the water at a point in a brook. There is indeed a fairly steady average velocity of the water at the point and a certain mean rhythmic variation, but superposed upon this average motion there is an erratic variation of velocity which is infinitely manifold, the details of which are beyond the scope of any descriptive science. A descriptive science like mechanics is concerned with how things progress as a phenomenon develops itself; how the structural parts of a bridge stretch and shorten as a car passes across the bridge; how the pressure and temperature of steam vary during the successive stages of admission, expansion and exhaust of a steam engine; how electro-motive force, current strength, electro-magnetic force and all of the changing variables play in the operation of a dynamo. But who could recite the story of the most minute details of these phenomena? It can not be done, and if it could be done, it would be of no avail, for these details can never be twice alike and the very essence of a science lies in the discovery of types which in their important features recur so that a knowledge of these types may serve as a basis for anticipation and design.

Fire is the most familiar example of a turbulent phenomenon, and its most striking characteristic is that its progress is not dependent upon any external driving cause; when once started it goes forward of itself and with a rush. Tyndall in referring to this matter says that to account for the propagation of fire was one of the philosophical difficulties of the eighteenth century. A spark was found sufficient to initiate a conflagration, and the effect seemed beyond all proportion greater than the cause; herein lay the philosophical difficulty. Indeed the simple idea of cause and effect is not applicable to physical phenomena involving turbulence. Every physical phenomenon involving turbulence is to some extent self-sustaining, and every such phenomenon has a certain impetuous quality which may carry it beyond anything that is commensurate with the original initiating cause. These remarkable characteristics of turbulence are now definitely formulated as the second law of thermodynamics.

The most important practical thing in connection with the turbulent aspect of any physical phenomenon is its general result or consequence, just as the important thing about the burning of a house is the loss. How utterly useless and uninteresting it would be, for example, to study the minutest details of a conflagration (assuming such study to be possible), recording the height and breadth and the irregular and evanescent distribution of temperature throughout each flicker of consuming flame, the story of each crackling sound and the extent and character of every yield and sway of timber and wall! The fact is that we are immersed in an illimitable sea of phenomena, every single detail of which is infinitely manifold, and no completely adequate science can ever be developed.

Physical science, then, aside from those branches which are dependent upon the atomic theory, consists of three branches, namely, (1) mechanics, including hydraulics, electricity and magnetism, light and sound; the science of those phenomena in which turbulence may for practical purposes be ignored; (2) statistical physics, the science of those phenomena in which turbulence introduces an appreciable and practically important erratic element. Such phenomena can be studied only by the statistical method, the record of individual cases and the study of averages. Meteorology is the best example of statistical physics, although every physical phenomenon has its statistical aspect; and (3) thermodynamics. Some of the features of thermodynamics have already been pointed out. It is the study of changes of state of substances. A most important aspect of thermodynamics remains, however, to be considered and the preliminary idea of this new aspect may be obtained by drawing a parallel. In every-day life we see the fire-insurance companies concerned with certain broad features of statistical physics in their examinations and records of fires, and we see them also concerned with a profit and loss account which is wholly abstracted from the details of the phenomena of conflagration. Thermodynamics is the profit and loss branch of physics as it were; and like the profit and loss branch of fire insurance, thermodynamics is completely abstracted from any consideration of the details of any physical phenomenon. Thermodynamics is concerned with the measurement and counting of that type of physical degeneration which accompanies turbulence just as fire insurance is concerned with the estimate and counting of what we might call, using a fine phrase, structural degeneration by fire.

Thermodynamic Degeneraton

Every one has a feeling of the irretrievable effects of disaster, the collapse of a bridge, the destruction of a house by fire, or the wreck of a ship; these things involve losses which indeed may be forgotten after reconstruction, but never balanced. The havoc wrought is essentially irreparable. It is desirable to use the word degeneration in a very narrow technical sense when we come to consider the second law of thermodynamics, and the way may be paved to a clear understanding of the later and accepted use of this word in physics by applying it now to designate that aspect of disaster which is irreparable. The burning of a building, for example, is a process of degeneration. It is very important, however, to avoid the carrying over of this idea of structural degeneration into thermodynamics, where a much more limited conception of degeneration arises. The term thermodynamic degeneration applies to the effects of turbulence which always plays a certain havoc in a system. Thus a certain degeneration is associated with the turbulence which is produced when a hot iron is dipped into water, a certain degeneration is associated with the escape of a compressed gas through an orifice, a certain degeneration is associated with the flow of heat from a region of high temperature to a region of low temperature, a certain degeneration is associated with the conversion of work into heat by the rubbing of a coin on a board, and so on.

Reversible Processes

A substance in thermal equilibrium is generally under the influence of external agencies. Thus surrounding substances confine a given substance to a certain region of space, and they exert upon the given substance a definite constant pressure; surrounding substances are at the same temperature as the given substance and according to the atomic theory the molecules of the given substance rebound from the surrounding substance with their motion on the average unchanged; surrounding substances may exert constant magnetic or electric influences on the given substance; and so on. If the external influences which act upon a fluid in thermal equilibrium are made to change very slowly, causing the pressure, volume and temperature of the fluid to pass very slowly through a continuous series of values and in general involving the doing of work upon or by the fluid and the giving of heat to or taking of heat from the fluid, then the fluid will pass slowly through a process consisting of a continuous series of states of thermal equilibrium. Such a process is called a reversible process, for the reason that the fluid will pass through the same series of states in reverse order if the external influences are changed slowly in reverse sense.

Irreversible Processes

When a substance is settling or tending to settle to thermal equilibrium it may be said to undergo a process. Such a process can not be arrested or held at any stage short of complete thermal equilibrium, but it always and inevitably proceeds towards that state. Such a process may, therefore, be called a sweeping process or simply a sweep. The settling of a closed system to thermal equilibrium may be called a simple sweep. For example, the equilibrium of a mixture of oxygen and hydrogen in a closed vessel may be disturbed by a minute spark, and the explosion of the gases together with the subsequent settling of the water vapor to a quiescent state constitutes a simple sweep. The equilibrium of a gas confined under high pressure in one half of a two-chambered vessel may be disturbed by opening a cock which connects the two chambers, and the rush of gas into the empty chamber constitutes a simple sweep. When external influences change continuously a substance in its tendency to settle to thermal equilibrium never catches up with the changing conditions, but trails along behind them, and we have what may be called a trailing sweep. Thus the rapid heating or cooling of a gas in a vessel is a trailing sweep. So long as heat is given to or taken from the gas at a perceptible rate there will be perceptible differences of temperature in different parts of the gas; and the gas in its tendency to settle to thermal equilibrium never catches up with the increasing or decreasing temperature of the walls of the containing vessel.

Steady Sweeps

A substance may be subjected to external action which, although permanent or unvarying, is incompatible with thermal equilibrium. When such is the case the substance settles to a permanent or unvarying state which is not a state of thermal equilibrium. Such a state of a substance may be called a steady sweep. For example, the two faces of a slab or the two ends of a wire may be kept permanently at different temperatures, and when this is done the slab or wire settles to an unvarying state which is by no means a state of thermal equilibrium. Heat flows through the slab or along the wire from the region of high temperature to the region of low temperature. This flow of heat through the slab or along the wire is an irreversible process and it constitutes a steady sweep. The ends of a wire may be connected to a battery or dynamo so that a constant electric current flows through the wire and the heat which is generated in the wire by the current may be steadily carried away by a stream of water or air. Under these conditions the wire settles to an unvarying state which is by no means a state of thermal equilibrium, the battery or dynamo does work on the wire and this work reappears steadily as heat in the wire.

Thermodynamic Degeneration

Every one must admit that the impetuous character of a sweeping process suggests a certain havoc, a certain degeneration in the substance or system in which the sweep takes place. Consider, for example, a charge of gun-powder which has been exploded; if it is exploded in a large empty vessel, everything is there after the explosion, all of the energy is there and all of the material substance is there, but it can not be exploded a second time! The man on the street has heard much during recent years of the conservation of energy and of the conservation of matter, and the old proverb that "you can't eat your cake and have it" presents to his mind a question which in its less familiar forms, as relating to engines for example, he tries in vain to rationalize in terms of these principles of conservation. Nearly all of the intuitive sense of the man on the street concerning these matters (and he has a great deal) is involved in the second law of thermodynamics, which is not a law of conservation at all. It is a law of waste.

At this point of our discussion it is necessary to use the word degeneration so as to express more or less tentatively the idea that every sweeping process brings about a definite amount of degeneration, an amount that can be expressed numerically just as one speaks of so many pounds of sugar or so many yards of cloth. Thus a certain amount of degeneration is brought about when a compressed gas escapes through an orifice, a certain amount of degeneration is brought about when heat flows from a region of high temperature to a region of low temperature, a certain amount of degeneration is brought about when work is converted into heat by friction or by the flow of an electric current through a wire, and so on.

In a simple sweep the degeneration lies wholly in the relation between the initial and final states of the substance. This is necessarily the case because no outside substance is affected in any way by the sweep, no work is done on or by the substance which undergoes the sweep and no heat is given to or taken from it. In a trailing sweep the degeneration may lie partly in the relation between the initial and final states of the substance which undergoes the sweep, partly in the conversion of work into heat, and partly in the flow of heat from a high temperature region to a low temperature region. In a steady sweep, however, the substance which undergoes the sweep remains entirely unchanged as the sweep progresses, and the degeneration lies wholly in the conversion of work into heat, in the transfer of heat from a region of high temperature to a region of low temperature, or in both. Therefore the idea of thermodynamic degeneration as a measurable quantity can be reached in the simplest possible manner by a careful scrutiny of a steady sweep.

Proposition (*a*).—The thermodynamic degeneration which is represented by the direct conversion of work into heat at a given temperature is proportional to the quantity of work so converted. Consider, for example, a steady flow of electric current through a wire from which the heat is abstracted so that the temperature remains constant. This process is steady, that is to say, it remains unchanged during successive intervals of time, and therefore any result of the process must be proportional to the time which elapses, that is to say, the amount of degeneration occurring in a given interval of time is proportional to the time, but the amount of work which is degenerated into heat is also proportional to the time. Therefore the amount of degeneration is proportional to the amount of work converted into heat at the given temperature.

Proposition (*b*).—The thermodynamic degeneration which is represented by the transfer of heat from a given high temperature T_1 to a given low temperature T_2 is proportional to the quantity of heat transferred. Consider a steady flow of heat from temperature T_1 to temperature T_2 constituting a steady sweep, a sweep which remains entirely unchanged in character in successive intervals of time. Any result of this sweep must be proportional to the lapse of time, and therefore the degeneration which takes place in a given interval of time is proportional to the time; but the quantity of heat transferred is also proportional to the time, therefore, the amount of degeneration is proportional to the quantity of heat transferred from temperature T_1 to temperature T_2.

Kelvin's Definition of Temperature Ratio

The definition of the ratio of two temperatures previously given was understood to be a provisional definition. We are now in a position to propose a definition of the ratio of two temperatures which is independent of the physical properties of any particular substance. This definition will remain somewhat vague, however, until the action of the steam engine is discussed in the later sections of this article. According to proposition (*a*) above, the thermodynamic degeneration which is involved in the conversion of work into heat at a given temperature is proportional to the amount of work so converted and the proportionality factor depends upon the temperature only. Therefore, we may write

$$\phi' = m_1 W \tag{2}$$

and

$$\phi'' = m_2 W \tag{3}$$

where ϕ' is the degeneration involved in the conversion of an amount of work W into heat at temperature T_1, and ϕ'' is the degeneration involved in the conversion of an amount of work W into heat at temperature T_2, and m_1 and m_2 are factors which depend only upon T_1 and T_2, respectively. The amount of work W having been converted into heat at temperature T_1, imagine the heat to flow to a lower temperature T_2, thus involving an additional amount of degeneration according to proposition (*b*) above. The conversion of work W into heat at temperature T_1 and the subsequent flow of this heat to a lower temperature T_2 gives the same result as would be produced by the conversion of the work into heat at the lower temperature directly. Therefore the lower the temperature at which work is converted into heat the greater the amount of degeneration involved. That is to say, the factor m_2 in equation (3) is larger in value than the factor m_1

in equation (2), temperature T_1 being higher[6] than temperature T_2. Therefore, since m_1 and m_2 depend only upon T_1 and T_2, respectively, it is permissible to adopt the equation

$$T_1/T_2 = m_2/m_1 \tag{4}$$

as the definition of the ratio T_1/T_2. This definition of temperature ratios is originally due to Lord Kelvin.

Another way to express the definition which is involved in equation (4) is to consider that the factor m_1 is the smaller the higher the temperature T_1, so that we may adopt k/m_1 as the measure of the temperature T_1 and k/m_2 as the measure of the temperature T_2, giving

$$m_1 = k/T_1 \tag{5}$$

and

$$m_2 = k/T_2 \tag{6}$$

where k is an indeterminate constant. Therefore equations (2) and (3) may be written in the general form

$$\phi = kW/T \tag{7}$$

where ϕ is the thermodynamic degeneration involved in the conversion of an amount of work W into heat at temperature T, and k is an indeterminate constant.

The ratio of two temperatures as defined by equation (4) is very nearly the same as the ratio of two temperatures as measured by the gas thermometer, and therefore gas thermometer temperatures may be used throughout this discussion without appreciable error.[7]

Since the factor k in equation (7) is indeterminate, we may use as our unit of thermodynamic degeneration the amount which is involved in the conversion of one unit of work into heat at a temperature of one degree on the "absolute" scale; then the value of k is unity and equation (7) becomes

$$\phi = W/T \tag{8}$$

[6] The idea of higher and lower temperature is not dependent upon any method of measuring temperature. When a substance receives heat definite observable effects are produced, and when these effects are produced by placing one substance in contact with another substance, the other substance is known to give heat to the given substance and its temperature is known to be higher than the temperature of the given substance. Does not one know that a stove is hotter than the floor, for example, when one spills water partly on the stove and partly on the floor?

[7] One of the most important discussions in elementary thermodynamics is that which establishes this fact. See Art. 58 of Franklin and MacNutt's "Elementary Theory of Heat" for a very simple discussion of this matter.

in which W is expressed in joules and T in degrees centigrade; and ϕ is expressed in terms of joules per degree. Thus one joule per degree is the degeneration involved in the conversion of one joule of work into heat at 1° C. on the absolute scale, or the amount involved in the conversion of 1,000 joules into heat at 1,000° C. on the absolute scale.

To convert an amount of work W into heat at temperature T_1 involves W/T_1 units of degeneration, to convert the same amount of work into heat at temperature T_2 involves W/T_2 units of degeneration, and therefore to transfer an amount of heat equal to W from temperature T_1 to temperature T_2 must involve an amount of degeneration equal to the excess of W/T_2 over W/T_1 or an amount equal to $W(1/T_2 - 1/T_1)$, or $H(1/T_2 - 1/T_1)$, where H is the amount of heat transferred.

The Second Law of Thermodynamics

(*a*) The thermodynamic degeneration which accompanies a sweeping or irreversible process can not be directly repaired, nor can it be repaired by any means without compensation.

This is an entirely general statement of the second law of thermodynamics. The *direct repair* of the degeneration due to the sweeping process means the undoing of the havoc wrought by the process by allowing the sweep to perform itself backwards, an idea which is exactly as absurd as the idea of allowing a burned house to unburn itself. Following are several specialized statements of the second law of thermodynamics.

(*b*) Heat can not pass directly from a cold body to a hot body, nor can heat be transferred from a cold body to a hot body by any means without compensation.

(*c*) Heat can not be converted directly into work, nor can heat be converted into work by any means without compensation.

The direct conversion of heat into work would be the simple reverse of any of the ordinary sweeping processes which involve the degeneration of work into heat, that is, the direct conversion of work into heat would be to allow the sweeping process to perform itself backwards. For example, work is degenerated into heat in the bearing of a rotating shaft, and we all know that to reverse the motion of the shaft does not cause the bearing to grow cold and the heat so lost to appear as work helping to drive the shaft. That would be a rotary engine indeed! There is an important general theorem in thermodynamics to the effect that if two sweeping processes A and B involve the same amount of degeneration, and if either of the processes, say A, has been allowed to perform its sweep, then by a lever arrangement, as it were, the process

B can be carefully *let down*, and the havoc wrought by the sweep of A can be undone. The result of this operation, however, would be to leave the system B in the condition in which it would be degenerated if the process B had been allowed to sweep instead of being *let down*. This is very much as if, having two similar houses A and B, one of which A has been burned, we could rig up a mechanism which would *let down* B to ashes and cause A to be restored in the original actual materials of which it was first constructed. This is of course impossible in the case of the two houses, but it is possible in every known case of thermodynamic degeneration. This general theorem is as thoroughly established as any generalization in physics, and if it is true and if we ever find a way to convert heat into work unconditionally and without cost or compensation, then it will be proved indirectly that a shaft *can* be driven by heating one of the bearings in which it rotates, for direct conversion of work into heat by one process must be according to this general theorem equivalent to and replaceable by the reverse of any ordinary sweeping process which converts work into heat.

(*d*) A gas cannot pass directly from a region of low pressure into a region of high pressure, nor can a gas be transferred from a region of low pressure to a region of high pressure by any means without compensation.

Imagine a gas squirting itself backwards through a nozzle into a high-pressure reservoir! The repeated statement of self-evident facts concerning direct repair in these statements of the second law of thermodynamics may seem ridiculous to the intelligent reader, but the second law of thermodynamics is a statement of a fact which every one knows coupled with a generalizing clause which, once thoroughly understood, is almost if not quite self-evident.

Here is one more statement of the second law of thermodynamics, the oldest English version of it:

Humpty Dumpty sat on a wall,
Humpty Dumpty had a great fall,
All the king's horses and all the king's men
Can not put Humpty Dumpty together again.

This is perhaps the most sensible of all the statements of the second law, for which we will allow it to pass for the moment, inasmuch as it ignores direct repair and refers at once to the most powerful of external means. It is important, however, to remember that in Humpty Dumpty's case we are concerned with structural degeneration, not with the much simpler kind of degeneration in a structureless fluid due to turbulence.

Of all the generalizations of physics, the second law of thermodynamics is certainly the most deeply seated in the common sense of men, and one of the most humorous of children's verses refers to the man whose wondrous wisdom enabled him to circumvent it by direct repair:

There was a man in our town,
  And he was wondrous wise;
He jumped into a bramble bush
  And scratched out both his eyes.
And when he found his eyes were out,
  With all his might and main,
He jumped into another bush
  And scratched them in again.

Let us return to the fourth statement (*d*) and consider with the help of an example what is meant by compensation in its thermodynamic sense. A gas *can* be transferred from a region of low pressure to a region of high pressure by means of a pump, and the work that is done in driving the pump, even supposing the pump to be frictionless, is all converted into heat. This conversion of work into heat is the necessary cost or compensation for the transfer of the gas from the low pressure region to a high pressure region.

Consider the second statement (*b*). In an artificial ice factory heat *is* continually abstracted from the freezing-room and transferred to the warm outside air; but to accomplish this result, even by an ideally perfect frictionless mechanism, a certain amount of work is required to drive the ammonia pump and this work is converted into heat. This conversion of work into heat compensates for the transfer of heat from the freezing-room to the warm region outside.

Consider the third statement (*c*). In ordinary steam engines, heat *is* converted into work, but to accomplish this transformation a large quantity of heat must be supplied to the engine at high temperature, and some of this heat (about nine tenths of it in the very best of steam engines) must be let down, as it were, to the low temperature of the exhaust to compensate for the conversion of the remainder into work.

Heat Engines

An engine, or to be more specific, a heat engine is a machine for converting heat into mechanical work. The engine is supplied with heat at a high temperature, it transforms a portion of this heat into work, and it delivers the remainder of the heat to a low temperature region. Figure 1 is a diagram for fixing in the reader's mind the various temperatures and quantities of heat and work which are involved in the operation of an engine. The boiler is at high temperature T_1, and the condenser is at low temperature T_2. When the engine is operated for a time, a quantity of heat H_1 is taken from the boiler, an amount of heat W is developed by the engine (in excess of the work required to drive the feed water pump), and the quantity of heat H_2 is delivered to the condenser.

According to the first law of thermodynamics, the work W must be equal to $H_1 - H_2$, both quantities of heat being expressed in energy units. Therefore

$$W = H_1 - H_2 \tag{9}$$

As far as the net result is concerned the operation of the steam engine may be thought of as (*a*) the conversion into work of the whole of the heat H_1 from temperature T_1, and (*b*) the reconversion of a

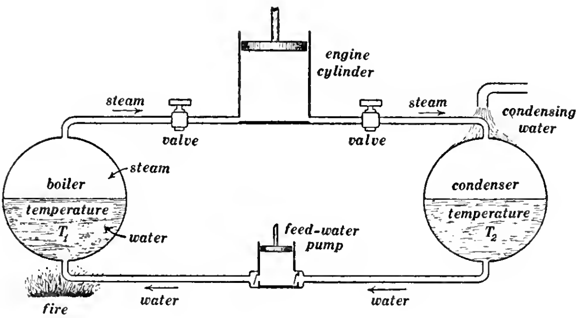

FIG. 1.

portion H_2 of this work into heat at temperature T_2. The regeneration[8] associated with process (*a*) is equal to H_1/T_1 according to equation (8), and the degeneration associated with process (*b*) is equal to H_2/T_2 according to equation (8). If the operation of the engine involves sweeping processes, then the degeneration H_2/T_2 must exceed the regeneration H_1/T_1, that is, we must have

$$H_2/T_2 > H_1/T_1 \tag{10}$$

or, substituting the value of H_2 from equation (9) and solving for W, we have

$$W < \frac{T_1 - T_2}{T_1} H_1 \tag{11}$$

The fractional part $[(T_1 - T_2)/T_1]$ of the heat H_1 which is converted into work by the engine is called the efficiency of the engine, and the inequality (11) shows that the efficiency of any engine working between temperatures T_1 and T_2 must be less than $[(T_1 - T_2)/T_1]$ whatever the nature of the working fluid and whatever the design of the engine.

The Perfect Engine.—An engine involving no irreversible or sweep-

[8] To convert an amount of work W into heat at a given temperature involves an amount of degeneration, and to convert the heat into work involves the same amount of what may be called thermodynamic regeneration.

ing processes in its operation would be called a perfect engine. In such an engine the degeneration H_2/T_2 above mentioned would be equal to the regeneration H_1/T_1 so that for a perfect engine we should have

$$H_2/T_2 = H_1/T_1 \tag{12}$$

or

$$T_1/T_2 = H_1/H_2 \tag{13}$$

Substituting the value of H_2 from equation (9) in equation (12) or (13), and solving for W, we have

$$W = \frac{T_1 - T_2}{T_1} H_1 \tag{14}$$

This equation shows that the efficiency of any perfect engine working between the temperatures T_1 and T_2 would be equal to $[(T_1 - T_2)/T_1]$.

Lord Kelvin's definition of the ratio of two temperatures may be understood with the help of equation (13) in which H_1 and H_2 are the amounts of heat taken in and given out by a perfect engine during a given time, and T_1 and T_2 are the temperatures between which the engine is working.

Efficiencies of Engines in Practise.—A fraction of the heat which is delivered to an engine with the steam which drives the engine is converted into work. In order that this fraction may be large, the ratio T_1/T_2 must be as large as possible, and sweeping processes must be obviated as much as possible in the operation of the engine; T_1 being the temperature of the steam supplied to the engine, and T_2 being the temperature of the exhaust. The ratio of the initial temperature to the final temperature of the expansion steam or gas in an engine depends upon the ratio of the initial volume to the final volume of the steam or gas.

In order that moderately small cylinders[9] may be used for the development of a given amount of power, the initial pressure of the steam or gas must be high; and in order that the final temperature may not be lower than atmospheric or available condenser water temperatures, the initial temperature must be high. The first point concerning high initial pressures is exemplified in the operation of the ordinary gas or gasoline engine in which the mixed charge of gas and air is highly compressed before it is exploded.

In the gas engine the initial temperature is the temperature of the

[9] The objections to large cylinders are: (*a*) their great cost, (*b*) the great amount of heat radiated by them, (*c*) the great amount of cylinder condensation in a large cylinder as explained later, and (*d*) the great amount of piston friction and cost of lubrication.

mixture of air and gas immediately after the explosion and it may be from 1,200° to 1,700° C. on the absolute scale; and the temperature is reduced by expansion to perhaps half this value. The temperature and pressure of the steam which is supplied to a steam engine is seldom higher than 190° C. (463° on the absolute scale) and about 175 pounds per square inch, respectively. Any higher temperature and pressure involves a great deal of danger in the boiler. The lowest condenser temperature in steam engine practise is about 50° C. (323° on the absolute scale).

The sweeping processes which take place in a steam engine are as follows:

(*a*) Friction between the moving parts of the engine. This friction results in the immediate reconversion into heat of a portion of the mechanical energy developed by the engine.

(*b*) Wire drawing. If the pipes and passages traversed by the steam through the boiler to the engine are small, the pressure in the cylinder with open ports will be lower than boiler pressure, so that the entering steam passes from a region of high pressure into a region of low pressure. Also as the cut-off valve closes, steam will rush into the cylinder through a narrowing aperture. This effect is called wire drawing, and to provide against loss of efficiency from this cause the pipes must be of ample size and the cut-off valve must operate very quickly.

(*c*) Radiation. The cooling of pipes and cylinders by the giving of heat to surrounding cooler bodies is a sweeping process, and is to be obviated as much as possible by covering the pipes and the cylinder with a thick coating of porous insulating material.

(*d*) Cylinder condensation. As a charge of steam in the cylinder expands it cools and cools the cylinder and piston, so that when steam is next admitted it heats cylinder and piston up again and is itself cooled. This effect can not be eliminated, but it can be largely reduced by providing separate passages for the ingress and egress of steam; and by using a series of cylinders of increasing size of which the smallest cylinder takes steam directly from the boiler and exhausts into the next large cylinder, which in turn exhausts into a still larger cylinder, and so on. In this way the range of temperature in each cylinder is small and the effects of cylinder condensation are greatly reduced. A steam engine in which expansion of the steam takes place in two stages (in two cylinders) is called a compound engine. An engine in which the expansion of the steam takes place in three stages (in three cylinders) is called a triple expansion engine.

The loss of efficiency due to cylinder condensation is greatly reduced by the use of superheated steam because the exchange of heat between the steam and the cylinder walls is very greatly reduced when the steam does not condense. Thus, S. LeRoy Brown has found that heat is imparted to a metal surface about twenty-four times as fast by condensing steam than by a gas at the same temperature.

(*e*) Effect of high piston velocity. If the piston speed is too great, the pressure of the expanding steam becomes ineffective because the portions of the steam near the moving piston are expanded and cooled before the remote parts of the steam are affected. This effect is negligible at the highest piston velocities which are mechanically feasible.

(*f*) Puffing. When the steam at the end of a stroke is still at a pressure which exceeds the pressure in the condenser (or which exceeds the pressure of the outside air when no condenser is used), it rushes through the exhaust port as a sharp puff. Puffing is to be avoided by sufficiently reducing the steam pressure by expansion in the cylinder.

The greatest items of waste in the ordinary sense of actual loss of heat are (*a*) the incomplete combustion of the fuel and (*b*) the carrying away of great quantities of heat in the flue gases. The economic use of fuel for the production of mechanical power requires, therefore, a properly designed furnace and intelligent and careful stoking to insure complete combustion, and it requires a sufficient exposure of boiler surface and frequent cleaning of the same to facilitate the flow of heat from the hot gases into the boiler.

The most pronounced sweeping process which intervenes between the completed combustion and the final exhaust of the steam is the flow of heat from the very high temperature of the fire in the furnace to the moderately low temperature of the water in the boiler, and the greatest waste in the operation of the steam engine in the sense of loss of availability of heat for conversion into work is involved in this sweeping process, and it can hardly be avoided in the steam engine because of the danger involved in the generation of steam at very high pressure in a large boiler.

The best gas engines convert about 30 per cent. of the heat of the fuel into mechanical work. The best steam engines convert about 10 or 12 per cent. of the heat of the fuel into mechanical work. The ordinary run of steam engines convert only 4 or 5 per cent. of the heat of the fuel into mechanical work.

(*This article is to be followed by a second article on entropy.*)

CLIMATE IN SOME OF ITS RELATIONS TO MAN[1]

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Climatology and Meteorology.—In a course of lectures dealing with the present status of meteorology the subject of climate, upon which I have the honor to address you this afternoon, finds an appropriate place. For meteorology and climatology are interdependent, and it is impossible to distinguish very sharply between them. In a strict sense, meteorology deals with the physics of the atmosphere, and those of you who have attended the preceding lectures in this course have listened to able discussions of the physical problems with which meteorologists are to-day concerned. The view taken by meteorology is largely theoretical, but the main object in the solution of most of these problems is to make this science of immediate practical service to man, in improving and extending our weather-forecasts.

When the term meteorology is employed in its broadest sense, climatology is a subdivision of meteorology. Climatology is largely descriptive. It rests upon physics and geography, the latter being a very prominent factor. In fact, climatology may almost be defined as geographical meteorology. The main object of climatology is also to be of practical service to man. Its method of treatment lays the most emphasis upon the elements which are of the most importance to life. Climate and health, climate and industries, climate and crops, climate and transportation—these are subjects of vital human interest. It is my privilege this afternoon to suggest a few of the points of contact between man and his climate. If my discussion seems disjointed and haphazard, I beg of you to remember that the subject is one of the widest possible range; it concerns all men, in all parts of the world. To select from this immense body of facts the few which it is possible to touch upon in an hour is like trying to decide which of a thousand snowflakes is the most symmetrical: or to determine, in a wonderful view across the snow-covered mountains on a brilliant winter's day, whether it is the sun, or the crisp air, or the snow, or the contour of the hills, or the grouping of the trees, or the picturesque farmhouses, which really contribute most to make the picture what it is.

The Climatic Zones.—So great is the variety of climates to be found in the world that it has long been customary to classify these climates into certain broad belts, which we call the zones. These were first suggested, on purely astronomical grounds, in the times of the early Greek philosophers and geographers. It is to be noted

[1] Lecture delivered at Columbia University, March 2, 1909.

that these zones are really zones of sunshine, or of solar climate, a subject which Professor Libbey has already considered in his lecture on "Astronomical Climate" (January 19, 1909). The so-called "torrid" zone has the greatest annual amount of sunshine. It is the summer zone. The polar zones have the smallest amount of sunshine. They may well be called the winter zones. The temperate zones are intermediate between the tropical and the polar, in the matter of the annual amount and of the annual variation of sunshine.

The Temperature Zones.—The usual classification of the climatic zones on the basis of the distribution of sunshine serves well enough for purposes of simple description, but a glance at any temperature-chart shows at once that the lines of equal temperature (isotherms) do not coincide with the lines of latitude. In fact, in the higher latitudes, the lines of equal temperature often follow the meridians more closely than they do the parallels of latitude. The astronomical zones—*i. e.*, the zones of light—therefore differ a good deal from the zones of heat. Hence, in recent years, it has become quite customary, at least in climatology, to limit the zones by lines of equal temperature, thus making a closer approach to the actual conditions of climate.

Characteristics of the Tropics.—The dominant characteristic of the great equatorial zone is the remarkable simplicity and uniformity of its climatic features. The tropics lack the proverbial uncertainty and changeableness which characterize the weather of the higher latitudes. Within the tropics, weather and climate are essentially synonymous terms. Regular conditions, which depend upon the daily and annual march of the sun, are dominant. Irregular weather changes are wholly subordinate. In special regions only, and at special seasons, is the regular sequence of weather temporarily interrupted by an occasional tropical cyclone. These cyclones—the hurricanes of the West Indies and the typhoons of the China seas belong to the group—although infrequent, are notable features of the climate of the areas in which they occur. The devastation produced by one such storm often affects the economic condition of the people in the district of its occurrence for years.

Over nearly all the equatorial zone the difference between the average temperatures of the warmest and coldest months is less than 10°, and over much of it it is less than 5°. At Equatorville, in the interior of Africa, on the Congo, the difference between the average temperature of the warmest and coolest months is only a little over 2°. The variation in temperature during the day is usually larger than this seasonal difference. Thus, at Equatorville it is seven times as large. It has been well said that "night is the winter of the tropics." Over much of the equatorial zone the lowest temperatures usually do not fall below 60°. Maximum temperatures of 115°–120° occur over the deserts of northern Africa.

In a true tropical climate seasons, in our sense, do not exist. The variations in temperature throughout the year are so slight that the seasons are not classified according to temperature, but depend on rainfall and the prevailing winds. The life of animals and of plants in the tropics, and of man himself, is regulated very largely, in some cases almost entirely, by rainfall. Although the tropical rainy season is characteristically associated with a vertical sun (*i. e.*, "summer"), that season is not necessarily the hottest time in the year. In fact, the temperature is usually somewhat lower under the clouds, and hence the rainy season often goes by the name of "winter."

Within the tropics the equatorial belt of calms and variable winds —the "doldrums" of sailors—offers exceptionally favorable conditions for abundant rainfall. The rainfall is so heavy that the surface waters of the ocean are actually fresher than in the latitudes to the north and south. The sky is prevailingly cloudy; the air, hot and oppressive; heavy showers and thunderstorms are frequent. In the latitudes of this belt are the dense tropical forests of the Amazon and of equatorial Africa. Here drought and frost need not be feared. The belt of calms and rains shifts north and south of the equator after the sun. It is dreaded by seamen because sailing vessels are apt to be delayed in crossing it, but delays of great length are infrequent nowadays, since a careful study of the prevailing winds over the ocean areas has shown navigators at what points the belt of calms is narrowest, and where the crossing may be the most successfully made.

In striking contrast are the easterly trade winds, which blow toward the equator from about latitude 30° north and south. Of great regularity, embracing about one half of the earth's surface, the trades have long been favorite sailing routes because of the steadiness of their winds, the infrequency of their storms, the brightness of their skies and the freshness of the air, all of which are in pleasing contrast with the muggy, oppressive calms of the doldrums. All sailing routes which pass through the trade wind belts in any ocean are controlled by these winds. Steady winds like the trades certainly tempted the early navigators to put to sea. The famous voyage of Columbus was facilitated, if not made possible, by the northeast trade. The easy outward voyages of the early Spanish adventurers and colonists took them naturally to that portion of the Americas where they found even-tempered climates in which they and their descendants could live comfortably. The monsoons of India have from the earliest days of trade with the east been important agents in aiding commerce.

The most desirable house sites in the tropics are very commonly on the top of some elevation, exposed to the trades. The sea breeze, also, is an important climatic feature on many tropical coasts. With its regular occurrence, and its cool, clean air, it serves to make many districts habitable for white settlers, and has deservedly won the name of "the doctor." The location of dwellings is often determined by the exposure of a site to this wind. For this reason, many native villages are placed as near the sea as possible. The houses of well-to-do foreigners often occupy the healthiest and most desirable locations, where the sea breeze has a free entrance, while the poorer native classes live in lower, less exposed, and less desirable places. A social stratification is thus determined by the sea breeze. In our own latitudes, exposure to sunshine is very important, as is well known, in determining house sites. Lugeon's study of one of the principal valleys between Martigny and the Rhone Glacier, has brought out some interesting facts in this connection. In this district the villages, with one or two exceptions, are on the sunny side. In fact, a distinction of classes results from this difference. There is developed what may be called an "aristocracy of the sun." The people on the sunny side are more prosperous and better educated, and look with some contempt upon the people on the shady side.

The trades, except where they blow onto windward coasts, or over mountains, are dry winds. On the lowlands swept over by the trades, beyond the polar limits of the equatorial rain belt (roughly between latitudes 20° and 30°) are most of the great deserts of the world. The interior of Africa has been out of contact with the civilized world largely because of the deserts to the north and south of it. Goods and passengers go around rather than across these deserts. In the desert, population gathers in oases, as on islands. Here the trails followed by the caravans converge like sailing routes at sea. There are small Arabian towns, built at oases, where the houses are almost crowded on top of one another, producing something not unlike the modern "sky scraper" of an American city, where land is scarce and expensive.

The overflow of the Nile results from the rainfall on the mountains of Abyssinia during the northward migration of the belt of equatorial rains; and one of the most difficult problems in the construction of the Panama Canal, viz., the control of the floods of the Chagres River, is due to a similar cause.

The monsoons, reference to which was made a moment ago, are a special development of the general trade wind system. Monsoon regions have summer rainfall, and these rains are particularly heavy where the winds have to climb over high land. Thus, in India, the precipitation is heaviest at the head of the Bay of Bengal, where in the Khasi Hills, at a height of a little less than a mile above sea level, the rainfall averages between 35 and 40 feet a year. This is about ten to twelve times as much as the rainfall of New York City, and all this water falls in less than six months. Truly, at that place, "it never rains but it pours." In certain parts of India stores of provisions are laid in before the rains begin, the preparations being similar to those made on board a vessel bound on a long voyage. Special mention may be made here of a peculiar relation between climate and man in the case of certain tropical mountains which are high enough to receive snow instead of rain on their upper slopes. These mountains furnish a supply of snow and ice for refrigerating purposes in the towns below them. Thus, in Ecuador, snow is carried to Quito from the upper slopes of Pichincha; to Riobamba and Ambato from the slopes of Chimborazo. Guayaquil was formerly supplied with ice in the same way. In Colombia, Popayan, in the department of Cauca, is also supplied with ice and snow from the neighboring mountains. In Mexico, snow is carried from the summit of Colima to the towns on the hot plains below. The occupation of the Indians who bring down this ice from their tropical mountain tops is a curious example of climatic control.

Characteristics of the Temperate Zones.—The so-called "temperate zones" occupy about one half of the earth's surface. The north temperate zone includes the greatest known extremes of temperature, and if the word "temperate" were not so firmly established it would be well to change the name to "intermediate." A marked changeableness of the weather is a striking characteristic of these zones. For most of the year, and most of the temperate zones, settled weather is unknown. Climate and weather are here by no means synonymous. The changeableness of the weather suggests our never-failing subject of conversation. In the tropics no one talks about the weather, for it is monotonously the same, day after day.

In the north temperate zone the differences in temperature between the warmest and coldest months reach 120° at their maximum, in northeastern Siberia. An average January temperature of — 60° and an average July temperature of 95°, with maxima of over 120° and minima lower than — 90°, occur in this same zone.

The prevailing winds of the "temperate zones" are the westerlies, which occupy about as much of the earth's surface as do the easterly trades. The westerlies are, however, less regular than the trades, being much confused and interrupted by storms. So common are such interruptions that the prevailing westerly wind direction is often difficult to discern without careful observation. The south temperate zone is chiefly water. Hence the westerly winds are there but little interfered with by land. "Roaring forties" is a well-known designation for the southern middle latitudes, and between latitudes 40° and 60° south the well-named "brave west winds" blow with a constancy and a velocity hardly known in the northern hemisphere. Storms, frequent and severe, characterize these southern hemisphere westerlies. Voyages to the west around Cape Horn against head gales, and in cold, wet weather, are much dreaded, and are apt to be long and dangerous.

Between the trades of the tropics and the westerlies of the temperate zones lies a debatable belt, shifting seasonally. Within it, stormy westerlies and drying trades alternately hold sway. It is known as the "subtropical belt." With prevailingly fair skies, even temperature and moderate rainfall, the subtropical belt is a favored climatic region, where invalids seek health, and an escape from the rigors of a cold winter is found by many who have the time, and the means, to leave their northern homes. The long list of well-known health resorts on the Mediterranean, and the shorter list for southern California—"the American Riviera"—bear witness to the popularity of this subtropical belt.

Seasons in most of the temperate zones are classified according to temperature—not, as in the tropics, by rainfall. The four seasons are important characteristics, especially of the middle latitudes of the north temperate zone. These seasonal changes are of the greatest importance in the life of man. They control his occupations, his crops, his place of residence, to a considerable extent his health.

The north temperate zone embraces so great a variety of climates that no single district can be taken as typical of the whole. Its climate has been called "a crazy quilt of patches." The south temperate zone, on the other hand, may be described as a piece of fairly uniform texture and appearance throughout. This is the effect of the large ocean surface. The whole climatic régime is more uniform than that of the northern zone. The south temperate zone may truly be called "temperate," but our own zone is certainly in the highest degree "intemperate."

Characteristics of the Polar Zones.—The climate of the polar zones gains a peculiar character by reason of the longer or shorter absence of the sun. At the poles themselves, the day and the year are alike. In the Arctic climate, plants must make rapid growth in the short, cool summer. They grow and blossom with great rapidity and luxuriance where the exposure is favorable, and where the water from the melting snow can run off. Over great stretches of the northern plains the surface only is thawed out in the warmer months, and swamps, mosses and lichens are found above eternally frozen ground. In high latitudes, where the exposure is good, snow melts in the sun even when the temperature of the air in the shade is far below freezing. It has been reported that at Assistance Bay, latitude 74.5° north, in March, when the air temperature was about —25°, snow near stones and other dark objects melted in the sun. The temperature in the immediate vicinity of the North Pole is probably a little below —40° in January; below 32° in July and a few degrees below 0° for the average of the year. It may be noted, however, that northeastern Siberia has a January mean temperature which is 20° lower than that at the North Pole in the same month.

For the Antarctic our knowledge is still very fragmentary. The low temperatures of the south polar summer, which are probably due to the great continental mass of ice around the south pole, are responsible for much of the difficulty of Antarctic exploration. The average annual temperatures have been in the vicinity of 10°–15°; and the minima of an ordinary Antarctic winter go down to — 40°, and below, but so far no minima of the severest Siberian intensity have been noted. The British expedition on the *Discovery* recorded a minimum temperature of — 67.7°, and also noted — 40° in midsummer. The highest temperatures have varied between about 35° and 50°. It is likely that near the south pole will prove to be the coldest point on the earth's surface in the average for the year, and also that the lowest winter and summer temperatures in the southern hemisphere will be found in the immediate vicinity of the pole.

The polar zones have a permanent deficiency of precipitation (15–10 inches, or less). The polar deserts of snow and ice are therefore deserts in more senses than one, although it is natural that these extended snow and ice fields should tend to give an exaggerated idea of the actual amount of snowfall. So far as exploration has yet gone into the highest northern latitudes, rain has been found to fall in summer, and it is doubtful whether there are any places in the world, near sea-level where *all* the precipitation comes in the form of snow. Perhaps the interior of the south polar continent may never have rain. The snow of the polar regions is characteristically fine and dry, and it has been pointed out that the snow huts of the Eskimos could not be built with our kind of snow. At low polar temperatures *flakes* of snow are not found, but precipitation is in the form of ice spicules.

The inner polar areas seem to be beyond the reach of the most frequent and most violent storms, and as most of the observations thus far obtained from the Antarctic come from the marginal zone of great storm activity, violent winds and wet, disagreeable weather, they do not show us the features of the actual south *polar* climate. Extraordinary records of storm and gale have been brought back from the far south and the far north. During the long, dreary winter night the temperature falls to very low readings. Snowstorms and gales alternate at irregular intervals with calmer spells of more extreme cold and clear skies. There is no really warm season. The summer is essentially only a modified winter, especially in the Antarctic. Yet the Arctic summer, with its long days, crisp, clean air and sunshine, has many attractive qualities, and we may fairly safely predict a considerable development of summer resorts within the Arctic circle for the pleasure-loving, wealthy and unoccupied persons of the north temperate zone.

Climate and Health.—We have now seen something of the climatic zones and of their characteristics. Let us turn for a few minutes to the question of climate and health—a subject which is surely of the greatest concern to man. From the earliest times people have sought in atmospheric conditions an explanation of the occurrence of disease. Many fairly obvious facts naturally point to some relation of cause and effect in this matter. Some diseases are found principally in warmer climates; others seem to prefer the colder. Some are usually more active in the warmer, or the drier months; others have shown the contrary relation. High altitudes are free from some of the diseases which prevail near sea-level, and have certain favorable climatic characteristics long recognized in the treatment of disease. In the case of other diseases, again, altitude has no effect. Dry climates, especially deserts, whose air is usually exceptionally pure and aseptic, are generally healthful, and are beneficial in many cases where mountain climates are too stimulating. The climates within forested areas have proved especially favorable in cases of phthisis. Ocean air, pure and dust-free, with its saline constituents and equability of temperature, is beneficial to most persons as a moderate tonic and as a restorative in many illnesses. Winds are active ventilating and purifying agents where population is congested. Fogs and clouds, by cutting off sunlight, weaken one of the best agents in promoting health, for sunlight, in the words of Dr. Sternberg, is "one of the most potent and one of the cheapest agents for the destruction of pathogenic bacteria." In London, a higher death-rate follows a long fog, but this may result from the lower temperature during the fog, and not from any direct effect of the fog itself.

A Complex Subject.—Facts like these naturally prejudice one in favor of a causal connection between atmospheric conditions and disease. Nevertheless, such studies have often led to very contradictory conclusions. Some of the difficulty arises from untrustworthy statistics, but most of the disagreement comes from the fact that not only may each of the different weather elements have some effect in the production of the disease, but so many other factors are concerned in the matter that confusion and contradiction in the conclusions reached are inevitable. Sanitation, food, water, habits, altitude, character and moisture of the soil, race, traffic and other controls, serve to complicate the problem. In most studies of climate and health some, or even many, of these factors have not received attention. Overcrowding under unhygienic conditions, especially indoors during cold weather, and traffic by rail, steamship, caravan or on foot, are often more important than climate. The frequent escape of mountain, of desert and of polar peoples from epidemics is to be attributed in most cases to the smaller chance of importing disease because of little intercourse with the outside world, and of spreading it, when imported, because of the scattered population. It may be noted, however, that crowding indoors in winter, and the sparseness of population just referred to, are themselves climatically controlled.

Climate, Microorganisms and Disease.—The cause of disease is no longer sought directly in meteorological conditions, but in the effects, more or less direct, of these conditions upon the microorganisms which are the specific cause of the disease. Atmospheric conditions may help or may retard the development of the microorganism, and may strengthen or weaken the individuals' power of resistance. Winds used to be regarded as the chief agents in spreading epidemics: now it is known that disease can not be carried far by winds, for the microorganisms do not long maintain their power in the free air and under the sun. Rain has been supposed directly to control the distribution of disease: now we believe that precipitation acts only indirectly, through drinking-water, or through its control over the dust in the air. Dust from dry soil, and from city streets, may contain the germs of infectious diseases, and aggravate affections of the respiratory organs.

Geographical Distribution of Disease.—The scheme of classifying disease geographically, on a broad climatic basis, is attractive, but not very satisfactory. For, on the one hand, many diseases are practically universal in extent, showing great independence of climate, and, on the other, the history of many diseases is still in the making. In spite of this complexity, however, certain broad statements may be made, useful in enabling the layman properly to coordinate his ideas on the subject, and fairly accurate within reasonable limits.

Tropics: General Physiological Effects.—Tropical monotony of heat is associated with high relative humidity, except over deserts and in dry seasons. The air is therefore muggy and oppressive. This "hot-house air" has an enervating effect. Energetic physical and mental action are often difficult, or even impossible. The tonic effect of a cold winter is lacking. These conditions have certain fairly well-established physiological effects, which, combined with less power to do work, greater fatigue from work, and lowered vitality, render the body less able to resist disease.

Hygiene in the Tropics.—Under the peculiar conditions of tropical climates, the resident who comes from a cooler latitude should take special precautions regarding his mode of life and personal hygiene. A rational, temperate life, especially the avoidance of alcoholic excess; regular exercise; non-fat-producing food; clothing suited to the climate; all possible sanitary precautions; protection against mosquitoes; frequent change of climate by returning to cooler latitudes—all these are important. It seems like a contradiction, but it is a fact, that the danger of becoming chilled in the tropics is very great and must be carefully guarded against. General Wolseley is reported to have said of the tropics, "not to get cold is to avoid almost certainly all the causes of disease," and a recent writer has well said that these words should be inscribed on the walls of all barracks in the tropics. The situation may be summed up in this rule: "Respect the sun, and rain and wind; clothe with a view to avoiding chill; live temperately." On the Calcutta docks are painted the words: "Beware of the sun."

Tropical Diseases.—Certain diseases are so much at home in the tropics that they have come to be known as *tropical diseases*. This designation, however, does not mean diseases confined to the tropics, but is employed in a meteorological sense for diseases associated with, but not solely, or even necessarily directly due to, high temperatures. Sir Patrick Manson has made it clear that the difference between the diseases of tropics and extra-tropics lies in the specific cause of these diseases. For the development of certain disease germs, tropical temperatures are required; or a third organism, other than the disease germ itself and man, may be necessary. If this organism is a tropical species, as in the case of the tsetse fly, the disease is a tropical disease. "The more we learn," Dr. Manson says, "about these [tropical] diseases, the less important in its bearing on their geographic distribution, and as a direct pathogenic agency, becomes the *rôle* of temperature *per se*, and the more the influence of the tropical fauna." The fact that plague, and leprosy, and to some extent cholera as well, are practically limited to the tropics, is the result of modern sanitary precautions in the extra-tropics. The unsanitary conditions among tropical peoples favor the spread of these, and similar, diseases, and not the climate *per se*. Nevertheless, it is clear that these very unsanitary conditions are "more or less an indirect outcome of tropical climate."

General Conclusions: the Tropics.—All parts of the equatorial zone are not equally disagreeable or hostile to the white race. Many elderly persons, and those who are overworked, may find rest from nervous tension in the enervating climate of the tropics. Much-needed relief from the heat at sea-level may be obtained at tropical mountain stations, and many of these have become well-known health resorts. In India, the hill stations are crowded during the hot months by civilian and military officials, and it has been well said that India is governed from 7,000 feet above sea-level.

Acclimatization of the White Race in the Tropics.—The acclimatization of the white race in the tropics is a question of vast importance. Upon it depend the control, government and utilization of the tropics. It is a very complex problem, and it has been much discussed. It is complicated by race, diet, occupations, habits of life and the like. To discuss it fully is impossible at this time. The gist of the matter is this: white residents from cooler latitudes, on coming into the tropics, must adjust themselves physiologically to the new climatic conditions. During this adjustment there is more or less strain on various organs of the body. The strain may be too severe, then the individual suffers. The adjustment is usually much retarded and hindered by a persistence in habits of food, drink and general manner of living which, however well suited to the home climate, do not fit tropical conditions. During the adjustment, especially if complicated by irrational habits, the body is naturally sensitive to the new diseases to which it is exposed. Even should no specific disease be contracted, there are anæmic tendencies and other degenerative changes. Experience teaches that white men can not, with impunity, do hard manual labor under a tropical sun, but that they may enjoy fairly good health as overseers, or at indoor work, if they take reasonable precautions.

Acclimatization, in the full sense of having white men and women living for successive generations in the tropics, and reproducing their kind without physical, mental and moral degeneration—*i. e.*, colonization in the true sense—is impossible. Tropical disease and death rates, as has been abundantly shown, can, however, be greatly reduced by strict attention to sanitary laws. And with increasing medical knowledge of the nature and prevention of tropical diseases, as well as by means of modern sanitary methods, a white resident in the tropics will constantly become better able to withstand disease. For greater comfort, for better health and for greater success, properly selected hill stations will, however, always be essential to northerners who have to live in the tropics, especially to white women and children.

It has been well said that the white soldier in the tropics is "always in campaign; if not against the enemy, at least against the climate." This sentence may be made to fit the case of the white civilian in the tropics by making it read: the white race in the tropics is always in campaign against its enemy, the climate.

Health in the Temperate Zones: General.—In the temperate zones the organs of the body act more equally than in the warmer and cooler latitudes. The winter cold is met by means of warm clothing, heated houses and other means of protection. Unless too severe, or too prolonged, the cold winter acts as a healthful stimulant upon body and mind. In the tropics, the body is unused to adjusting itself to temperature changes, because such changes are there slight, and is readily affected by them. But the frequent, sudden and severe changes of many parts of the temperate zone are usually borne without serious discomfort or injury, if the body is in good health, and is accustomed to adjusting itself readily to these changes. The habit of keeping houses very warm in winter, and of having the air indoors very dry, weakens the body's power to resist the cold outdoors, especially if the air be damp, and aggravates affections of throat, lungs and nose. The summers, although hot in the lower latitudes of these zones, and marked by spells of warm weather even to their polar limits, are not characterized by such steady, uniform moist heat as is typical of much of the tropics. When the heat is extreme, and the relative humidity is high, night and day, sunstroke is occasionally noted, but the invigorating cool of autumn and winter are never far off, and may always be trusted to bring relief.

Winter and Summer Diseases of the Temperate Zones.—It is natural that such marked seasonal and such sudden weather changes as ours should be reflected in the character, distribution and frequency of the diseases which are found in these zones. Diseases of the respiratory system, bronchial and rheumatic affections, diseases that result from colds and chills, pneumonia, bronchitis, influenza, diphtheria, whooping cough, are all common in climates with sudden marked temperature changes, especially if these changes are accompanied by cold, damp winds. These diseases are also most frequent in the winter months, when the weather changes are more common and more severe, and when, in consequence, the vitality of the body is lowered and its power of resistance against the attack of the disease germs is weakened. A greater prevalence of diseases of the respiratory system, catarrhs and rheumatic affections in cool, moist weather, with sudden changes, has been shown by Weber, and several investigators have found a higher mortality after a greater variability of temperature. Many contagious or infectious diseases, such as diphtheria, influenza, measles and scarlet fever, for example, are also more common in the colder season, not because the lower temperatures are the direct controlling factor, but largely because the colder weather drives people indoors; houses and buildings generally are less well ventilated; more clothing is worn, less attention is paid to personal cleanliness and there is increased opportunity for contagion, especially among the poorer classes. Obviously, these are indirect effects of meteorological conditions.

In the warmer months, fevers and diseases of the digestive system, diarrhœa, malaria, typhoid fever, are prevalent. Thus there are usually two maxima of mortality: one in the colder season, when the changeableness of temperature is greatest, chiefly due to respiratory diseases, and another in the warmer months, largely due to infant mortality from disorders of the bowels.

Climate and Man: General.—Let us turn now to some larger, more general, relations of climate and man. Man's climatic environment affects him in many ways. His clothing, dwellings, food, occupations and customs; his physical and mental characteristics; his systems of government; his migrations; his history—all are affected to a greater or less degree.

Civilized man protects himself more or less successfully against unfavorable climatic features. Thus, there is a gradual transition from the primitive shelter made of branches of trees, of skins or leaves, to the permanent and highly elaborate modern building, which is both heated and cooled artificially. There is also a transition from the primitive and scanty clothing made of leaves or bark, where trees grow, or the skin of an animal, where trees are lacking, or where warmer clothing is needed, to the manufactured or perhaps imported garment of wool, cotton or silk. Again, there is the increasing variety of food, from that of primitive man, supplied directly where he lives, to the highly varied diet found in a civilized community to-day, to which distant latitudes are made to contribute their local delicacies. Nowhere has man given a more striking exhibition of his ingenuity in meeting and overcoming, at least partially, the obstacles put in his way by climate than in his construction and operation of railroads. Transportation by rail is necessarily closely affected by climatic conditions, for trains have no protection against snow, wind or heat. The trans-Siberian railway was constructed with great difficulty because of frozen soil, spring thaws and upheaved tracks. Across the rivers and across Lake Baikal, rails were laid on the ice during construction times. Later, the trains were carried across the lake in winter on ice-breaking ferry-boats. The snow-blockades on the northern railroads of America led to the invention and use of the ingenious and effective rotary snow-plough, and to the construction of snow fences and of the highly interesting modern snow sheds, made in sections, which may be "telescoped" into one another in summer, in order to prevent the destruction of many miles of these sheds by fire. The campaign of a modern street railway system against the winter's snow is carefully planned in the previous summer, and a mild, open winter means a saving of money, time and labor, which results in increased earnings and larger dividends. The freezing of harbors at the termini of the northern railroads is a serious handicap in many countries. Russia's desire for an ice-free port at the terminus of the trans-Siberian railway on the Pacific led to her acquisition of Port Arthur, and ultimately to the war with Japan. The construction of railroads across deserts presents many difficulties. Ties dry up and twist; the danger from fire is greatly increased; fire patrols are often necessary; fuel is expensive and must be imported; water, for men and for locomotives, must be brought in by water-trains, tank cars or pipe-line; drifting sands cover the track and must constantly be shoveled off; the blowing sand hinders seeing, and increases friction and wear on the rolling-stock; watchmen are employed to guard against accidents from blowing sand on the track. A curious effect of sand-blasting is noted in the California desert, where the telegraph poles along the railroad are so worn near their bases by the blowing sand that they have to be protected by piles of stones. In the dense vegetation of the tropics, the roadway is constantly being overgrown, and men must be kept at work cutting down the weeds and underbrush. This involves great expense, and seriously reduces the earnings of the roads. Recently, tank-cars, which frequently spray the right of way with a strong poison, have come into use, as on the Guayaquil-Quito line in Ecuador, and elsewhere.

All this man has brought about in his combat with climatic conditions. But he can not change his climate. Slight local modifications may be secured here and there, as by planting trees to serve as wind-breaks, or in the case of protection against frost by the use of "smudges," or screens, or fires, or by erecting lightning rods to guard buildings against the danger of being struck. Man can not make it rain; nor can he prevent hail from falling, nor can he change his climate by planting forests. No such modification is possible in man's climatic environment as has been accomplished on the surface of the land under human agency. The atmosphere is as essentially unalterable as it is all-pervading.

Some Old Views Regarding the Effects of Climate on Man.—It is, however, easy to go too far in calling upon climate to explain certain phenomena which we may otherwise find it difficult to account for. This was the mistake formerly made by many writers on this subject. The broad generalizations of Montesquieu, Voltaire, Hume, Buckle and others, furnish interesting reading, and contain much that is suggestive and instructive, but they usually carry us well beyond the range of reasonable probability. Even Hippocrates's observations on climatic controls are not without value to-day.

Factors in the Problem other than Climate.—To most of these older writers, climate meant more than it does to-day. It included much of what is now termed our whole physical environment. We must remember that we are dealing here with large, highly complex phenomena. Man moves readily from place to place, from climate to climate. His food, drink, habits, occupations; to some extent his physical and mental characteristics, change in consequence. Inheritance, intermarriage, environment, opportunities, soil and many other factors enter in to determine what changes individual man and the race as a whole shall undergo. Time is a very important element in the final result, for in time a gradual adaptation to new conditions takes place. Climate is but one of many controls, albeit a most important one, for it largely determines what many of the other factors, such as diet, customs and occupations, for example, shall be. The task of giving climate its proper place as a factor controlling the life of man as a whole is a difficult one, which can not be definitely and satisfactorily solved to-day—or to-morrow.

Climate and Habitability.—Climate determines where, as well as how, man shall live. It classifies the earth's surface for us into the so-called habitable and uninhabitable regions. The deserts of sand and the deserts of snow and ice, whether the latter be near sea-level or high up on mountain tops, are alike climatic, the former because of aridity, the latter because of cold. The only non-climatic deserts are recent lava flows. Where a soil is present which is not frozen much over half the year, and where there is reasonable temperature and sufficient rainfall, plants and animals are found, ranging from few and lowly forms where conditions are hardest and where all life has to be especially adapted to these conditions, to the greatest abundance where conditions are most favorable.

Man is influenced by much the same controls as those which affect plants and the lower animals. From the highest latitudes he is excluded by cold. The highest altitudes are hostile both because of cold and of diminished pressure. The deserts of sand are uninhabited, or thinly populated, by reason of aridity. Forests, where rainfall is abundant, are unfavorable to a dense population. The trees must be cleared away before settlement is easy. The waves of civilization, as one writer has expressed it, beat up against the forest, but only with difficulty do they break through it. The equatorial forests of Africa; the densely wooded Amazonian provinces of Peru; the forests of northern Sumatra; the eastern forested slopes of Central America, left longest to the native tribes, while the western, more open, and drier slopes were first settled by white men, and are best developed—these are examples of the repelling effect of dense tree-growth where the advance of civilized man is concerned. Even the earlier American civilizations, the Aztec and the Inca, halted before forested areas. The Incas were almost as much hemmed in by the forests on the east as by the Pacific on the west. Travel through dense forests is difficult. Narrow paths, along which travelers move in Indian file, are the natural, and in fact the only, ways of communication, unless travel can be by boat. It requires no wide stretch of the imagination to see a connection between the method of carrying goods in the African forests, on the backs or heads of negro porters, and the slave trade, which sells the man who carried the goods as well as the goods. Many of the natives who secure the rubber from the Amazonian forests, or from those of the Congo, are to-day subjected to hardships which equal those of slavery.

Man is widely distributed over the earth's surface. The coldest place in the world in January is a large Siberian city, Verkhoyansk, while one of the hottest places in the world is Massowa, on the Red Sea, the capital of the Italian colony of Eritrea. But the life of man is harder here and easier there, according to climatic conditions, and the scarcity or abundance of plant and animal life.

Man is distributed in great belts around the world, corresponding roughly to the broad zones of vegetation, desert, steppe and forest, the limits of which are set by temperature and rainfall, but man is far more dependent on rainfall than on temperature. There are certain common conditions of life which affect the people who live in the same zone in the same broad, general way. This, as Ratzel first pointed out, means that there is a climatic factor at work to maintain differences between the people of different zones, in spite of the great movements which are constantly tending to produce uniformity. All the regions of sparse population are gradually being encroached upon by an invasion from their borders. Forests are being cleared, and replaced by agricultural lands. Wheat and corn are replacing grass on the steppes, especially where irrigation can be practised. Deserts are being reclaimed here and there where water is available. The more civilized man becomes, the denser the population which the different parts of the earth can be made to support. From the wandering hunting and fishing tribes of the African forest or of the borders of the Arctic Sea, through the farming populations of the cleared forest and of the steppe, to the crowded industrial centers of the modern city, there is such a gradation. It is the story of a more complete to a less complete mastery of man by his environment.

But in spite of all that man can do, the larger climatic limitations persist. The Greenland desert of snow and ice, the Saharan desert of sand: these remain, deserts.

Primitive Civilization and the Tropics.—There are reasons for thinking that primitive, prehistoric man, in his earliest stages, when most helpless, was an inhabitant of the tropics; that he lived under the mild, uniform, genial climate of that zone, where food was easily obtained and protection against the inclemencies of the weather least necessary. There has been a belief that southern Asia, with its numerous bays and archipelagoes, was probably the cradle of humanity. Civilized man is believed by many to have appeared first on the delta formed at the head of the Persian Gulf by the Tigris and Euphrates rivers. Ancient civilizations seem to have developed in the drier portions of the tropics, where irrigation was necessary in order to insure abundant and regular crops, and where lived races more energetic and more hardy than those of the damper and rainier portions of the tropics, with more luxuriant vegetation. Within the tropics, the greatest progress later came, not on the damp lowlands, but on the less fertile plateaus of Mexico and Peru, where the Aztecs and the Incas made their marvelous progress in the drier, cooler and somewhat more rigorous climates over 7,000 or 8,000 feet above sea-level.

The Development of the Tropics.—Within the tropics, under the equatorial sun, and where there is abundant moisture, animal and plant life reach a very full development. Here are the lands which are most valuable to the white man because of the wealth of their tropical products. Here are the tropical "spheres of influence" or "colonies" which are among his most coveted possessions. It is in this belt that food is provided for man throughout the year without labor on his part; where shelter and clothing are so easily provided, and often so unnecessary, that life becomes too easy. Nature does too much; there is little left for man to do. The simplicity of life, so far as providing food is concerned, has been emphasized by writers almost without number. Captain Cook put the case very emphatically when he said that a South Sea Islander who plants ten bread-fruit trees does as much towards providing for his family as does a man in northern Europe who works throughout the year.

In a debilitating and enervating climate, without the necessity of work, the man who inhabits the tropics not unnaturally lacks the will to develop himself, and also the will to develop the resources of the tropics. Voluntary progress towards a higher civilization is not reasonably to be expected. The tropics must be developed under other auspices than their own. As Professor John R. Commons has well put it: "Where nature lavishes food and winks at the neglect of clothing and shelter, there ignorance, superstition, physical prowess and sexual passion have an equal chance with intelligence, foresight, thought and self-control." The energetic and enterprising nations of the world have not developed under the easiest conditions of life in the tropics. As Edward Whymper's Swiss guide said of the natives of Ecuador: "It would be good for tropical peoples to have a winter."

The Labor Problem in the Tropics.—"What possible means are there of inducing the inhabitants of the tropics to undertake steady and continuous work, if local conditions are such that from the mere bounty of nature all the ambitions of the people can be gratified without any considerable amount of labor?" In these words, Alleyne Ireland well sums up the labor problem in the tropics. If the natives are, on the whole, disinclined to work of their own accord, then either forced native labor, which is contrary to the spirit of the times, or imported indentured labor, becomes inevitable if the tropics are to be developed. With few exceptions, and those where the pressure of a large population necessitates labor, effective development has been accomplished only where imported Chinese, Japanese or coolie labor has been employed, usually under some form of contract. Negro slavery began in the West Indies, under early Spanish rule, and its perpetuation was certainly in part aided by climatic controls. The best development of many tropical lands depends to-day upon Chinese or Japanese labor. It will be so in the Philippines.

With a large native class which is indolent, working intermittently for low wages, or which is bound under some form of contract, it follows that the native or imported laboring classes are separated by a broad gulf from the upper, employing class, which is usually essentially foreign and white. The latter class tends to become despotic, the former, servile. Marked social inequalities thus result, accentuated by the fact that the foreign-born white is usually debarred from all hard labor in a hot, tropical climate. White laborers are not likely to become dominant in the tropics for two reasons: first, because the climate is against them; and second, because the native is already there, and his labor is cheaper. White men are not doing the hard daily labor of India, of Java, of the Philippines, or even of Hawaii. They are directing it.

The Government of Tropical Possessions.—The government of European possessions in the tropics has thus far been determined chiefly by three considerations: (1) The general incapacity of the natives, through ignorance, or lack of interest, or their undeveloped condition, to govern themselves properly. (2) The fact that the white residents are generally comparatively few in number and are only temporarily in the country, to make money and then go home again. This white population is often composed chiefly of men—soldiers, officials, merchants, adventurers. There is little inducement to found permanent homes. (3) The marked class distinctions already referred to. These generalizations must obviously not be carried too far, but what has been said is in the main true. The white residents constitute a caste, and naturally become the rulers, the home government retaining general control, often by force of arms. The native population, although largely in the majority, may have little or no voice in its own government. This is clearly not a democracy. It thus comes about that the tropics are governed largely from the temperate zone; the standards, ideals, motives, come from another land. And where governed under their own auspices, as independent republics, the success has not been great. Buckle first strongly emphasized the point that hot countries are conducive to despotism and cold countries to freedom and independence; and James Bryce has recently clearly set forth the climatic control of government in an essay on "British Experience in the Government of Colonies."[2] The very Europeans who exercise the controlling power in the tropics, themselves tend to become enervated if they live there long; they lose many of the standards and ideals with which they started; they not uncommonly tend to fall towards the level of the natives rather than to raise the standards of the latter. The peculiar situation which may arise from the government of a tropical possession in which the white race does not become acclimated has been emphasized by Dr. Goldwin Smith in a recent discussion of British rule in India. He says:

> British empire in India is in no danger of being brought to an end by a Russian invasion. It does not seem to be in much danger of being brought to an end by internal rebellion. Yet it must end. Such is the decree of nature. In that climate British children can not be reared. No race can forever hold and rule a land in which it can not rear its children.

The future of tropical possessions and "spheres of influence" offers many problems of great complexity, the solution of which is largely controlled by the factor of climate.

Climate and Man in the Temperate Zones: General.—Intermediate in location, in mean temperature and in their physiological effects, the temperate zones, whatever was the condition in the past, are to-day clearly the center of the world's civilization, as they have also been the

[2] *Century*, March, 1899, 718–729.

scenes of the most important historical developments for several centuries. From the temperate zones have come the great explorers and adventurers of the past, and are coming the exploiters and colonizers of to-day. In the occurrence of the temperate zone *seasons* lies much of the secret—who can say how much of it?—of the energy, ambition, self-reliance, industry, thrift, of the inhabitants of the temperate zones. The monotonous heat of the tropics and the continued cold of the polar zones are both depressing. Their tendency is to operate against man's highest development. The seasonal changes of the temperate zones stimulate man to activity. They develop him physically and mentally. They encourage higher civilization. A cold, stormy winter necessitates forethought in the preparation of clothing, food and shelter during the summer. Carefully planned, steady, hard labor is the price of living in these zones. Development must result from such conditions. In the warm, moist tropics, life is too easy. In the cold polar zones it is too hard. Temperate zone man can bring in what he desires of polar and tropical products, and himself raises what he needs in the great variety of climates of the intermediate latitudes. Near the poles the growing season is too short. In the moist tropics it is so long that there is little inducement to labor at any special time. The regularity and the need of outdoor work during a part of the year are important factors in the development of man in the temperate zones. Where work is a necessity for all, labor becomes dignified, well-paid, intelligent, independent. Behind our civilization there lies what has been well called a "climatic discipline"—the discipline of a cool season which shall refresh and stimulate, both physically and mentally, and prevent the deadening effect of continued heat. On the other hand, a very long winter is about as unfavorable as a very long summer. If outdoor work is seriously interrupted, progress is retarded. It is not surprising to learn that the difficulty of keeping farm-hands through the long winter has in the past been a handicap in western Canada, and that it was urged against the abolition of slavery in Russia that it would be impossible, without some form of compulsion, to keep farm-hands through the winter.

Northward Movement of Civilization in the North Temperate Zone.—The gradual migration of the center of civilization away from the tropics, and the highest development of the human race, not where life is easiest, but in extra-tropical latitudes, are significant. "Slowly but surely," as Benjamin Kidd says,[3] "we see the seat of empire and authority moving like the advancing tide northward. The evolution of character which the race has undergone has been northwards from the tropics." From the Mediterranean region, where the world's civilization, its commerce and its power were long centered, westward through Spain and Portugal, the migration continued farther and farther

[3] "Control of the Tropics," 51–52.

north in Europe, until Holland, and then England, became the dominant power. From lands of more genial climates to lands of colder and longer winters, but also of the most active and energetic races, the migration has taken place.

Present-day Migrations in the Temperate Zones.—Within the north temperate zone especially, and also across from the north to the south temperate, vast, peaceful migrations are taking place, determined to no small degree by climatic considerations. From Europe and Asia to the United States alone, a million people a year are now migrating. These aliens have shown marked tendencies to settle where climate, soil and occupations are most like those of their old homes, although the fact that most of them land at one port on the eastern seaboard, the concentration of industries in certain sections, and other artificial controls, have operated very effectively to counteract and interfere with this tendency. Scandinavians, for example, have gone largely into the northwest; and in the future, unless steps are at once taken to prevent it, the southern parts of the United States will doubtless have a population predominantly of Latin blood. I say this although I am well aware of the very homogeneous "native" character of the southern population to-day, and of the high birth-rate among that population. Canada has grown slowly, partly on account of the repelling effect of her long, cold winters and her generally severe climate.

This migration within the temperate zone is peopling Canada, South Africa and Australia with the same stock as that which occupies the home-land of the British Isles. Therefore, institutions and government essentially similar to those at home are possible in these colonies of England beyond the seas. The case is very different in tropical climates, as has been seen. Russia will later be found to gain great strength from the fact that she has expanded eastward within the same zone. I think it was Leroy-Beaulieu who first pointed out what a unifying influence in Russia is the severe winter cold and the snowfall. In spite of the many factors which make for diversity and lack of coherence, there comes a great factor of unification in the possibility of continuous sleighing over those immense stretches of country, from north to south and from east to west, when the frozen rivers can be crossed without bridges and when the traveler, on his sledge, can journey straight across country to the farthest limits of the empire.

It is interesting to observe how immediately controlled by the special weather conditions or even one season these voluntary migrations may be. Years of sufficient rainfall and abundant crops in the United States are always followed by a large immigration. A failure of crops in Europe, whether it be of wheat in one country, or of fruit in another, or of potatoes in another, resulting from drought, or storms, or excessive rainfall, always promotes a larger exodus from the country concerned. There is, furthermore, a considerable seasonal migration across the Atlantic. Thousands of Italians come to the United States in the spring, to work during the warmer months, when farm and outdoor laborers are in demand, and return to the milder climate of Italy for the winter. Similarly, there is a seasonal migration, also chiefly of Italians, to Argentina at harvest time.

In connection with these larger migrations, there is an interesting tendency westward, observable not only in the westward "course of empire," but in the advantages enjoyed, in the belt of prevailing westerly winds, by those who live in the western quarters of cities. The "west ends" are usually the most fashionable and the newest sections of these cities, while the quarters to leeward, the "east sides" and "east ends," are inhabited by the poorer classes.

The Continents and the Temperate Zones.—So far as the continents are concerned, in their relation to the zones, Europe is well situated, being almost altogether in the temperate zone, and open to the ocean on the west, so that nearly all parts of it are well watered.

Asia is an overgrown continent. Much of it is in the temperate zone, it is true, but the interior is so far from the sea that the climate is severe, and the rainfall very deficient. This condition of hopeless aridity is depressing in the extreme, and this region is prevented from becoming thickly populated, or important, on that account.

Most of Africa is within the tropics. Its plateaus will furnish areas not wholly unfavorable for white settlement. The southern part of Africa is just within the marginal subtropical belt of the south temperate zone. The same is true of Australia. Most of the latter continent is a trade-wind desert, and therefore hopelessly arid.

South America is, unfortunately for white occupation, widest within the tropics, while its southern portion tapers off into the temperate zone. As a future home for the white race, it offers much less attractive possibilities than it would were the continent narrow within the tropics, and broad to the south. Its western portion is peculiar in having the tempering influence of high plateaus in the interior, and of a cool ocean current along the coast.

North America is widest in the temperate zone. This is one of its greatest assets. It suffers from the extreme cold of its winters in the north, and from the rain-shadow effect of its western mountains, which gives the interior basin and part of the western plains deficient precipitation. The interior of North America has more favorable rainfall conditions than Asia, because our continent is narrower. The eastern portion of North America is freely open to the Atlantic and the Gulf of Mexico, and this condition is much better than is the case in Asia. Most of the United States is wonderfully adapted, climatically, to serve as the home of a dense population.

The Life of Man in the Polar Zones: a Minimum of Life.—In the polar zones a "monotony of cold" replaces the "monotony of heat" of the tropics, and instead of the spur of the temperate zone seasons there is the depressing, long, polar night. There is a minimum of life. Plants are few and lowly. Land animals which depend upon plant food must therefore likewise be few in number. Farming and cattle raising cease. The reindeer, which manages to find sufficient food in the lowly Arctic vegetation, is the mainstay of the Arctic natives. But the reindeer must wander far and wide in search of their moss. And many reindeer are needed to provide sustenance for one man. Population is small, and scattered. There are no permanent settlements at all within the Antarctic Circle. In the Arctic, human settlements are fairly well scattered over a considerable range near the margins of the zone, but with increasing latitude man is more and more rarely seen, and finally he disappears altogether. There will never be permanent settlements at the poles.

Life is hard. Man seeks his food by the chase on land, but chiefly in the sea. Hardly one tenth of Greenland's population could live there without food from the sea. It has been well said that, with every degree of higher latitude, man is forced more and more to obtain his food from the sea. Gales, snow and cold, cause many deaths on land, and also at sea. It has been estimated that about one twenty-fifth of the population of Iceland perishes through being lost in snowstorms, by freezing or by drowning. The polar limit of permanent human settlements is believed by Bessels to be fixed, not by the decreasing temperature, but by the increase in the length of the night, which shortens the time during which man can lay up food, by hunting and fishing, to last him through the polar night.

Culture in the Polar Zones.—Under such adverse conditions it is not hard to see that progress towards a higher culture is not a reasonable expectation. There is little time in which man may seek to develop and satisfy his higher needs. Much truth is contained in Guyot's somewhat picturesque statement:

> The man of the polar zones is the beggar overwhelmed with suffering, who, too happy if he but gain his daily bread, has no leisure to think of anything more exalted.

A sparse population, not far advanced in culture or in social relations, is inevitable under polar conditions of climate.

Deserts of Sand and Deserts of Snow.—There is a singular similarity, in their relation to man, of the deserts of sand, near the equator, and the frozen deserts of snow, near the pole, to which I have referred. The relations are interesting, for they illustrate very clearly how similar climatic controls, acting through plant and animal life, affect the life of man in the same large way. I can not select a better example for closing my discussion this afternoon.

Deserts of sand and deserts of snow: both alike repel man. Both are largely or wholly destitute of vegetation, of wood and of water. The yellow desolate waste of the sand desert is matched by the monotonous white surface of the snow desert. There are no opportunities for accumulating wealth in either. Travel is difficult in both. In one, the camel is the typical beast of burden; in the other, the reindeer and the dog are man's most useful possessions. The monotonous heat and glare and silence of the sand desert find their counterpart in the cold, and glare, and silence of the snow desert. The air is generally clear in both, except for the dust over the sand desert and the ice-needles in the air of the snow-desert. In both deserts, man is very limited in his food supply: in the Sahara the date, in Greenland the seal, are typical staple articles of diet. The aridity in one, and the cold in the other, are man's great enemies. The inhabitants of both deserts are nomadic. Settlements of some permanency are found in oases or along the edges of the sand desert, where there is water; similarly, the natives of the far north live along the edges of the ice desert, where they can best find their food. The sand deserts are deserts because they are arid. The snow deserts are deserts because they are cold. Denudation of exposed rocks in the desert of sand is largely due to the action of wind, carrying sand; and denudation of the surfaces of ice in the desert of snow is due to the action of wind carrying ice spicules. The polar deserts are perhaps on the whole better suited to life than the sand deserts, for the former supply water from the melted snow and ice. Man has, however, a harder struggle to protect himself against the cold than against the heat, for he needs more clothing, and better shelter, and fire. In both deserts life is isolated and primitive. The sand desert is crossed by caravans and trade routes between the more populous lands on either side, and the people of these deserts have more contact with civilization than do most of the natives of the far north. The polar desert of snow and ice: who travels across it except the occasional explorer, seeking the Pole?

THE STRUCTURE OF THE WORLD-STUFF[1]

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SCIENCE, and the humanities. How often are they placed in opposition. There is doubtless a utilitarian aspect of science which though admirable in itself tends to foster a spirit antagonistic to culture. But science is many-sided. And in the single-minded seeking for the truth amidst clouding obscurities, in the searching out the laws of the development be it of an atom, a tree, a man or a star, in the aim to express that unity which we instinctively feel is the key to the interpretation of nature's marvelous complex, I feel that she earns an honored seat among the immortals. And so I need make no apology for speaking to you upon a scientific subject, one which lies at the very basis of natural science, one whose development has demanded not only zealous, strenuous research but calm judicial, wise speculation,—the subject of the constitution of matter, the stuff of which the physical world is made.

The ultimate structure of the material world around us must always have been a problem of deep interest to thoughtful minds, and has formed a fruitful subject of speculation from the time of Thales to the present day. But it is not of the philosophical aspect of the question that I venture to speak. I can not claim to be a philosopher—save such a one as is characterized by Touchstone as a "natural philosopher"—but only a student of physics; and it is therefore to the physical side of the problem that I shall confine myself. The substance and the form of Aristotle, the monad of Leibnitz, the strife between idea and thing-in-itself, and other metaphysical contributions toward the interpretation of the universe, important though they be in the history of thought, are beyond the limitations of the present speaker and of the present occasion. Our attention is rather to be directed to the physical theories which have been framed as to the constitution of matter, especially to the one which has won almost universal acceptance, that known as the atomic theory; its development from the past, its modern form, and its promise for the future.

For the hypothesis of atoms is not a product of modern science. Indeed the question of the divisibility of matter must necessarily arise in the early stages of scientific thought. In our youth when we inquire as to the structure of things we are told that

Little drops of water,
Little grains of sand,

[1] Address delivered before the joint meeting of Phi Beta Kappa and Sigma Xi, University of Pennsylvania, June 16, 1909.

Make the mighty ocean
And the wondrous land,

and we doubtless speculate as to whether the sand grain and the water drop are not likewise divisible into smaller portions, and whether these smaller portions differ in quality from the larger. And so in the youth of science we find some philosophers maintaining the infinite divisibility of matter, and on the other hand the school founded by Leukippos and Demokritos, to whom we owe the conception and the word *atom*, the indivisible (or at least never divided) particle which forms the ultimate structure of matter. In these atoms, their ceaseless motion and their various groupings, is to be found the interpretation of the manifold phenomena of nature.

Both of these schools of thought have contributed to modern science. From the former we obtain the conception of a continuous medium which has developed into the theory of the all-pervading ether. From this school too we received the doctrine of the limited number of elementary substances from which all things are formed; a number which has grown from the four of Empedokles—earth, air, fire, water—through many vicissitudes into the eighty or so of the present day. But to the opposing school we owe a far greater debt, a debt which we can not lightly repudiate with Clifford by saying "The atomic theory of Demokritos was—no more than a guess—which was more near the right thing than the others." The atomic theory is much more than a guess. Incorporated into the system of Epikuros, and expounded in the marvelous poem of the Roman Lucretius, it forms a well-reasoned and well-balanced system of thought which it is true lacked in definiteness but was not without marked success in furnishing a framework on which to erect an image of nature. So successful was it that after two millenniums it has suffered little modification. As an illustration let us compare the atom of Lucretius with that of Newton.

These are the words of the Roman poet:

> The atoms are of solid singleness, and, compact of smallest parts are closely coherent—not compounded from a combination of these parts but strong in their everlasting singleness; from these Nature allows nothing to be broken off or diminished; . . . very different are they in their forms; varied by manifold shapes.[2]

While the description by Newton is as follows:

> It seems probable that God in the beginning form'd Matter in solid, massy, hard, impenetrable, moveable Particles, of such Sizes and Figures, and with such other Properties . . . as most conduced to the End for which he form'd them; and that these primitive Particles being Solids, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break in pieces.[3]

A comparison of these passages shows how the two conceptions are

[2] I., 609, and II., 333.

essentially the same. Indeed in some respects the older view has the advantage, as it lays greater stress upon the motion of the atoms; a forecast of the modern kinetic theory of matter.

The lack of development of the atomic theory is to be ascribed largely to the adverse criticism of Aristotle. The overwhelming influence of the Aristotelian philosophy was thrown against it, and it made little headway down through the middle ages. Not until the downfall of scholasticism do we find any extensive revival of the system; a revival culminating in the seventeenth century school of atomists, among whom are to be noted Gassendi, Boyle and, as we have seen, Newton. But still another century of stagnation was to elapse before it was to be transformed and modernized at one stroke by the genius of the English chemist John Dalton.

The modern atomic theory founded by Dalton and developed during the nineteenth century must not be regarded merely as an extension of the older theory, but as a new structure built upon the old one as a foundation. That was speculative, this was scientific. That was vague, this was definite. That was based merely upon observation and introspection, this upon experiment and calculation. The theory of the elements and the theory of atoms was blended into a single comprehensive whole. The prime distinction between the different kinds of atoms was found in a single property—that of their relative mass. The older theory was not inadequate in the early days of science; but it failed when the quantitative relations of phenomena were brought into prominence by the development of experimental methods; and such was the case when the principle of the indestructibility of matter was raised by Lavoisier from a philosophic dogma to a scientific truth, and emphasis was thus laid upon mass as the fundamental property of matter.

I need not detail to you the marvelous growth of the theory during the past century; how it met every demand made upon it by modern chemistry, and indeed inspired much of the development of that science; how, on the other hand, it has lent its aid to the progress of physics and especially how by the founders of the kinetic theory of gases,

> the flaring atom streams
> And torrents of her myriad universe
> Ruining along the illimitable inane

were marshaled to the defense of the great principle of the conservation of energy, and the science of heat was annexed to the domain of mechanics. Let me rather recall to you the salient points of the theory as held by the close of the century, for comparison on the one hand with the theory of the past and on the other with its developments in the future.

[3] Opticks, 4th edition, p. 375.

Matter, it is held, consists of minute indivisible particles or atoms, of which eighty-one different varieties are at present recognized. These correspond to the chemical elements, oxygen, carbon, sulphur, iron, gold and the rest, by the combination of which all other substances or compounds are found. The atoms of each element are exactly alike, while those of the various elements differ in mass. Thus atoms of sulphur are twice as large as atoms of oxygen, silver atoms are nearly twice as heavy as those of iron. The largest atom known—that of the rare element uranium—is over two hundred times as massive as the smallest, the atom of the elementary gas hydrogen, which is taken as the unit of comparison.

These atoms are indestructible and can not be converted into one another. However, they are not, like the atoms of Lucretius,

Solida pollentia simplicitate,

"strong in their solid singleness," but are of complex structure, capable of vibrating in many different ways. From the evidence of the spectroscope we learn that each kind of atom has its own modes of vibration and is distinguishable from others by these no less than by its mass.

While the atoms are the fundamental units they can not in most cases exist in isolation, but are drawn together by the forces of chemical affinity into groups which we call *molecules*. The atom bears to the molecule the relation of the letter to the word on a printed page. While the number of kinds of atom is limited, that of the varieties of molecule is practically unlimited, there being as many kinds of molecule as there are substances, or words in the chemical dictionary. The number of atoms in a molecule varies greatly. In a few exceptional cases the atom and molecule are identical. This is the case, for example, with mercury and with rarer gases of the atmosphere. These elements are the *a*, *I* and *O* of chemistry. The inorganic molecules with which we begin our chemical studies are appropriately words of one syllable, containing but a few letters; while some of the organic molecules, with their hundreds or even thousands of atoms, surpass even the creations of Aristophanes and would require the mouth of Gargantua to utter.

This distinction between atom and molecule is one of the most important characteristics of the theory. The atom it is often said is the unit of the chemist, the molecule of the physicist. To determine the relations of the atoms in the molecule is one of the problems of chemistry; while it is the task of the physicist to form from the interactions and motions of the molecules a consistent theory of physical phenomena. To be sure, the boundary between the sciences thus laid down is somewhat arbitrary, and we need not be surprised to find it often overstepped from either side. There is in fact a whole borderland occupied by troops of marauders who style themselves physical chemists or chemical physicists, according to their predilections, and who make frequent raids impartially into either territory, usually carrying off rich spoils.

It is natural to inquire as to the size of these molecules and atoms of which we are thus assured the world is made. The question of the relative size is accurately answered by chemical analysis. We know, for instance, that the atom of oxygen weighs 15.88 times as much as that of hydrogen, and so on. But this gives no answer to the question as to the absolute size. It may seem that it would be impossible—even presumptuous—to attempt to estimate the size of particles which must be far beyond the reach of the most powerful microscope; but this has been accomplished. Time would not permit me even to outline the methods of wonderful ingenuity by which this problem has been attacked. The study of the laws of expansion of gases, the phenomena of the soap bubble, the action of the electric current, the blue of the sky, the settling of fine drops of mist or of specks of dust, these and other classes of phenomena have all contributed to the solution; and the evidence from such varied sources has been strikingly concordant.

Let me give you the results. Small indeed are these atoms, but not immeasurably small. So small that when they are expressed in ordinary units the mind shrinks from the attempt to grasp them. But the scientist is not limited to a single unit of measure. The geographer uses a mile, the carpenter a foot. The astronomer's staff with which he gauges the motions of the planets in their courses stretches from the earth to the sun; while in estimating the distances of the fixed stars the unit is the far greater distance traversed by light in a year. And so in the world of the little a convenient standard of comparison is the wave of light, some fifty thousand of which are contained in an inch, of the order of the thickness of a brightly colored soap bubble or of the smallest things that we can see with our best microscopes. Measured in these units, we find the diameter of a hydrogen atom to be about one two thousandth part of a wave of light, or, in our ordinary measure, a hundred-millionth of an inch. We hear much of millions, especially in the daily press, though perhaps we have but a vague conception of them. For example, we heard not long since of a celebrated fine of $27,000,000. If that fine had been paid, and paid in dollar bills, and the bills laid end to end, they would have reached from Maine to California. (I do not suggest this as a desirable method of laying out money, though we often meet with suggestions of even less merit; but to help in expressing the magnitude of the quantities with which we are dealing.) Now if each bill were replaced by an atom, and the line closed up, it would extend a quarter of an inch. Or we may express the result in another way: The diameter of an atom bears the same relation to that of a tennis ball that the tennis ball does to the earth; and the masses are in about the same proportion. If we emulate Archytas,

numero carentis arenæ mensorem,

"the measurer of the innumerable sands," and estimate the number of molecules in even a drop of water, we obtain a result far beyond our powers of realization; a number requiring 22 figures for its expression. It is surely not to be reckoned among the least achievements of science that it has determined the order of this enormous quantity and has even made us reasonably certain of the first figure.

Such is the modern atom. It would seem impossible to penetrate farther into the details of so minute a structure, one too whose elements defied attack by physical and chemical agencies. It was felt, however, that a system based upon some eighty distinct kinds of primordial matter could hardly be an ultimate solution of the problem; and the suggestion was early made that the atoms are complex groups of a fundamental atom—possibly that of hydrogen, the smallest known. This hypothesis, suggested and supported by the fact that many atoms are very nearly exact multiples of the hydrogen atom in mass, has proved attractive to those who saw in the orderly succession of properties among the elements (known as the periodic law) indications that matter has reached its present state of multiplicity through some process of evolution. Similar indications were thought to be found by some in the study of the spectra of the stars. But these views were speculative, and direct evidence was lacking; and little light was thrown upon the subject until just before the close of the last century new lines of investigation were opened which greatly extended and modified our views as to the nature of the atom. This expansion was determined by the simultaneous development of the modern or what might be called the atomic theory of electricity, usually known as the electron theory.

That electricity, like matter, consists of indivisible units or atoms had long been suspected, since experiments of Faraday had shown that the quantities of electricity carried by atoms were always either equal to or exact multiples of a single charge—that carried by the hydrogen atom; and the term *electron* had been suggested as a name for the atom of electricity. As early as 1878 the great Dutch physicist Lorentz had based an explanation of the refraction and dispersion of light upon the presence in matter of equal discrete particles or atoms of electricity, and this hypothesis was afterwards developed into a complete framework of a theory of electrical and optical phenomena. But in the absence of experimental confirmation little attention was paid to these theories until the investigations to which I alluded brought the electrons themselves forcibly before the scientific world.

In 1897 J. J. Thomson was investigating the electrical discharge in highly rarefied gases—the so-called kathode rays. These had been proved to be negatively charged particles, and were supposed to be atoms or molecules of the gas. Thomson showed that they were identical in their properties whatever was the gas used; and while he was not able to determine their mass nor charge directly he succeeded in measuring the ratio of their charge to their mass and showed that *either* their charge was much greater than the atomic charge, *or* the mass much less than that of an atom. Of these alternatives he chose the latter as the simpler and more probable—a choice justified by subsequent research. Later investigations showed that particles identical in properties were emitted from metals under the influence of light, and from incandescent solids. If we assume that the unit charge is carried by these particles the mass is calculated to be about an eighteen-hundredth part of that of a hydrogen atom. They are also shown to be enormously more concentrated, as their diameter is estimated to be only a few millionths of the atomic diameter.

Let us note as the result of these investigations three highly significant facts. First, that here we are presented with bodies smaller —much smaller—than atoms. Secondly, that from whatever source they are derived—gas, metal or hot lime—their properties are identical. Finally that they are associated with a definite charge of electricity, and that this charge is negative. Here is the electron, the atom of electricity demanded by the theory of Lorentz.

But what of the positive electron? Search for this has often been made, but the mass of the positively charged particles has always proved to be comparable with that of an atom. There are some indications that positive electrons may be identical with positively charged atoms of hydrogen or of the gas helium whose atomic mass is four times that of hydrogen; but for the present we can say only that positive electricity is never found dissociated from matter of atomic dimensions.

These conclusions received confirmation from two other sources. The year before Thomson's measurement of the electron marks the discovery of radioactivity and the beginning of the researches which speedily led to the discovery of radium and similar substances. The properties of the rays emitted by these substances were carefully investigated and it was proved that they consist partly of negatively charged particles identical with the electrons, and partly of positively charged particles having a mass equal to that of a helium atom.

The other confirmation to which I alluded, while less direct, penetrates even more deeply into the structure of matter. In this same year (1896) a minute effect of magnetism upon light, discovered by Zeeman, was shown to be completely concordant with the theory of Lorentz, and to lead to the conclusion that the light of a luminous vapor was due to negatively charged particles circling in or about the molecules, of dimensions similar to those almost simultaneously discovered by Thomson. Later developments of optical theory stimulated by this discovery indicated the presence in molecules of positively charged particles as well, but that these were atomic in size.

Thus three independent lines of investigation have almost simultaneously converged to furnish a basis for a new theory of electricity, which we need follow only so far as it affects the theory of matter. Of the two kinds of electricity we find but one—the negative—that can be detached from atoms. We find the negative electron too as a constituent of the atom. The electron, whatever its source, is always the same, while the positive charge partakes of the varying nature of the matter with which it is associated. Emphasis is thus laid upon the electrons as forming the true electrical fluid, the positive electricity playing a subordinate part. According to this theory a neutral atom, which we know contains some electrons, contains also enough positive charge to exactly neutralize them. If one or more additional electrons become attached to it, it becomes negatively charged with the atomic quantity or its multiple. If, on the other hand, it loses some of its electrons, it becomes positively charged. The terms positive and negative have here exchanged their usual rôles. It is the positive electricity that is

der Geist der stets verneint,

"the spirit of negation." Except for this exchange (due to the unfortunate original allotment of the terms) the theory bears a remarkable resemblance to the single fluid theory of Franklin.

Some atoms normally contain too many electrons, others too few. These will attract each other, forming neutral molecules. Thus an oxygen atom, which normally holds two extra electrons, will attract to itself two hydrogen atoms which each lack one, and thus will form a molecule of water. By the number of electrons in excess or deficiency the combining power of an atom with others is determined. Such considerations have proved efficient in disentangling many puzzling questions connected with chemical combination.

The most salient point of this theory is that we seem to be confronted with a dualism, matter and electricity, atoms and electrons. A closer study of the electron has suggested a possible way of escaping this, or rather of turning it, in what is called the electrical theory of matter.

Long before electrons were observed J. J. Thomson had shown theoretically that a body when charged with electricity would by mechanical tests appear to have a slightly greater mass than when uncharged, and the smaller the body the greater the effect. Thus it would require more work to stop a moving charged body than if it were uncharged; a greater force would be needed to deflect it from its path. But even an atom is not small enough for the difference between its charged and uncharged states to be appreciable.[4] With an electron, however, it is different. Application of the theory has shown convincingly that the entire observed mass of the electron may be accounted for by its electrical charge and that there is no evidence of any other mass apart from its charge. An electron is thus literally a disembodied spirit—a concentrated charge, and nothing more.

But what of the atom? We have seen that its mass can not be accounted for by its positive charge. We may, however, meet the difficulty in another way. Let us imagine a structure of the following nature. Scattered through the volume of a sphere of the size of our microcosmic tennis ball let us suppose a congeries of some 1,800 electrons. To get the scale of our image correct we shall have to magnify it still more and we shall then see this number of fine shot scattered through a space the size of a large hall. Let the equivalent neutralizing positive charge be uniformly diffused throughout the sphere. The electrical mass of such a system would be that of its electrons, in other words would be equal to that of a hydrogen atom. It is, therefore, unnecessary to attribute to such an atom any additional substance, "matter," distinct from the positive and negative charges.

This is the electrical theory of matter. I do not say that it has been established. It is at present only a fruitful speculation. But it strongly appeals to those who seek for unity in science and who prefer to have a single interpretation of a phenomenon rather than two separate hypotheses to account for the same thing. Some of the mass of atoms must be electrical. Why not all?[5]

Let us call upon the scientific imagination and attempt to picture the atom of the twentieth century for comparison with the atoms of the earlier theories. We see a large number of electrons immersed in what may be called a positive jelly. In some cases, if not in all, the atom is partly at least compounded of sub-atoms of the size of the hydrogen or helium atom. Of the electrons some may be vibrating about neutral positions, or circling in closed orbits, and in doing so sending forth waves of light; others may be more firmly fixed. We may even have systems of electrons revolving in concentric rings like the rings of Saturn. A few, especially if the atom is that of a metal, are so loosely attached that they readily escape, leaving the atom positively charged. Sometimes under the action of light-waves a vibrating electron is so violently shaken that it breaks its bonds and

[4] The electrical mass of a hydrogen atom due to its atomic charge is calculated to be about one hundred-millionth of its whole mass.

[5] It may be said that the dualism still remains. But it is now a dualism of form rather than of fact. Positive and negative electricity, like action and reaction, are but two sides of the same phenomenon. We can not have one without the other. But this would lead us too far into speculations as to the nature of electricity.

escapes. High temperature or a powerful electrical field may produce the same effect.

If our atom belongs to the group of radioactive elements such as radium, thorium, etc., we shall see from time to time, if we watch attentively, a kind of explosion. Perhaps an electron will be hurled forth with enormous velocity, perhaps one of the sub-atoms, sometimes both. The positively charged sub-atom, after it has given up most of its energy by collisions, will attract to itself a pair of neutralizing electrons and settle down, a staid helium atom. The remainder of the original atom rearranges itself into a new condition of more or less stability, and we have a new atom. It is no longer an atom of radium, for instance, but an atom of something else; another element with an atomic mass some four units less, and differing from radium as gold does from mercury. Its spectrum will be different; its properties will be different. It may perhaps be a gaseous atom instead of an atom of a solid. And we shall see this process continuing at irregular intervals, the atom gradually becoming smaller until a state is reached which is so stable as to seem permanent.—And all these processes are taking place within the bounds of our diminutive tennis ball.

Here we have the transmutation of the elements of which the alchemists dreamed. It is true that these changes now seem to go on "like the stars without haste without rest" uncontrollable by human agencies, but one would be rash to predict the impossibility of such control.

I have pictured a radioactive atom. But need we make that limitation? The intervals at which these transformations occur vary greatly. Thus we are told that the average life of a radium atom is about 2,000 years, that of its first product but four days, and a similar product of another element, actinium, lasts but a few seconds. It is estimated that an atom of uranium or thorium lasts some thousand million years, but still eventually changes into another form. In our imaginary picture we need set no limits to our measurement of time. The 200,000,000 years that we are told the earth has endured may be but a mere incident in the life of an atom; and an element surpassing uranium as much as that does some of the more rapidly disintegrating substances would appear permanent by all known tests.

The atoms would thus appear to be crumbling, perishing—indeed their death-knell has already been sounded. I find it in a recent number of a scientific journal.[6] I do not know the author, but the initials appended to it—W. R.—are those of the foremost chemist of England.

Old Time is a'flying; the atoms are dying;
Come, list to their parting oration:
"We'll soon disappear to a heavenly sphere
On account of our disintegration.

[6] *Nature*, **73**, 132.

"Our action's spontaneous in atoms uranious,
Or radious, actinious or thorious;
But for others, the gleam of a heaven-sent beam
Must encourage their efforts laborious.

"For many a day we've been slipping away
While the savants still doz'd in their slumbers,
Till at last came a man with gold leaf and tin can,
And detected our infinite numbers."

Thus the atoms in turn, we now clearly discern,
Fly to bits with the utmost facility.
They wend on their way, and in flitting, display
An absolute lack of stability.

'Tis clear they should halt on the grave of old Dalton
On their path to celestial spheres,
And a few thousand million—let's say a quadrillion—
Should bedew it with reverent tears.

But lest these views seem too somber and devoid of hope for the future, we must not forget that we may be looking at but one side of the mighty rhythm of nature. There may be also, still veiled from us, the compensating process by which atoms are formed and developed. This the author seems to feel and to express in his final verse:

There's nothing facetious in the way that Lucretius
Imagined the Chaos to quiver
And electrons to blunder, together, asunder,
In building up atoms forever.

The imaginative sketch of the atom which I have drawn must not be regarded as an accurate photograph. Many details are imperfectly known, many doubtless erroneous. But in its general outlines it reproduces the views of the foremost investigators, and it has proved eminently successful in unraveling the most extensive and perplexing body of facts that has ever been accumulated in so short a time.

But even when all difficulties shall have been smoothed away, and the electron enthroned above the atom, we shall not have reached the end. Even now we begin to hear discussions as to the shape of the electron, some holding it spherical, others flattened like the earth. There is, in fact, no final theory. "Every ultimate fact," says Emerson, "is only the first of a new series. Every general law only a particular fact of some more general law presently to disclose itself." We live in a succession of infinities. The earth with all its multiplicity is but a small part of the solar system; that is but an insignificant unit in a mighty stellar group. And so within the smallest sensible particle of matter is the world of atoms, within the world of atoms the world of electrons. Who shall set a boundary in the one direction or in the other?

THE RELATION OF THE LAW TO PUBLIC HEALTH

By ALFRED HAYES, Jr.

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PUBLIC interest in the preservation of health has generally found expression in a demand for legislation increasing the powers of governmental agencies charged with the protection of health. Boards of health, state and local, are more liberally sustained, have greater facilities for the investigation of disease and are armed with greater powers than heretofore, but nevertheless common law, that is, the great body of law which the colonists brought with them from England, has an important bearing on public health, chiefly in two ways. Without resort to statutes, means of protection are frequently available to the individual or to the community. On the other hand, unless in fact a common-law nuisance exists, boards of health are often, perhaps usually, powerless, either by reason of the express language of the statutes or because of the constitutional guarantees as to private property. The rules of the common law, therefore, as to nuisances, are fundamental to an understanding of the problems involved in safeguarding public health.

A variety of wrongs are classified as nuisances, which have little relation to each other and many of which have no relation to public health. In a general way, a nuisance may be said to be anything which wrongfully interferes with a public right or with the enjoyment of property. But stopping here, little progress has been made toward ascertaining what interferences are wrongful.

There are many things which render one uncomfortable which are not wrongful. A certain plaintiff was annoyed when his neighbor rented his property to an undertaker, but one has an absolute right to make any use he wishes of his property provided he does not create a nuisance, and the courts said that the plaintiff was unduly fastidious. So long as burial continues, some persons must be undertakers. It is annoying to be awakened in the morning by the roar of a city's traffic or by the crowing of a cock in the country, but such annoyances are necessary incidents to life in a given locality and must be endured. A case involving this principle arose in Philadelphia where a woman claimed that she was kept awake to the injury of her health by pneumatic riveting machines in a locomotive works. The inferior courts decided in her favor, prohibiting the operation of such machinery from eight P.M. to seven A.M., but the Supreme Court of Pennsylvania unanimously held that though there was no doubt inconvenience and discomfort, such were the necessary incidents of life in a manufacturing neighborhood.

To constitute a nuisance, there must be a condition created or maintained by man. A swamp may be pestilential, but no one is responsible for the natural condition of land. Swamps are the work of nature and no matter how unhealthful they may be, any right to improve them must be sought in statutes.

In an early New York case the question arose whether at common law there was any right to remove a person with smallpox to a hospital. The court decided that if a man had smallpox, it was his misfortune and not his fault, and therefore announced that a person in his own house suffering from an infectious disease is not a nuisance.

Nuisances are classified as private and public. They are private when they affect private individuals. They are public when they interfere with a common right, such as the right to use a public street, or when they interfere with a considerable number of persons and thus take on a public character. The two classes run into each other. A public nuisance may be a private nuisance and frequently a private nuisance which could with difficulty be proved to affect the public may be ended by the enforcement of the private individual's right and thus the individual in helping himself may confer a great benefit upon the public in preventing the continuance of a dangerous condition.

Nuisances may be classified also in accordance with the nature of the injury done. Nuisances affecting health fall into two great classes. First, the pollution of flowing water. Second, the escape of deleterious things such as noise, smells, gases, disease germs, heat, electricity and vibration. The law is very different as regards these two classes.

One owning land along a stream is called a riparian owner and he has a right to the flow of the water in such stream in its natural purity undiminished, except by the ordinary domestic or agricultural uses of upper owners. If the quantity is substantially diminished or if the purity of the water is materially affected the lower owner may maintain an action without reference to the question as to whether he has suffered any actual damage or not. He may not have wished to use the water of the stream at all, but he is none the less entitled to use it. A single riparian owner then may be in a much stronger position to protect the community from stream pollution than a board of health or the community as a whole.

The commissioner of health of the state of New York has announced as his battle cry, "The continued pollution of our streams and lakes must stop."

The practical effect of a private individual's action in preventing pollution in contrast with the results of inaction by a community can be shown in the following cases. The report of the New York State

Department of Health for 1906 shows the correspondence relative to the pollution of a certain creek. On September 26, 1906, the state commissioner wrote to the president of the local board of health that numerous complaints had been made as to this creek, and that the state inspector had observed that seepage from cesspools found its way to the water. This letter was not answered. On November 14, the state commissioner again wrote. On November 26, the president of the local board replied that rules and regulations had been adopted, but as appears in a letter of December 17 from one of the four local justices of the peace nothing was done other than to post a printed copy of the rules. Cesspools and manure heaps continued to work, and on December 10 the president of the local board of health died of typhoid fever, while others in the town suffered from the same disease. The justice of the peace adds, "What we plainly need is some authority strong enough and courageous enough to order a thorough clean-up and see that it is done." In the other case the proprietor of a summer hotel situated on a brook above the plaintiff's land, discharged sewage into that stream. The local board of health had ordered such discharge to prevent the defendant from maintaining a cesspool, but this plaintiff, although she did not use the water of the stream for domestic purposes, but only for bathing and driving a turbine wheel, and although it appeared that the water was not affected either to sight or smell, was "strong enough and courageous enough" to fight the hotel proprietor in spite of the board of health. She won her fight in the trial court, then in the appellate division of the supreme court and finally in the court of appeals, and the discharge of sewage was forbidden. It might have been exceedingly difficult, perhaps impossible, to show that a public nuisance existed here, but the purpose of preventing stream pollution was accomplished by the riparian owner who defended her private rights.

The chief offenders in stream pollution are villages and cities, but the law is that such municipal corporations have no greater right than an individual to interfere with the riparian owner. There are numerous cases where actions have been maintained against municipalities, and in many of these cases injunctions have been issued. Where, however, the municipality constructs the offensive sewage system with statutory authority the private individual may ultimately fail in preventing pollution, for since his action is based not upon a claim that public health is interfered with, but merely that he is deprived of property rights, if the municipality has been granted the power of eminent domain, it can not be permanently enjoined if compensation is made to the private owner.

Most of the second great class of nuisances are those where the air has been contaminated, as by smoke, smells or gases. The law protects much more rigorously the right of a riparian owner to pure water than to pure air. The water right is violated if there is any substantial pollution, but in the cases of air no nuisance exists unless the party alleging that there is a nuisance proves that he has actually been damaged. That is, not that he has been annoyed or inconvenienced, but that his occupation of the premises has been so affected that the comfortable enjoyment thereof has been interfered with. Such interference may result from a variety of causes, as smells from a slaughter house, noise from a boiler works, disease germs from a tuberculosis hospital, excessive heat from a neighbor's bakery, gaseous fumes from a brick kiln, or the vibration of heavy machinery.

When such interference is shown, it is no defense that the defendant's business is lawful or that the injury is unavoidable. The defendant may show that he is guilty of no carelessness in the conduct of a lawful business, that he uses the latest and best appliances and that his business is necessary to the community, but the courts answer that if one can not carry on this business without injuring his neighbors, he must carry the business on elsewhere or go into some other form of employment. This is an exceedingly difficult principle to apply. The business of slaughtering animals can not be made agreeable and yet it is necessary. Factories can not be carried on without smoke or noise. Some waste products usually result from any manufacturing business. While it may not be physically impossible to dispose of waste products by destruction, such destruction may be so expensive as to be prohibitive. A given concern may not be able to compete with its rivals if this added expense is put upon it, and so the sympathy of the courts and of the community may often be with the offender, but nevertheless such nuisances are not infrequently enjoined.

The case of the American Smelting and Refining Company against Godfrey was brought by four hundred and nine persons owning farms in Salt Lake County, Utah. They alleged that the smelters operated by the four defendant companies emitted one thousand tons of sulphur dioxide daily and also arsenical fumes, which destroyed their crops, poisoned their stock and injured the health of themselves and their families. The defendants showed that the location of their mines and the railroads made this place the most convenient for smelters and that they used the latest and best instruments to prevent the escape of obnoxious gases, but the court decided for the plaintiffs, saying, "You must not permit arsenic to escape and you can not smelt at this location any ores having in them more than ten per cent. of sulphur."

In many jurisdictions by the lapse of a long period of time one may acquire the right to do acts which would otherwise be a private nuisance, but it is held that one can not thus acquire the right to commit a crime, and therefore if a nuisance affects the public health and is thus a public nuisance, no prescriptive right to do such acts can be acquired.

Is it a defense to an alleged nuisance that the defendant was on the ground first? He may contend that he built his brick kiln, when all the surrounding land was vacant and thereafter the plaintiff voluntarily purchased and built on ground adjoining the kiln. This alleged defense is spoken of as "coming to a nuisance." Most of the cases, however, hold that this makes no difference. The injury arises only when the plaintiff's enjoyment is interfered with, but if he can not build a house, then the defendant would be in effect permitted to destroy the value of the plaintiff's property. If he must leave his land vacant it is worthless or at least its value is greatly impaired.

Assuming that the law is clear and that if the defendant is doing certain acts he is maintaining a nuisance, the plaintiff is always confronted by the necessity of proving by legal evidence that such acts are being done. This is often a difficult task. Ordinarily the defendant has large interests at stake and fights desperately to the last ditch.

The extent of the task of establishing by legal evidence the existence of a nuisance is shown in a recent case in which the question was whether one state could be enjoined from interference with the riparian rights of another state.

The state of Missouri brought suit against the state of Illinois to prevent the discharge of the sewage of Chicago by means of an artificial channel into the Des Plaines River, whence it entered the Illinois River and then the Mississippi. If this was a nuisance, by what law was it to be decided, that of Illinois or Missouri? The United States Supreme Court held that it could decide such controversies between states. Otherwise there would be no means of determining contests between states which in the absence of federation would be decided by war. But the court held that the rules applicable to private riparian owners did not necessarily apply between states and that the injury must be greater than a private injury to warrant relief. Missouri contended that the daily discharge of 1,500 tons of poisonous filth into this channel caused great injury to the public health in the state of Missouri since St. Louis and other cities took their water from the Mississippi River. Missouri showed that the number of deaths from typhoid fever had largely increased after the opening of the Chicago drainage canal. Missouri also showed by the presence in increased numbers in the Illinois River of the *Bacillus coli communis,* which it was agreed was an index as to the organic matter in the water, that the contamination was increased, but Illinois denied that injury to health had been caused, and so both sides conducted experiments to show the duration of life and capacity for travel of the *Bacillus typhosus.* It was conceded that typhus, cholera, dysentery, anthrax and tetanus are water-borne diseases and that it was practically impossible to discover the bacilli of typhoid in running water. It was proved by means of floats that the journey from Chicago to St. Louis, 375 miles, required from eight to eighteen and one half days. Then Missouri caused 107 barrels of the *Bacillus prodigiosus* to be put into the drainage canal near the starting point on November 6 On December 4, one of these bacilli was found at the St. Louis Intake Tower, and a few others later. The duration of life of this bacillus in sunlight in living water, being alleged to be about the same as that of the *Bacillus typhosus,* it was urged that the typhus bacillus in the sewage of Chicago could reach St. Louis. But Illinois contended that typhoid bacilli could live only for three or four days, and so the representatives of Illinois suspended in the Illinois River, sacs which water could penetrate. In these sacs were bacilli of typhoid and in three or four days there were no living typhoid bacilli in the sacs. Illinois therefore claimed that they had died, to which Missouri replied that the constant change of water made conditions different, that these bacilli may have been of less than normal strength, or that they may have escaped from the sacs. On all the evidence the court held that it was not sufficiently clear that a nuisance existed and the bill was dismissed without prejudice to the right of Missouri to commence over again if it believed that it had evidence strong enough to prove its case.

If under the law, the alleged acts are a nuisance and if there is legal evidence to prove the facts, one additional question remains, that of procedure. What remedy is to be applied? The ingenuity of lawyers has been taxed to the utmost in devising remedies for nuisances. So difficult is it at times to succeed in ending a nuisance that the law provides as many remedies for nuisance, perhaps more remedies, than for any other form of injury, an entire arsenal of weapons, some public, some private, civil and criminal, judicial and non-judicial, legal and equitable, and sometimes all are required.

First there is the right of abatement. The law is jealous about permitting parties to remedy injuries with their own hands, but if the existence of a nuisance is clear, then one may himself put an end to it. The person who thus makes his own determination of right acts at his peril, and is liable if he has made a mistake. When abatement is threatened, if the case is doubtful the courts will forbid the use of this method, and unless there is pressing necessity, it should seldom be resorted to, particularly by private individuals.

The injured person may bring an action to recover compensation in money for his injuries and very frequently this remedy is selected. But as it does not put an end to the nuisance, it does not aid the cause of public health, unless the defendant voluntarily abates the nuisance through fear of further pecuniary loss.

The plaintiff may prefer to ask the court to prohibit the defendant from continuing the nuisance. Such relief is called equitable as distinguished from compensation in money, and this form of relief by injunction in equity is most effective, not only because it prevents threatened injury instead of operating upon harm which has been fully wrought, but in equity the defendant is required to terminate the nuisance under pain of punishment for contempt of the court's order. Frequently, however, at this point the controversy between the parties is hardly more than begun, for the form of injunction may be so indefinite as merely to prohibit causing material discomfort to the plaintiff or injuring his health, things which the defendant usually disavows doing from the beginning. The court struggles not to frame its injunction in such a way as to absolutely destroy the defendant's business, seeking rather some device by which the business may be continued without the accompanying nuisance, often a difficult and sometimes impossible task. The defendant may therefore succeed in having the injunction in so weak a form that it is ineffective, or he may after a period of compliance slowly resume the wrong doing, thus compelling the plaintiff to prove his case anew in contempt proceedings. While the private individual is thus seeking an injunction, the municipal body affected as to its property interest or as to its health, may as a matter of common law likewise procure an injunction.

Where the nuisance affects the right of the public, it is ordinarily punishable as a crime, and in some states abatement may be had by an order in the criminal proceedings.

Such is the law of nuisances relating to the public health. Laws do not execute themselves. A vigorous administration of statutory laws, adequate appropriations for the ascertainment and proof of the facts, enlightenment of the public mind as to the dangers from polluted streams and poisonous air, and a civic earnestness which not only will make easy the enforcement of law by public authorities, but will impel private individuals at some cost to themselves to set in operation the machinery of the common law, are all necessary. Many death-dealing nuisances await the attack of those who would protect public health.

INTERNATIONAL COINAGE

By THEO. F. VAN WAGENEN, E.M.

ZACATECAS, MEXICO

IT is quite impossible to discuss the subject of coinage without touching that of money. But the reference to the latter will be brief, and will consist mainly of a statement of certain fundamentals that are now practically accepted by all.

The long and bitter controversy between monometalism and bimetalism has ended in an understanding that there is no such thing as "intrinsic value" in money. When gold monometalism became universal, silver took at once the status of a commodity, became subject to fluctuations in price according to the law of supply and demand, like all other commodities, and declined markedly in value as one of its former uses was curtailed by law. If the civilized world should agree that only certain kinds of clothing could be made of cotton, and that all others must be manufactured of wool; or that cane sugar must be the only kind employed for food, similar effects would take place in the prices of cotton and beet sugar. Again, as silver declined in price, silver mining became less profitable, and silver miners gradually forsook the business and turned their attention to gold. Immediately the production of the latter began to increase until at the present time its annual output is about double in value that of the combined product of silver and gold a generation ago. As this increase occurred, the value of gold declined, establishing the quantitative theory of the value of money. For, though by law an ounce of gold was still and is now, legally transformable at the mints of all modern nations into coin of a face or money value of about twenty dollars, yet the coins so produced and put into circulation have been capable of buying each year less and less of all other commodities; or, to put it differently, sellers of all commodities have each year demanded more money for their wares, that is, prices have steadily risen since the flood of gold began. Thus the commercial world is faced to-day with the same problem that was up for solution thirty years ago in the matter of silver, viz., how to render more stable the purchasing power of the money unit, in view of the enormous and rapidly increasing output of the world's gold mines.

Here a word as to the two metallic schools may not be out of place. Monometalism was (and is) based upon the theory that either one of the precious metals (but gold surely) is so rare in nature, so hard to win, and exists in such really limited quantities as compared with the demand for coins, that if made by law the basis of money, it could be depended upon to exhibit permanent stability of value. Bimetalism, on the other hand, was founded upon the idea that in the development of the resources of the globe by man the discoveries of new sources of the two metals had, in the past, occurred in a roughly alternate sequence, would continue to occur so in the future, and that if both were admitted freely to unlimited coinage at an agreed ratio, based upon the proportionate tonnage output in the past, as far as records went, in the long run, through any considerable term of years, this tonnage ratio would be maintained. If so, the value ratio would be justified, and the two would float side by side. It was also held that the world needed both, because neither could be produced in sufficient quantity to meet the demand for coin. There was much in the way of historic fact to support these views. Considering only the era since the discovery of the new world, which is as far back as statistics on the subject are at all reliable, there was first the great output of gold from the Brazils, Venezuela and Colombia, which was followed by the silver flood from Mexico, Bolivia and Peru. Later came the almost simultaneous discovery of the Australian and Californian gold mines, after which occurred the vast silver output from the Nevada, Utah and Colorado silver deposits. But during the height of each of these metallic waves it became a strain on commerce to maintain the theoretical parity as based upon the average output, and because united international cooperation towards that end could not be secured, the effort was finally abandoned.

Since the civilized world became welded together by commercial ties as well as by railroad and steamship lines, the post office, the telegraph and cable, and now finally the telephone; as banks of deposit, discount and issue multiplied, and exchanges for produce as well as for stocks and bonds became fixities in all the great financial centers, the use of paper in the way of warehouse receipts, bills of exchange, checks, drafts, bank and government legal tender notes, has enormously expanded, so that among the wealthy and well-to-do the use of coin for money has already decreased almost to the vanishing point, and there is a positive dislike to a silver coin larger than an inch in diameter, and a decided preference to leave all gold coins in the custody of the banks, and use in place their notes and bills, or those issued by the governments. This is a perfectly natural evolution, and one that is bound to continue until the average citizen above the class of wage earner will carry only enough visible money to meet the spot cash necessities of the day, and will transact all the balance of his business with a check book. The process is already so far advanced that few people besides travelers and sports now-a-days carry upon their persons or in their homes the equivalent of more than five to ten dollars in money. What is to be the outcome? Will all coinage ultimately degenerate to a mere matter of tokens? Will all other kinds of money disappear between the covers of a check book? Will bank vaults become in the end the only place where one can get a sight of one hundred dollars in coin at a time?

But even with the banks the same process is in progress. Vaults are steadily becoming smaller, and are being used more for the paper evidences of property than for coin, or even bills. In large cities the bulk of the money is kept at the clearing house. In countries that possess central national banks it is stored in their cellars or kept at the government treasury. Money, as money, is undoubtedly disappearing rapidly from view, and in its place is arising a system of credits and credit transfer agencies, capable of being used not only by the people of each nationality, but between the nations themselves. How far the process can go remains yet to be seen, but a realization of the advance to date will show the road along which the financial world is traveling, and give some idea as to the goal that may be ahead.

But as yet only a very small part of the inhabited world has become really civilized. The United States and Canada on our side of the Atlantic, northwestern Europe on the other side, Australia, New Zealand and parts of Japan, a little patch of South Africa, a few spots in Latin America, and small areas in eastern Europe and India. The balance of the inhabitants of the globe may be considered financial barbarians. In numbers they will outbalance us nearly ten to one. With them money (where it has advanced beyond the idea of shells, hides or cattle) is still coin. For bills they have yet no use. There are living nearly fifteen hundred millions of such people that are capable of earning an average daily wage of as much as twenty-five cents or more. If all could be set to work the weekly pay roll would be about two and a quarter billion dollars. Assuming a month as the time required for coins among this class to make the trip from earner around through the hands of merchants and banks back to employers, it would take ten billion dollars' worth of silver money to permit of the steady employment of this army of laborers. Of course between sixty and seventy per cent. of this mass of individuals would not be earners (the women, children, old and decrepit), but, on the other hand, the actual laborers would be paid from fifty cents to a dollar a day, according to capacity. Here then is a large field for the use of the metal that the civilized world is rapidly discarding. For silver only could be used, gold representing too much value. At its present market value of say $15,000 per ton, it would take nearly seven hundred thousand tons of the white metal to produce the above mentioned stock of coin. The present annual production of the world is a little less than 7,000 tons. Hence it would require the entire product at the present rate for the next one hundred years to supply the demand. In view of the large use the western world yet has for small coin, and for silver in the arts, it will probably be safe to say that if the progress of civilization is not stayed, if it advances only at the rate that has obtained during the nineteenth century, there could be created a demand for the metal to the extent of the full output of the mines of the world at the present time, for probably the next two hundred years.

The question is, how to inaugurate and encourage this demand, how to introduce among the black and yellow men the coin of the white man, and interest them in its acquisition. Each in its way, the great commercial nations of the day are unconsciously engaged in the task. The English shilling is working northward from the Cape of Good Hope, has already come in touch with the German Mark and the Portuguese peseta which have been introduced on both the east and west sides of the continent, and will in due time meet the French franc and Italian lira coming south from the shores of the Mediterranean. In Asia, the Indian rupee, the Russian rouble, the Japanese yen and the American-Philippine coins are already competing for the patronage of the Malay and the Chinaman. In South America neither American nor European coins have any foothold, the Latin-American nations being well supplied by systems of their own, all related more or less closely to the coinage of Mexico or Portugal. Thus the plainly evolutionary task of pushing civilization into the uneducated parts of the world through commerce is as badly hampered by the different coins offered to the barbarian, as are the efforts of the evangelists to introduce Christianity by the existence of the various denominations and creeds. The church is beginning to appreciate the wastage in its efforts, and is trying to minimize it by combinations among the denominations having for their object to standardize Christianity, so to speak, by reducing tenet and dogma to the lowest possible terms. Commerce must do the same. The white man's coins must be standardized and simplified. If this can be accomplished, not only will the western nations be able to push their commercial influence much faster than now, but a new and immense field will be opened to the producers of silver, which should not only stay the decline in values, but restore it for a century or two to the position it held fifty years ago. This achievement in its turn should have the effect of checking the present flood of gold, which is already a menace to commerce, and which in another decade will certainly culminate in disaster to the world's financial system. For if silver mining should become as profitable as of old, by reason of a return of value to $1.30 per ounce, many who are now reluctantly engaged in the extra-hazardous business of gold mining will abandon it in favor of the much less hazardous one of silver production.

In looking over the field to devise ways and means to secure an international coin, it would seem as if the harvest is almost ripe for the gathering, that much preliminary work has already been done, and that if the cooperation of America, England, France and Germany was arranged, the step would be easily taken. The French franc, under different names but identical in value, is the legal unit in Greece, Italy, Belgium, Switzerland and the French colonies in north Africa. The English have been agitating for fifty years the reform of their currency, appreciating how great a handicap it is in commercial competition, and are only awaiting a plan that can be put into effect without too serious a wrench to the national susceptibilities. The German Mark presents the greatest difficulty, for it is the business unit of sixty millions of intelligent and pushing people. To North Americans the dollar of course seems to be the most satisfactory money unit in existence. Canada and Mexico already have it, the latter, however, at the silver valuation. It differs but a few cents in nominal value from that of the units of most of the Central and South American nations except Brazil. As the dollar was originally a Teutonic coin (known as the Thaler), and the Mark is a unit of comparatively recent origin, it would seem as if the Germans should not object too seriously to take it up again, and they would carry with them the Scandinavians, the Hollanders and the citizens of Austro-Hungary, with whom they have intimate financial and commercial relations.

The franc (and also the Mark) seems too small a unit for these days of great fortunes and huge capital aggregations, and the pound sterling is too large. As the shilling is really the retail unit of the British Empire—except in Canada and India—and has very nearly the value of our quarter, but little difficulty could be experienced by England and her colonies in changing to the dollar and a decimal system. Altogether the way seems very clear to us, but national pride in a coin, and national habits of long standing, are difficult matters to overcome. Perhaps the best argument in favor of the dollar is the rapidly growing financial preponderance of the United States and North America in general in the commercial world. This in time will force the financiers of all nations to think, write and act in terms of dollars as well as of their own coins, if they intend to keep up with the procession of events. Just as the English language, by the spread and increase of English-speaking people, is likely to become in due time the vehicle of communication between business men all over the world, so the dollar, aside from its inherent good qualities as a convenient money unit, promises, by reason of the expanding population, trade and activity of the North American continent, to become each year better known and better appreciated, until its universal adoption becomes natural and inevitable.

Aside, however, from such an argument, which Americans can not press strongly without wounding the national pride of other people, and especially of the Europeans, the international coin will come in a comparatively short time, just as will arrive the international postage stamp, which, by the way, is very badly needed. For the upper classes of all countries, the people who travel, and have to stand the nuisance and loss of changing their money at every frontier, the bankers and international merchants who have to cumber their accounts with the fluctuating item of exchange between commercial centers will insist upon it. All the European nations with the exception of Russia and Turkey are ready for the change, and when these reach the stage of real constitutionalism in their progress upward, they will be compelled to follow, being already deeply in debt to the French, English and Germans. Japan may be counted upon to acquiesce instantly in any unit agreed upon by the rest of the civilized world. That virile and open-minded people will at once perceive the advantage to themselves in their program of the commercial conquest of China. Their present unit, the yen, will not stand in the way, but will rather assist in the change.

Consider the increased force of the commercial assault on continental Asia and Africa and the other untamed areas of the globe of an international coin which the half-civilized and barbarous people of the globe found could be used in trading with any of the nations. Asia is called "the sink of silver." Scores of thousands of tons of the white metal in the guise of Indian rupees, Mexican dollars and other coins have disappeared during the last four hundred years among its teeming millions, and the drain still continues at the rate of about 3,000 tons per annum. It is the result of sheer force of numbers, coupled with patient industry and frugality. When these people awake fully from their sleep of centuries, and begin to produce and consume with something like the vigor of the western world, they will be capable of overwhelming it with their output of raw material. With what can they be paid? The balance of trade has remained steadily in their favor as far back as records go. We can only at first satisfy a small portion of their demand in goods, for their wants will increase slowly. They know of but one kind of money, namely, silver, and require that inflexibly. The western world has silver in abundance. It is a drug on the market. Why not prepare unitedly to let them have what they desire, and what we can so easily furnish, and at the same time put it in the form of a coin, which, when it became their unit, would guide them along the path of increasing consumption of those articles which they can produce, and in the production of which we can never hope to be able to successfully compete?

THE HUBBARD GLACIER, ALASKA[1]

By Professor LAWRENCE MARTIN
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SOUTHEAST of Mt. St. Elias and the Malaspina Glacier, Alaska, in the fiorded upper part of Yakutat Bay, known as Disenchantment Bay, is the Hubbard Glacier. It is the largest ice tongue in this region, except certain tributaries of the great Malaspina glacier. It has a total *known* length of twenty-eight miles along the trunk glacier, exclusive of one broad tributary whose lower twelve and one half miles is all that man has ever seen, two other much narrower tributaries each twelve miles long, five other branches each over five miles in length and scores of smaller tributaries. This system of ice tongues (Fig. 1) has, therefore, nearly one hundred miles of valley glaciers larger than

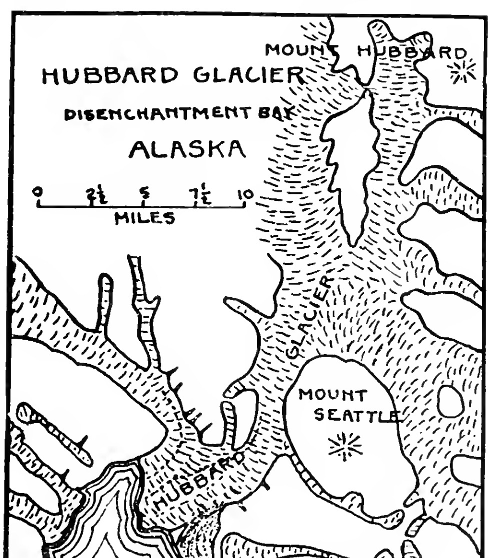


Fig. 1. Map of Hubbard Glacier and its known tributaries. The main glacier may rise at least twelve miles farther north, or over forty miles from the sea, while the northwest tributaries may be even longer.

[1] Published by permission of the Director of the U. S. Geological Survey. These observations are based upon (1) a U. S. Geological Survey expedition in 1905 under Professor R. S. Tarr, to which the writer was attached, his expenses being met by a grant of the American Geographical Society of New York, and (2) upon the National Geographic Society's Alaskan expedition of 1909, in charge of Professor Tarr and the writer. The illustrations are from photographs by A. J. Brabazon, of the Canadian Boundary Survey, Oscar von Engeln and the author.

FIG. 2. The Hubbard Glacier descending from its snow-fields to Disenchantment Bay. Mt. Hubbard, on the right, rises to 16,400 feet within twenty-five miles of sea-level, its slopes supplying large tributaries of the upper Hubbard Glacier.

the best-known glaciers in Switzerland, and the length of the upper parts of the three longest tongues is entirely unknown and the longest may exceed forty miles. No one of the tributaries as yet bears a name.

The Upper Glacier

The main glacier flows southward from the unexplored central part of the St. Elias Range past Mount Hubbard (Fig. 2), a beautiful 16,-400-foot peak named, like the glacier, for Gardiner G. Hubbard, former president of the National Geographic Society of Washington. North of Mount Seattle the Hubbard Glacier has a width of three and one half miles and receives a tributary nearly two miles wide which rises twelve miles back on the slopes of Mt. Hubbard.

Another great tributary from the east, as wide as the main glacier, has its confluence just to the southward. These three ice tongues form the main upper glacier. It is near this confluence that civilized man has made his farthermost traverse upon the Hubbard Glacier. Several intrepid prospectors advanced this far up an adjacent glacier highway and over a snow divide to the Upper Hubbard Glacier during the gold rushes of 1898 and 1899.

The Lower Glacier

Below this confluence, the Hubbard Glacier is crevassed and entirely impassable, and moves down its valley imperceptibly, like the hour hand of a watch, in its irresistible progress to the sea. It descends southwestward over a broad step near the steeply-cascading glacier, shown on the map and in the photographs (Figs. 3 and 4), where it is joined by its longest tributary, the northwest arm. This tributary, two miles wide and at least twelve and one half and probably over twenty miles in length, rises on the slopes of Mt. Vancouver and joins the main glacier at right angles. The combined glacier, with a width of over four miles, advances into Disenchantment Bay in a sinuous cliff four and one half to five miles long and 250 to 300 feet high, one of the most magnificent in the world. Upon this lower glacier surface the Aletsch Glacier, the Rhone Glacier and the Mer de Glace of Switzerland might be placed without covering over two thirds of the lower Hubbard ice tongue.

The surface of the Hubbard Glacier is traversed by several prominent medial moraines. One of these comes from the northwest tributary and sweeps in a broad curve to the ice front. Another comes from near the west side of the main glacier. The east side of the Hubbard ice cliff is dark and debris-laden (Fig. 5) because this side of the glacier is covered with lateral moraine. The basal layers are filled with dirt and stones (Fig. 6) which perform the work of ice erosion. To the eastward this nearly stagnant border almost joins the entirely

Fig. 3. West half of Hubbard Glacier, discharging icebergs into Disenchantment Bay. Mt. Hubbard in right background. Panorama with Fig. 4.

stagnant ice of the detached bulb of an adjacent glacier whose parti-colored crescentic moraines have led us to call it the Variegated Glacier. Ice underlies all this dark-colored area, however, where moraine mantles the quiescent and melting ice tongue in which there are numerous lakelets. The Hubbard Glacier is exceptional in having a small proportion of medial and lateral moraines, perhaps partly because it is so crevassed. Its surface is clear and attractive and its sea cliffs almost entirely snowy white.

The Ice Cliffs and Icebergs

The foreground of berg-dotted fiord, the silvery ice cliff (Fig. 7), the sea of serac and crevasse behind, and the mountain background rising to 8,000 and 10,000 feet within ten miles of sea-level, form a scene never to be forgotten. One might not presume to too great familiarity with this lordly glacier, however, for an approach to within a half mile of the ice cliff, even in a seaworthy dory, means danger of capsizing in the iceberg-generated waves from the cliff or from overturning bergs. The formation of icebergs from the glacier as seen at safer distances is of fascinating interest. The dazzling white cliff (Fig. 8) with its tints of blue and green in the crevasses suddenly crumbles as if the foundation of one of the castellated ice towers were suddenly removed. Liquid silver seems to slip for minutes from the cliff, then a pinnacle falls with a crash. Instantly the water in front of the glacier, even if clear of bergs a moment before, is filled with white ice fragments, while blue and green and dirty-black icebergs, released from the submerged part of the cliff, rise through the pack of small bergs, casting

FIG. 4. East half of Hubbard Glacier, discharging icebergs into Russell Fiord. Mt. Seattle (10,000 feet) on right. Panorama with Fig. 3.

many of them into the air and overturning others. This causes a wave that splashes with lightning rapidity against the ice cliff and crunches in the ice caves there, while other waves spread ring-like across the fiord, overturning great icebergs on the way and causing the surf to splash spitefully on shores two and a half miles away for ten minutes or more. The accompanying noises were never absent at our camp facing the Hubbard Glacier. The stream of icebergs thus produced (Fig. 9) moves endless out toward the sea.

Retreat of the Hubbard Glacier

This glacier, long known to the natives, was seen from a distance of about six miles by the searchers for the Northwest Passage, Malaspina and Vancouver, in 1792 and 1794. The former gave the undescriptive name of *Desangano* to this bay because of his disappointment at once again failing to find the passage. Before historic times the Hubbard Glacier extended southward more than thirty miles to the Pacific Ocean, receiving large tributaries on its way. In 1792 and 1794 it had probably retreated nearly to its present position, not being five miles down the bay as several have inferred.[2] When seen by the late Professor I. C. Russell, in 1890 and 1891, it was no doubt slightly farther back than in 1792 and 1794.[3] By 1899, when studied and

[2] See Tarr, R. S., and Martin, Lawrence, "Position of Hubbard Glacier Front in 1792 and 1794," *Bull. Amer. Geog. Soc.*, Vol. XXXIX., 1907, pp. 129–136.

[3] Russell, I. C., "An Expedition to Mount St. Elias, Alaska," *Nat. Geog. Mag.*, Vol. 3, 1891, pp. 90–100; see also "Second Expedition to Mount St. Elias," Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1892. p. 85.

FIG. 5. East margin of Hubbard Glacier, showing medial and lateral moraines and marginal lakes.

mapped by Messrs. G. K. Gilbert, Henry Gannett and the Harriman Expedition, it had retreated one or two hundred feet more.[4] Between 1899 and 1905, when the Hubbard Glacier was studied by Professor R. S. Tarr and the writer, the northwest side seemed to have advanced slightly and the southeast to have retreated.[5] That is, although continually advancing strongly, the glacier had extended its ice cliff farther into the fiord only about a quarter mile between 1891 and 1905, because ice was continually being discharged from the end in icebergs. Professor Tarr found very little change between 1905 and 1906, the west half having possibly advanced slightly.[6] It was about the same on this west side in 1909 (Fig. 10).

EFFECTS OF AN EARTHQUAKE

In September, 1899, however, this glacier, with the others in the region, was involved in an abnormal sort of experience which has notably affected its later history. This was a series of severe earthquakes.

Just east of the cliff of dirty ice shown in the photographs at the right of Hubbard Glacier (Fig. 11) there is a stagnant ice area which

[4] Gilbert, G. K., "Glaciers and Glaciation," Harriman Alaska Expedition, Vol. 3, 1904, pp. 63–66.

[5] Tarr, R. S., and Martin, Lawrence, "Glaciers and Glaciation of Yakutat Bay, Alaska," *Bull. Amer. Geog. Soc.*, Vol. XXXVIII., 1906, pp. 146–147.

[6] Tarr, R. S., Professional Paper 64, U. S. Geol. Survey, 1909, pp. 45–46.

looks black in the pictures and which forms the terminus of Variegated Glacier. Where the streams emerge from this area, eight men were washing the gravels for gold and platinum, their tents being near the base of the moraine-veneered gravel hills. Several earthquakes were felt by them upon September 3, 1899, and on the intervening days till September 10, when there was so severe a shock that seismographs recorded it throughout the world. Other earthquakes followed until September 29.

These prospectors tell us that on September 10 the ground shook and cracked and undulated, that waves washed up on the shore, small glacial ponds broke and caused floods, that the Hubbard Glacier crashed and roared, and that its front was broken instantly. The hundreds of ice towers shaken down at once and the great quantities of enormous icebergs released from beneath the sea by the shaking of the submerged part of the ice cliff so filled the bay that it seemed to them as if the glacier itself advanced half a mile into the fiord.

The men subsequently escaped with their lives and the glacier seemed in 1905 to have recovered from its loss. Its better-known neighbor, the Muir Glacier, 150 miles southeast in Glacier Bay, and other ice tongues there, however, have had a period of retreat initiated by this earthquake shaking in 1899 which has destroyed much of their scenic interest and removed nearly a mile of ice a year from their cliffs for the past eight years.

In Yakutat Bay, however, these earthquakes of 1899, which were

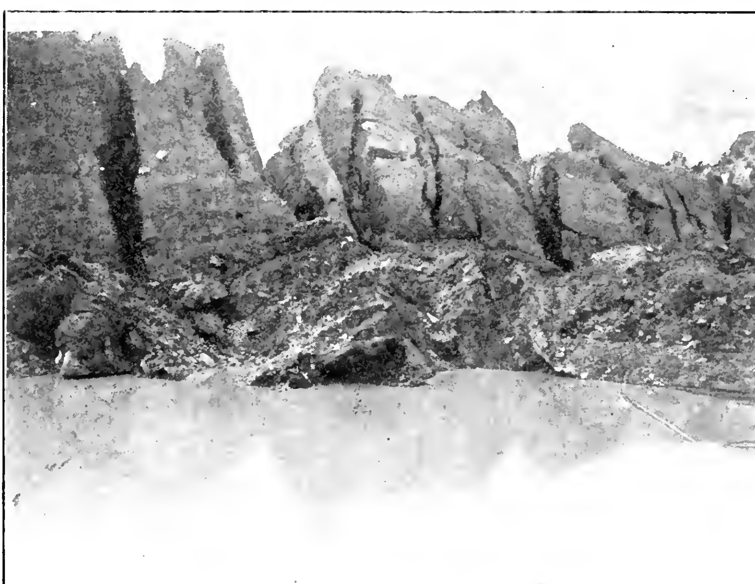


FIG. 6. Black ice of Hubbard Glacier margin laden with dirt and stones of basal ice. Such ice as this performs work of glacial erosion.

accompanied by faulting and by a $47\frac{1}{3}$ foot uplift of the coast six miles southwest of Hubbard Glacier, a $17\frac{1}{2}$ foot uplift $4\frac{1}{2}$ miles south of it, a $7\frac{1}{2}$ foot uplift four miles east of it, and a depression of the coast in some other places resulted in another sort of change. The prospectors encamped beside the Hubbard Glacier tell us of the great roar of avalanches during and after the shocks in 1899. In 1906 Professor Tarr found that several glaciers in this region had advanced a mile or more since we visited them the autumn before (Fig. 13). Only one had so advanced between 1899 and 1905. He has

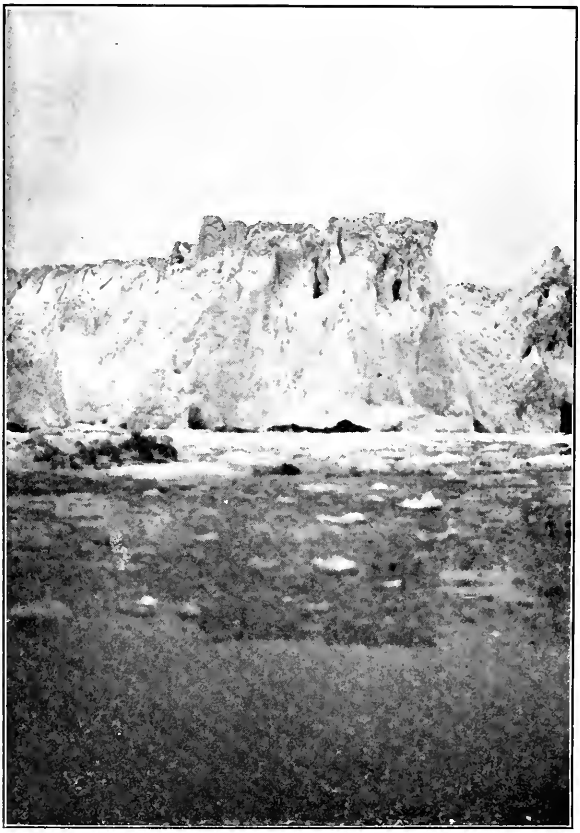


Fig. 7. The ice cliff of Hubbard Glacier, between 250 and 300 feet high.

shown this advance to be due to great avalanches which supplied abnormal quantities of snow to the heads of the glaciers during the earthquakes, resulting, after a delay of several years, in a spasmodic advance. The glacier shown on the map on the right and that on the left of Hubbard Glacier, advanced thus between 1905 and 1906 (Fig. 13). The Hubbard Glacier was unchanged in 1906. It may yet respond to a similar impulse imparted by this glacier flood and advance far into

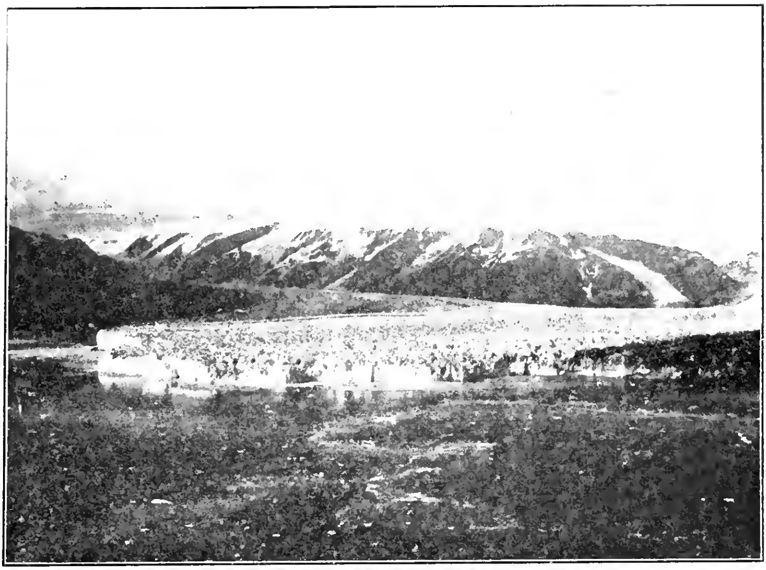


FIG. 8. A view of Hubbard Glacier from above Osier Island in 1905. Severely crevassed, with few medial moraines. Icebergs are continually floating away from this cliff and are swirled by the tide into fantastic streamers.

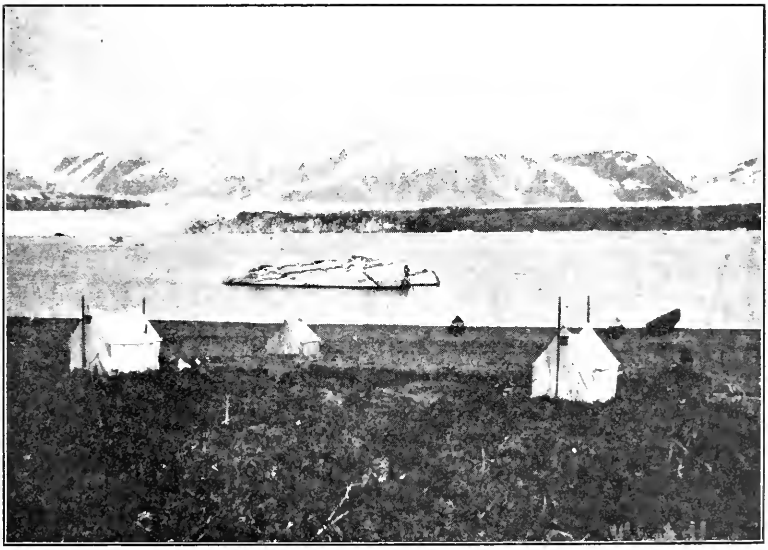


FIG. 9. An iceberg from Hubbard Glacier floating in front of our camp in Disenchantment Bay in 1905.

FIG. 10. The Hubbard Glacier from Osier Island in 1909, and essentially as in 1905 for the western portion of the front. It has had a net advance of at least a quarter mile since photographed from the same site by Professor Russell twenty years before.

FIG. 11. East margin of Hubbard Glacier where ice advance was beginning in dark cliff in 1909

Disenchantment Bay. If avalanches were not abundant enough, however, along its tributaries it may not feel this impulse at all. In any event it will continue to be, as it now is, one of the grand spectacles of nature, and worthy of the visits of appreciative men.

Beginning of Advance

The last paragraph was written in December, 1908. During the summer of 1909 the National Geographic Society's Alaskan Expedition, in charge of Professor R. S. Tarr and the writer, observed what seems to be the beginning of the advance predicted above, which has been

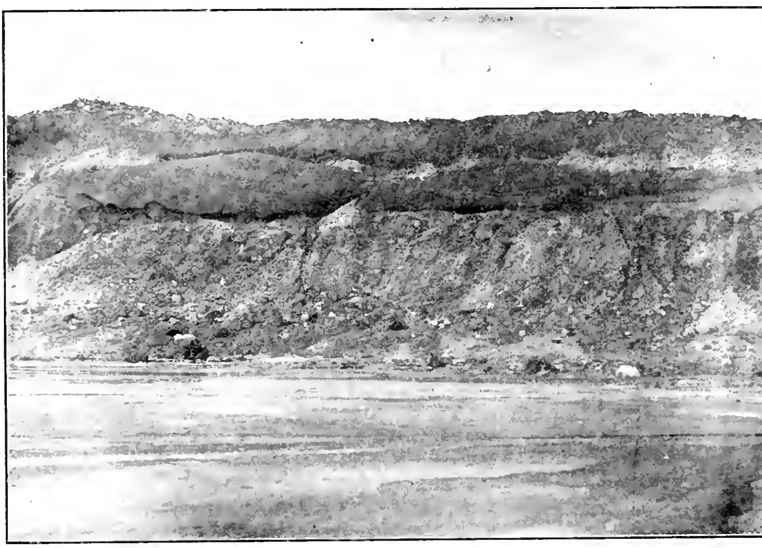


Fig. 12. Dark cliff of eastern Hubbard Glacier pushed up through ablation moraine between 1905 and 1909, and marking the beginning of the advance.

more fully described elsewhere.[7] The stagnant, dark-colored ice shown on the extreme right in Fig. 11 was resuming activity. Breaking had commenced, ice blocks were being pushed up through the morainic cover, as is shown in detail in Fig. 12. Stones were sliding down the surface and revived streams were burying willows growing near the ice front. A renewal of activity was in progress, but how great an advance there may be will not be known till studies can be made in the summer of 1910.

An adjacent ice tongue, the Hidden Glacier, advanced over two miles between 1906 and 1909. If the south side of the Hubbard Glacier advances a mile and half, however, it will override Osier Island once more (Fig. 13). This would change Russell Fiord southeast of the Hubbard Glacier from an arm of the sea to a fresh-water lake

[7] *National Geographic Magazine,* Vol. XXI., January, 1910.

FIG. 11. Model showing the relation of Hubbard Glacier to bifurcation of Disenchantment Bay and Russell Fiord, branches of Yakutat Bay. A slight advance will convert Russell Fiord into a long, narrow lake, draining southward across Yakutat Foreland and probably receiving icebergs from Nunatak, Hidden, Variegated, Hubbard, and other Glaciers.

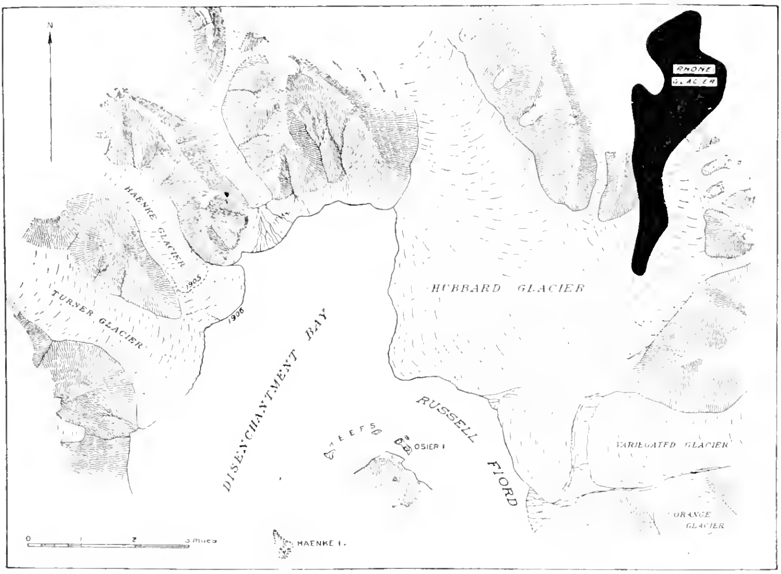


FIG. 13. Map of the lower fifth of Hubbard Glacier and adjacent ice tongues (after Gannett, Harriman Expedition, and Rich, U. S. Geol. Survey). The whole Rhone Glacier in Switzerland is drawn in black on exactly the same scale for comparison. The hitherto stagnant Variegated Glacier (on the right) and the Haenke Glacier (on the left) became crevassed and advanced between 1905 and 1906, the front of the latter moving nearly a mile in less than nine months and becoming tidal. In 1909 it once more ended on the land. A slight continuation of the advance of Hubbard Glacier would separate Russell Fiord from Disenchantment Bay and the Pacific Ocean.

(Fig. 14) which would be 33 miles long and 100 square miles in area. Its surface would be higher than the present fiord and would receive icebergs from four or more great glaciers, only one of which is now tidal. What would happen to the stagnant, moraine-veneered terminus of Variegated Glacier is a problem. The glacial lake would drain to the Pacific independently until future retreat of Hubbard Glacier resulted in the restoration of the lake to the fiord.

This renewal of activity by Hubbard Glacier is, therefore, of more than ordinary interest, especially as the advance is one of the type now well proved to be due, not to climatic variation, but to excessive avalanching during earthquakes.

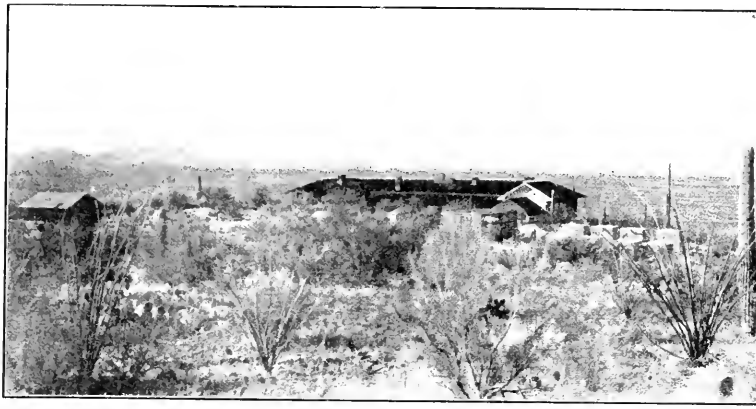
THE PROGRESS OF SCIENCE

THE WORK OF THE CARNEGIE INSTITUTION

The eighth year book of the Carnegie Institution of Washington gives an account of its activities during the past year. The appropriation amounted to about $650,000—about $467,000 being for the maintenance of its departments; $50,000 for minor grants; $30,000 for research associates and assistants; $54,000 for publication, and $50,000 for administrative expenses. As indicated in the last issue of the Monthly, the administration building was dedicated in November. No new department was inaugurated during the year, but the observatory for meridian astronomy at San Luis, Argentina, began its work under the direction of Dr. Louis Boss, of the Dudley Observatory, Albany. The Nutrition Laboratory adjacent to the Harvard Medical School was also for the first time in working order. The magnetic ship *Carnegie* made its first voyage. A new tower telescope, 150 feet high and extending 75 feet below the ground, has been begun at the Solar Observatory on Mt. Wilson, California. The work of the Geophysical Laboratory, of the Department of Botanical Research, the Cold Spring Harbor Station and the Marine Biological Laboratory at Tortugas were continued. During the year nineteen volumes were published containing 4,907 pages.

The scientific men who are working in the departments of the Carnegie Institution are accomplishing a great amount of valuable research; but it is not certain that the contributions from the United States have been increased to the extent that might have been hoped from the expenditure of four million dollars. All the leading officers of the institution were engaged in scientific work before its establishment, and it is a question whether their work is better than it would have been if they had remained in their previous positions. The places which they held have been filled by others and there is

The Geophysical Laboratory, Upton Street, Washington.



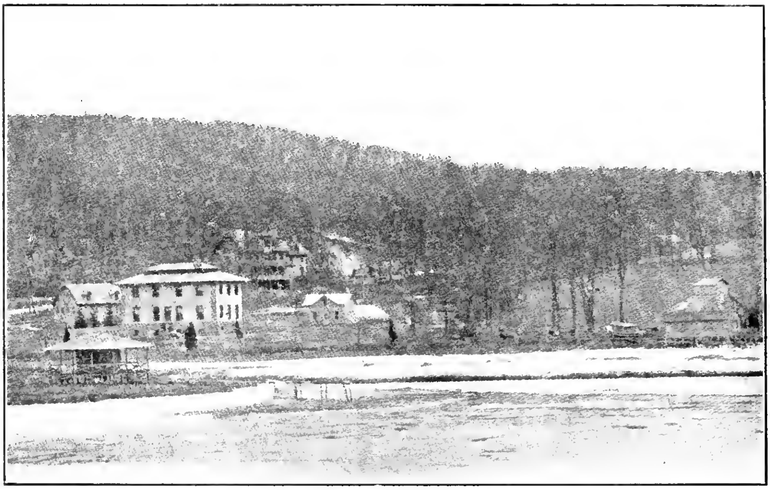
Main Building, Desert Laboratory, Tucson, Arizona.

thus opportunity for more workers. But the difficulty in the United States appears to be a lack of men rather than a lack of positions or of equipment. Those employed by the Carnegie Institution are somewhat isolated in their research stations and their influence in attracting men to research work and training them to it is less than it would be at the universities.

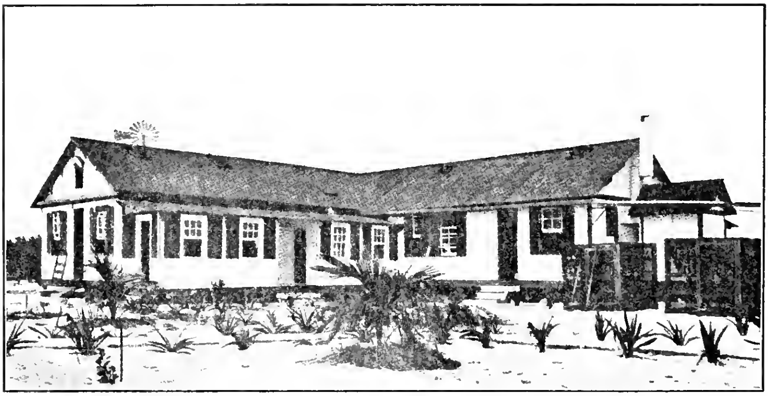
University professors have positions which should make the scientific career attractive to young men of ability and purpose. The associations of the university are on the whole pleasant and honorable. With his colleagues, his assistants and his more advanced students the professor has a stimulus to good work and opportunity to make it effective. As a rule the position is a life appointment; there are pensions, vacations and sabbatical leaves of absence. Yet, in spite of these attractions, it is difficult to find men of distinction for university chairs. It may be that they are not being born in sufficient numbers, but it is more likely that they are not found. The comparatively small salaries and the somewhat unsatisfactory methods of university control may be partly responsible. Whatever the difficulty may be, the pressing need of the present time is to find men: providing positions and equipment is scarcely of use except in so far as this may attract men.

The Carnegie Institution has taken men from universities and from other institutions; it has not made new men of science or attracted men to scientific work. This it might have done by giving opportunity to men who could not otherwise find it, or by paying such salaries and conferring such privileges on scientific men as would make the career attractive to the best men. The salaries paid are not made public, but they are probably as small as will obtain and retain the men that are needed. The bureaucratic or department store system, which is the chief danger of the university, is in the case of the Carnegie Institution carried to an extreme, for the collective sentiment of a group of scholars, which is the balance wheel of the university, is there absent. It may be impossible for such an institution to accomplish more for science than it is doing, but certainly the official statement of its plans published eight years ago appeal more to the imagination. It reads:

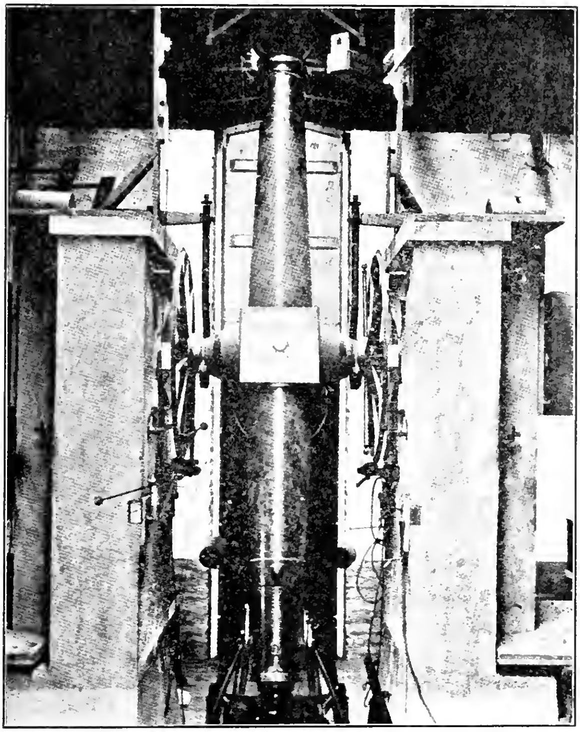
It is proposed to found in the city of Washington, in the spirit of Washington, an institution which, with the cooperation of institutions now or hereafter established, there or elsewhere, shall, in the broadest and most liberal manner, encourage investigation, re-



General View of Station of Department of Experimental Evolution, Cold Spring Harbor.



Main Building, Tortugas Laboratory



TRANSIT-CIRCLE, SOUTHERN OBSERVATORY, SAN LUIS, ARGENTINE REPUBLIC.

search and discovery, encourage the application of knowledge to the improvement of mankind; provide such buildings, laboratories, books and apparatus as may be needed, and afford instruction of an advanced character to students whenever and wherever found, inside or outside of schools, properly qualified to profit thereby. Among its aims are these:

1. To increase the efficiency of the universities and other institutions of learning throughout the country, by utilizing and adding to their existing facilities, and by aiding teachers in the various institutions for experimental and other work, in these institutions as far as may be advisable.

2. To discover the exceptional man in every department of study, whenever and wherever found, and enable him by financial aid to make the work for which he seems specially designed, his life work.

3. To promote original research, paying great attention thereto, as being one of the chief purposes of this institution.

4. To increase facilities for higher education.

5. To enable such students as may find Washington the best point for their special studies to avail themselves of such advantages as may be open to them in the museums, libraries, laboratories, observatory, meteorological, piscicultural and forestry schools and kindred institutions of the several departments of the government.

6. To insure the prompt publication and distribution of the results of scientific investigation, a field considered to be highly important.

These and kindred objects may be attained by providing the necessary apparatus, by employing able teachers from various institutions in Washington and elsewhere, and by enabling men fitted for special work to devote themselves to it, through salaried fellowships or scholarships, or through salaries, with or without pensions in old age, or through aid in other forms to such men as continue their special work at seats of learning throughout the world.

PETER LESLEY.

THE LIFE OF PETER LESLEY

THE life and letters of Peter and Susan Lesley have been edited by their daughter, Mrs. Mary Lesley Ames, and published in two volumes of considerable size by Messrs. G. P. Putnam's Sons. The biography and the letters are largely personal in character. They are documents of human interest in depicting the lives of two superior and attractive personalities in their relations to the social conditions of New England and Philadelphia during the larger part of the last century. They also throw some light on the history of science in this country.

Lesley was born in Philadelphia in 1819 of Scotch presbyterian stock and dedicated to the ministry. His health being broken at the age of nineteen he obtained a place as assistant in the newly-organized geological survey of Pennsylvania, in order that he might have outdoor work for a season. Thus he was drawn to geology almost by an accident, as indeed it may be held that the comparatively considerable contribution of America to geology during the last century was a by-product of the development of our natural resources. Lesley completed his theological studies at Princeton, studied in Germany at a time when this was unusual, became a missionary in the forest counties of Pennsylvania, and for three years had charge of a church in Milton, near Boston. There he was married and there he returned to live in his old age. But he was not sufficiently orthodox for the ministry and was fortunately driven back to geology.

In Philadelphia he became a geological and mining expert. He made maps of coal fields for the Pennsylvania Railway and compiled an iron manufacturer's guide. He was for many years secretary and librarian of the American Philosophical Society and in 1872 became professor of geology in the University of Pennsylvania. In 1874 the second geological survey of Pennsylvania was inaugurated and Lesley accepting the directorship carried out the great work of his life, though begun at the age of fifty-five years. The hundred and twenty volumes of the reports of the survey are due to the men he selected for the work, to his constant oversight, and to his careful editing. The work gives him high rank among those who have done most to advance geology in this country.

Lesley's interests were wide, being by no means confined to geology. He himself says in a letter to Professor O. N. Rood "I have done nothing worthy of record in science." He then tells what he believes his services to have been—improvements in certain instruments—the odometer, the measuring divider and the aneroid barometer; the introduction of contour curves in geological field work; and two theories—the determination of the present system of surface drainage by the dimpled form of the plicated original surface and the production of modern topography chiefly by the underground solution of limestone strata.

PETER AND SUSAN LESLEY.

In 1893 Lesley's health failed and he lived quietly until his death in 1903 at the age of eighty-four years. The photograph which his friends regard as the best is here given, and a reproduction of a portrait painted in the old age of her parents by Mrs. Bush-Brown.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Friederich Kohlrausch, the eminent

German physicist, of Dr. William Bradley Rising, professor of chemistry in the University of California, and of Dr. William George Tight, formerly professor of geology at Denison University and the University of New Mexico.

A NATIONAL testimonial to Commander Robert Peary was held at the Metropolitan Opera House, New York City, on February 8. Governor Hughes presided and a telegram was read from President Taft which expressed the hope that congress would take some substantial notice of Commander Peary's great achievement. Governor Hughes presented Commander Peary with a purse containing $10,000, which he immediately contributed toward fitting out an Antarctic expedition.—The Langley medal of the Smithsonian Institution, created in 1908 in commemoration of Professor Langley and his work in aerodromics, was presented to Messrs. Orville and Wilbur Wright on February 10. Dr. Alexander Graham Bell and Senator Lodge made addresses and Chief Justice Fuller presented the medals.

A STATUE of the late Morris K. Jesup, for many years president of the American Museum of Natural History, was unveiled in the foyer of the museum on February 9. Addresses at the unveiling were made by Dr. Henry Fairfield Osborn, who has succeeded Mr. Jesup as president of the museum, and Mr. Joseph H. Choate, one of the founders of the museum.

A DEPARTMENT of experimental biology has been organized in the Rockefeller Institute. Professor Jacques Loeb, of the University of California, has been elected head of the department.—The Geological Society of London has awarded the Wollaston medal to Professor W. B. Scott, of Princeton University.—The French Academy of Moral and Political Sciences has elected Professor William James, of Harvard University, a foreign member of the society, in the room of the late M. de Martens, of St. Petersburg. Professor James has been a corresponding member of the academy since 1898.

THE late Darius Ogden Mills, of New York City, has bequeathed $100,000 to the American Museum of Natural History, $50,000 to the New York Botanical Garden and $25,000 to the American Geographical Society of New York City.—The Sheffield Scientific School of Yale University has received from Messrs. George G. Mason and William S. Mason $250,000 for a laboratory of mechanical engineering.

THE POPULAR SCIENCE MONTHLY.

APRIL, 1910

LAWS OF DIMINISHING ENVIRONMENTAL INFLUENCE

By Dr. FREDERICK ADAMS WOODS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IT is a widely entertained belief, especially among reformers, philanthropists and many educators, that the force of environment is very great. This view may be the result of vague personal impressions, natural hope, kindliness of heart or perhaps at times professional and selfish interests. But do the facts of science support the expectant hope? Something is needed beyond dogmatic statements and wordy essays.

Experimentally and statistically there is not a grain of proof that ordinarily environment can alter the *salient mental and moral traits* in any measurable degree from what they were predetermined to be through innate influences. Yet there is naturally a feeling that environment must count for something, and from experimental zoology we know that in many ways its influence is very great. Surely the institutions, discoveries and inventions of civilization form an environment, the value of which from one point of view, is difficult to overestimate. How then can we bring relative order and laws out of the conflicting testimony? It is the purpose of this article by treating the subject from the comparative standpoint, and after a new method, to attempt to harmonize the diversified facts of inheritance and modification.

To distinguish between the relative importance of heredity and environment is not a mere academic question, but a practical one to be answered separately for each biological trait and always with an eye to comparative and proportionate influence. To say that both forces are important is to voice a platitude. To say that they are of equal importance is, in my opinion, to express a falsehood. To say that we can not unravel their interrelations is to turn our back, in a weak-minded way, upon a question of far-reaching consequence. The disputes and confusions which have so long entangled the question I believe to be due to the failure to see certain practical, or common sense aspects—the failure to distinguish between environments which are greatly changed and those which are only slightly altered, between those from which escape is impossible and those from which such escape is relatively easy; the failure to distinguish between environments which are expected and those which are not, and, lastly, perhaps most important of all, the failure to distinguish between effects on higher and on lower types and tissues.

About ten years ago I became convinced through an extended analysis of the genealogical and personal data which exist in histories concerning the royal families of Europe that the influence of environment in creating mental and moral differences among human beings had been greatly overestimated. This conclusion was arrived at from various points of view. Statistical analysis not only supported a theory of germ-cell, or innate causation, but, what was more compelling, an intensive study of each separate family and each isolated group of close relatives brought out such sharp contrasts among the close of kin, such variations in types of mind and character, even when narrowly environed in point of time and place, that a recourse to heredity became forced upon me. The explanation from environment would not work.

This conclusion concerning the relatively slight or unimportant influence of environment as a modifying force on the higher human traits, I announced at the Chicago meeting of the American Psychological Association in 1901; since which time I have been constantly on the lookout for any investigations which might either confirm this belief or necessitate a change of faith. Several direct researches on human heredity have appeared which have been confirmatory in one way or another, and as far as I know nothing has been brought forward to disprove even an extreme belief in the predetermined nature of psychological differences; but it is not the human side of the question that I wish to discuss so much as the results of experimental zoology and botany and their significance to the student of man.

From time to time a vast array of experimental proof has come to my attention showing the profound effect of modification on plants and animals. The word modification I use in its technical sense as proposed by Lloyd Morgan to cover those changes which occur—*in the life time of an individual* and known to be directly traceable to some natural or artificial (usually artificial) change in its surroundings. These modifications are known to occur and may be easily observed or measured. Whether they are inherited or not is another question, and one entirely outside of the present thesis, for I wish to treat solely of such modifications as are known to occur within the individual life at any time from conception to death or within a single generation. This will throw out of the question a hoard of cases where it is not quite clear whether the observed changes are the result of direct modification, in the true restricted sense, or are perhaps due in part to accumulated influences acting through several generations.

Confining ourselves then to a discussion of modification in the strict sense of the term, let us briefly survey the conclusions of experimental zoology, embryology and botany, and also experiments on regeneration, to see what lesson may be learned from the results of all this painstaking work. It will be of course impossible to treat of more than a fraction of the multitudinous results which have already been handed in as contributions to this young and rapidly growing branch of knowledge—experimental biology; but I believe that even a superficial survey will suffice to bring out my general contention.

The fact that ordinary differences in human environment, as shown in the history of royalty, appeared to alter the innate character and capacity for achievement but little, together with the fact that experimentally a great deal in the way of modification could be produced in the domains of zoology and botany, led me to suppose that there must be some inherent biological differences rendering tissues low in the organic scale especially susceptible to the molding of external influences.

This idea I advanced as an hypothesis in 1906 in the following words:[1]

> Among plants and the lower forms of animals, especially the invertebrates, many experiments have shown the remarkable changes which may be directly induced by changes in the outward conditions of life. *These are in general the more striking the lower we go in the scale of organic evolution, so that it may well be that in the highest attributes, namely, mental or moral, we can expect the least results from outward forces.* This hypothesis may prove a veritable generalization throughout the animal series.

In 1908[2] I expressed the same idea in the following passage:

> The profound modifications that may be induced in plants and the invertebrates by alterations of the surroundings are well known. But when one takes a survey of this whole question of modification, one sees that in general the lower we go in the scale of life the easier it is to effect the changes. It is significant that among vertebrates the modifications are largely associated with the integument, where cell-division is active and constant, and in a tissue that is not highly organized.

It is to offer the proof for this generalization that I now propose a survey of the whole question.

[1] "Mental and Moral Heredity in Royalty," New York, Henry Holt & Co., 1906, p. 294.

[2] Vol. V. American Breeders Association, Report of the Committee on Eugenics, p. 248.

I wish to state at the start that I have made an effort to collect notes bearing against this theory as well as for it. What I have here to offer is merely a report, almost statistical in its aim and methods, on the general significance of the total number of researches which have thus far been made touching upon modification. Original papers have been occasionally consulted, but the major portion of the notes are drawn from the well-known text-books dealing with these questions and have been rearranged, after a new scheme, under headings expressing in a general way phylogenetic rank. Text-books subdivide the experiments according to the external agents employed, *e. g.*, food, light, heat, gravity, etc., or discuss special types of modification in a disjointed way. The headings that I have made use of are: Plants, Low Metazoa, Mollusks, Crustaceans, Insects, etc., Fishes, Amphibians, Reptiles and Birds and Mammals, and finally Mental and Moral Traits.

It is of course impossible to say at times whether a certain species is higher or lower than another species, but surely we may expect agreement if we say that mammals are higher than birds, that the amniota are higher than the anamniota, and that amphibians are higher than fishes, and that all vertebrates are higher than the low invertebrates. It would be difficult to agree as to the relative rank of the highest of the invertebrates and the lower vertebrates, and difficult to compare the higher plants with low metazoa, but enough of relative rank will be admitted for the purposes of this generalization. Let us now see what chief modifications have been produced (that are nevertheless compatible with life) in these various organic groups.

Plants

The modifications in the plant world are so numerous and so striking that one scarcely needs to mention more than a small portion of all the experiments to show that plants are greatly influenced by their surroundings. For instance, plants may be made to grow ten or even twenty times as fast under optimum conditions as compared with their growth under the least favorable.[3] The Japanese dwarf trees show in a remarkable way the possibilities in this direction. The effect is due in part to a mechanical process which prevents the spreading of the branches, but the chief cause is found in poor soil and lack of nourishment.[4]

The great influence of gravity on the direction of the development of different parts of plants is also well known, as is their power of regeneration, where a single begonia leaf may produce a new plant, and even flowers if set in moist sand.[5] The great effect of differences

[3] C. B. Davenport, "Exp. Morph.," pp. 451–452.

[4] De Varigny, "Exp. Evolution," p. 71.

[5] Morgan, "Regeneration," p. 74.

in the amount or quality of heat, light, food, gravity, soil, manure and atmosphere may be easily verified.[6]

Low Metazoa

Among the low metazoa the influence of temperature, light and food is not so striking as among plants, still the changes may be called remarkable. For instance, the body-length of Echinus larvæ may be made, by raising the temperature, to increase about 25 per cent. of the average growth attained under a low temperature, while the arm-lengths in certain forms are at the same time increased from 200 to 300 per cent. If the number of larvæ of Echinus and Strongylocentrotus, which are growing together, be increased from under 1,500 per liter to over 3,000 per liter the mean length of the anal arms and the oral arms may be made to diminish from the figures 121.2 and 118.4 to 56.6 and 68.5, respectively.[7] No modifications like this have been induced among the higher vertebrates.

In the embryology of placental mammals the dorsal or ventral surface may be facing either up or down, right or left; all forces work out their destiny in disregard to the force of gravity. This force of gravity so important in moulding plants has been proved to be also very influential in the development of hydroids. Pieces of *Antennularia antennia* produce new stems that grow upward, and stolons that turn downward. Even if the piece is inverted the root arises from the lower end and the stem from the upper. Driesch observed in a species of *Sertularia* that whenever he altered the position of the piece the new growth changed its position so that the new part turned away from the center of the earth.[8]

The most remarkable of all experiments on low metazoa are the regeneration experiments. Since the exposed cells are subjected to a very considerable alteration of their normal environment, regeneration experiments may be considered as coming under the head of modification experiments. The power of regeneration possessed by worms and hydroids is so well known that only a passing reference is needed here. It is significant that among worms the tail will regenerate more than the head and that the reproductive organs, if removed, never regenerate at all, and the worm remains "incapable of reproducing itself."[9] This last fact is interesting as supporting the view that germ-cells are never reproduced from somatic cells of any kind, much less from

[6] Conf. Morgan, "Exp. Zool.," pp. 44, 265, 266. Vernon, "Variation," pp. 228, 245, 249, 262, 269, 282, 284–286, 312–314. C. B. Davenport, "Exp. Morphology," p. 480. E. Davenport, "Principles of Breeding," pp. 256–264.

[7] Vernon, "Variation," pp. 229, 296.

[8] Morgan, "Exp. Zool.," p. 266.

[9] Morgan, "Regeneration," p. 9.

the so-called "germinal epithelium," but are the direct descendants of cells that have never lost their germ-cell characteristics.[10]

Artificial parthenogenesis is also easily produced among the low metazoa, and this has been known for a long time. O. and R. Hertwig published in 1887 their experiments, which showed that various poisons might artificially induce segmentation in the eggs of echinoderms. Loeb carried the process further in 1899 and produced plutei from the unfertilized eggs of the sea urchins by raising the concentration of the sea water. "It was immaterial which substance was used to raise the concentration of the sea water, except for the fact that no substance could be used that injured the eggs too much."[11] Parthenogenesis may be initiated by such a variety of substances as chloroform, urea, sugar, salts and certain acids; but only in low forms of life. At least it is the legitimate inference that it is much easier to produce this effect among the simpler invertebrates. Experiments of this sort on the eggs of fishes are noticeable by their absence. Experiments on the eggs of frogs and Petromyzon have not, as far as I know, resulted in carrying the process beyond the segmentation stage. The experiments on insects which will be discussed under that heading have only a doubtful bearing on the present point, since parthenogenesis is among them more or less of a normal process.

Mollusks

Modification experiments on mollusks have been relatively rare in comparison with the lower invertebrates. This must be, to some extent, due to the practical difficulties which the experimenter would meet on attempting to modify an animal enclosed in a shell.

There is, however, much evidence to show that mollusks may be greatly influenced by their surroundings, at least as regards size. This especially concerns the question of the sizes of snails in relation to the extent of the media in which they are forced to live. The manner in which the volume of water affects the snail's growth is a matter of dispute and does not interest us here. The question for us is, how much are they affected? The answer is, that after about two months the snails grown under optimum environment were more than three times the length, or even five times the length, of those grown under the least favorable conditions.[12] Compare this with similar experiments on plants where the extreme variations artificially induced may be ten or twenty fold, and also with the experiments on the higher vertebrates where extreme variations resulting from any experimentally pre-

[10] For literature, see B. M. Allen, *Anatomischer Anzeiger*, Band XXIX., 1906, pp. 217–236.

[11] Loeb, "Dynamics of Living Matter," p. 167.

[12] Vernon, "Variations," p. 302. C. B. Davenport, "Exp. Morph.," p. 474.

scribed conditions are never anything like three to five fold in a linear dimension.

Other classes of modification experiments on mollusks are not so exact, but are perhaps worth mentioning. Vernon writes that "the permanent effects of temperature on size are probably very considerable among many of the mollusks," and quotes Cooke as stating that "a deficiency of lime, in the composition of the soil of any particular locality, produces very marked effects upon the mollusca which inhabit it; they become small and very thin, occasionally almost transparent." Unfortunately there is no statement that changes can be brought about in one generation, though very likely this is the case. Vernon says, in quoting Costa, page 314:

> On transferring young oysters from the English shores to the Mediterranean it was found that their manner of growth at once altered, and prominent diverging rays were formed, like those on the shell of the native Mediterranean oyster.

Regeneration experiments are numerous among the mollusks and indicate, as Przibram points out,[13] that these animals belong, with regard to their relation to the question of regeneration, in the middle rank between the lowest invertebrates and the highest vertebrates. He places mollusks in the fourth of six classes with respect to the power of regeneration, which can regenerate besides the tail, also limbs and organs of sense as long as the connection with the central nervous system is intact.

Crustaceans

There have not been many modifications experiments performed upon crustaceans except such as come within the more limited field of regeneration. There is evidence, however, that either different quantities of oxygen or differences in amount of the products of metabolism cause marked variation in the rate of reproduction of *Daphnia magna*.[14] There is also much evidence that among the Daphnias important changes in the life cycle may be artificially induced. These creatures may be made to continue parthenogenetic reproduction into the winter if kept in a warm place.

According to Irvine and Woodhead crabs can not produce their shells if they are allowed to grow in sea water from which chloride of calcium has been excluded, even if sulphate of lime and chloride of sodium are present. Chloride of calcium is absolutely essential for

[13] "Regeneration," Leipzig und Wein, 1909, Tafel XVI. Przibram here, in a chart, shows the general decrease in *regenerative power* with increase in phylogenetic and ontogenetic stages, but does not treat of other aspects of modification.

[14] Warren, *Q. J. Microsc. Society*, Vol. 43, p. 212, 1900.

[15] Morgan, "Exp. Zool.," pp. 312, 336.

the formation of the crab-shell. This, however, is not the case in the formation of the egg-shell of birds. To quote de Varigny, page 202:

When laying hens are deprived of carbonate of lime by being shut into a room lined throughout with wood, without sand or soil, they are able to lay normal eggs, provided with the usual shell, if sulphate of lime is given them in their food. It follows that when the hen's organism does not receive carbonate of lime, as is usually the case, it is able to transform sulphate into carbonate.

De Varigny then says that other animals offer the reverse instance and alludes to the facts about the crab-shell, but does not see that this apparent contradiction is in any way associated with the great differences in organic complexity between the two animals, or that similar environmental changes have here produced a marked difference in the end product in the case of the lower creature and nothing in the case of the higher.

But these experiments are overshowed, and the great plasticity of this group of invertebrates is chiefly shown by the powers of regeneration which they possess. Experiments showing remarkable regenerative powers of the claws of lobsters, shrimps, crabs, crayfish, etc., are well known, and may be found described at length in any text-book dealing with the subject. In this respect they stand, according to Przibram, about on a level with the mollusks.

Insects

As soon as our review brings us to this highly differentiated group of invertebrates we see for the first time the fact that remarkable modifications are now chiefly associated with changes in the integument, especially changes of pigmentation. Profound modifications of a structural sort, and marked differences in body size are no longer met with.

We find, however, that changes in the surrounding temperature, and changes in food, affect the length of time occupied in the different stages of development of *Lepidoptera;* but in the end the result appears to be the same as under normal conditions. Morgan says: "The moth is identical with the normal," and at the end of his description of these experiments quotes the following: "What the insect gains in the larval stage it loses in the pupa stage."[16]

Some change in the size of the wings of the adult imago is another modification of an unimportant sort, and noted by Standfuss as a result of raising and lowering the external temperature during the larval period.

For example, a pair of *A. fasciata,* of which the wings measured, respectively, 46 and 48 mm. across, produced three specimens measuring only 36 to 39 mm., when the larval stage was reduced to 68 to 87 days, and the pupal to

[16] "Experimental Zool.," p. 314.

15 to 20 days, by subjection to a temperature of 25° to 30°. On the other hand, some eggs from the same original pair of *A. fasciata*, which, though exposed to the same high temperature, developed more slowly—the larval period taking 142 to 163 days, and the pupal 25 to 31 days—yielding specimens having a wing measurement of 55 to 57 mm.[17]

It will be seen that these variations are not so great as those among plants or among snails.

There is, nevertheless, one very striking and curious kind of permanent modification possible among insects. I refer to the artificial production of royal couples among ants, and also to the production of queens among bees, both brought about by differences in the food supply. It would appear that the factor which determines whether a young female bee becomes a queen or a worker is whether she is, or is not, fed upon the royal food. In the case of ants this is not so clear, for the results may depend largely upon original differences in the eggs. Even if these transformations are brought about solely by environmental alterations they need not have much bearing on the present discussion, since this unusual possibility is of adaptive value to the species and may have been especially evolved and maintained. This is utilized by the insects themselves, "If an old queen dies, or if by accident all the prospective queens have been lost."[18]

Experiments which bring about changes in the life-cycle, and also those which produce parthenogenesis in insects which are normally sexual, can not be considered surprising. As to changes in the life-cycle, the case of the rose aphid is a good illustration. This insect produces parthenogenetically female offspring during the summer months, and normally on the appearance of winter begins to produce both males and females. This winter condition may be indefinitely postponed if the animals are kept in a suitable environment with plenty of food and water. Here we are not witnessing a profound modification, but only the failure of a certain normal change to take place in the failure of its normal stimulus.

Quite separate and different from this is the question of producing segmentation and growth in an unfertilized egg by some artificial chemical or physical means. This is called artificial parthenogenesis, and to have any special bearing on the present discussion must be produced in eggs that normally require fertilization by spermatozoa. The silkworm happened to be one of the first of the invertebrates to lend itself to this form of modification. "In 1886 Tichomiroff published the fact that the unfertilized eggs of the silkworm *Bombyx mori,* can be caused to develop by rubbing them gently with a brush, or by putting them for a short time into concentrated sulphuric acid."[19]

[17] Vernon, "Variations," p. 230.

[18] See Morgan, "Exp. Zool.," pp. 317–320; and Vernon, p. 287.

[19] Loeb, "Dynamics," p. 165.

We can not, however, consider this more than a slight alteration from the normal condition for two reasons. First, because the silkworm is closely allied to forms of moths in which parthenogenesis is normal; and second, because, as Loeb states, "Siebold had already mentioned, and Nussbaum confirmed his observations, that a small number of such eggs develop without these means." This is about the last we shall hear of artificial parthenogenesis, as our review takes us higher and higher in the organic scale of evolution. The results of such attempts as have been made to induce this form of modification among the vertebrates have been very unsatisfactory. Nothing can be made to develop beyond the segmentation stage.

Some experiments like those of Dorfmeister, Weismann, Eimer, Merrifield and Poulton show the direct results of changes in temperature, food and even the color of the surroundings; but these affect the character of the pigmentation in these normally highly pigmented forms, and we shall see, as we go higher in phylogeny, that pigmentation is one of the easiest characters to alter through environmental differences.

Regeneration experiments are naturally not numerous on the bodies of insects, for practical reasons, but their power to regenerate lost legs and wings falls in line with our generalization. The legs of the lower insects, like the walking-stick and cockroaches, will grow again if amputated, the legs of the higher insects, butterflies, ants, bees and wasps, not so well. Larval insects are placed by Przibram about on a par with adult mollusks, leeches and fishes, and a little behind Amphioxus as far as general power of regeneration is concerned. Insects in the final or adult stage are placed in the highest class along with mammals and birds, but since adult mammals and birds can not regenerate lost limbs[20] it seems as if further subdivision might have been made. Experiments which consist of grafting parts of different species on to one another are possible among insects at least during the pupal stage.[21] But the "integumentary organs" alone show successful union.

There is one way in which insects appear to show less modification than the vertebrates. Removal of the sexual glands from birds and mammals produces, as is well known, certain marked anatomical and physiological changes. These are supposed to be due to the cessation of an internal secretion which the gland normally produces. Removal of the sexual glands from insects does not cause changes in the secondary sexual characters. It seems fair to assume that this is because the sexual glands of insects do not produce any internal secretion. If

[20] "Experimental Zool.," "Regeneration," Taf. XVI. Die höchsten Formen regeneriern bloss Gewebsdefekte und ungegliederte einfache Hautbildungen (Schnäble, Insektenflügel). For aid in interpreting experiments on insects I am also indebted to Professor W. M. Wheeler.

[21] Morgan, "Exp. Zool.," p. 301.

this is true we should not expect any changes in the other organs of the body, since these other organs have not experienced any change from their normal environment. If, on the other hand, the environment is actually and certainly changed, as is the case when caterpillars are fed on different kinds of food, the variations associated with sex may, to a certain extent, be artificially induced.[22] It is very doubtful if the vertebrates will permit any such modification of sexual differences by changes in their diet.

Fishes

One of the first points noticed in looking over the results of modification experiments on fishes is that the total number of such experiments is significantly small. There is little to record that can in any way be considered striking or interesting as bearing on the present discussion.

If the under surface of flounders is exposed to light during the growth of the fish the side which is normally white will become pigmented like the upper side, though not so much so.[23] Here we see that what is perhaps the most striking modification produced in a fish is concerned merely in a change of pigmentation, which is probably always one of the easiest changes to bring about.

In hatcheries, it is sometimes desirable to retard the growth of fishes for commercial reasons. The experiments of Meyer, Earll, Rice and others show that lowering the temperature of the water lengthens the interval between fertilization and hatching to about a month. There are no further facts to show whether the fishes are permanently modified thereby. Presumably they are normal in the end, as is the case with retarded insects and frogs. Fishes show good regenerative powers and in accordance with their phylogenetic rank.

Fishes and frogs will not endure the high atmospheric pressure experiments that can be brought to bear upon low invertebrates without loss of life. Although the lower forms which submit to these high pressures (200 to 600 atmospheres) are only temporarily modified and afterwards regain their normal proportions,[24] the facts are significant as showing that higher protoplasm will not submit to the rude and abnormal treatment that the lower will. The higher protoplasm must have its accustomed environment and will not survive if it is ruthlessly forced into very unnatural surroundings.

Amphibians

Within this group one finds modifications brought about by differences in temperature, light, gravity, salt, electricity, atmospheric pres-

[22] Morgan, "Exp. Zool.," p. 437.
[23] Vernon, "Variation," p. 25.
[24] De Varigny, pp. 192–193.

sure and food. Experiments with differences of temperature cause merely differences in the rate of growth. These were first performed by Higginbottom some sixty years ago and have been repeated by O. Hertwig and by Lillie and Knowlton. Cold retards the rate of growth considerably; but the point here is, that if these animals continue to develop at all, the adult forms are not essentially different from the normal. Permanent differences in size, such as are produced in snails and especially in plants, are not effected among the amphibians by differences in amount of heat. Extra high temperatures, or those above the optimum, will often produce abnormalities or monstrosities, such as embryos with double heads or tails, but these do not live.

It is also noteworthy that the latitude for possible manipulation, by the use of high temperatures, is not as great here as among plants. Vernon says, page 228:

> Better instances, of the more and more unfavorable influence of increasing high temperature, are found among plants: as in them the optimum temperature is much further removed from the "maximum" temperature (the highest temperature at which growth can take place at all) than it is in animals.

Light has but little effect upon the growth of amphibians.[25] Gravity, on the other hand, has considerable demonstrable influence on cleavage during the very early stages of the developing egg.[26] This influence of gravity on the growth of amphibians should be contrasted with its far greater effect on plants and hydroids, and also with its probable effect on the developing embryos of mammals, which must here be very slight, if any, judging from the haphazard nature of placental attachments. Gravity may of course play a certain rôle in mammalian embryology in the very youngest stages. Investigation of this question would in the nature of things be very difficult. But even if it does, its influence in the later stages is certainly very slight and, so far as we can see, negligible. My argument is that the modifying influence of gravity is less in higher organisms than it is in lower, and less in older stages of development than it is in younger.

The effect of changes in salinity and density of the water in which frogs are developing are in general similar to those involving changes in the temperature. Retardation of the *rate* of growth may be brought about, but the evidence is lacking to show that the animals are any different in the end. It is of interest to note that in this connection there is something that might be thought contradictory to the generalization which I am making. H. de Varigny who has himself experimented upon the effect of introducing common salt into fresh water where tadpoles are growing, states[27] that it is easier to accustom tad-

[25] Morgan, "Exp. Zool.," pp. 262–263. Vernon, p. 249.

[26] Morgan, "Exp. Zool.," p. 267.

[27] "Exp. Evolution," pp. 189–190.

poles of three weeks of age to withstand an excessive amount of salt than it is younger larvæ.

But it is not my contention that younger stages of ontogeny may not be more sensitive than older ones to certain abnormal external conditions. A young chick is more sensitive to cold than an older one. My contention is that if we wish to produce a modification, which is nevertheless compatible with life, we can succeed best with the younger stages of development and with lower organisms. In this case no life-compatible modification was produced in either case. The younger tadpoles modified, but died. The older ones did not modify, but continued their development in a normal way. The real reason of the difference may here have been that the vital cells of the older tadpoles were better protected by the outer covering (ectoderm), so that the interchange of fluids (osmosis) worked more gradually in these vital cells. In just the same way the cold injures the young chick more, because from the absence of feathers, the same degree of cold reaches his vital organs more suddenly.

Experiments involving the effects of electricity on the growth of frogs' eggs are not of any special significance. They produce changes in the arrangement of the pigment and sometimes abnormal cleavage, or abnormal development. Differences of atmospheric pressure (presumably really differences in the amount of oxygen absorbed by the water) cause differences in the *rate* of growth. The researches of Rauber[28] show that

> At a pressure of three atmospheres no growth occurred. At a pressure of two atmospheres growth was slower than at the normal pressure. At three fourths of an atmosphere death generally occurred. Thus the optimum condition of oxygen tension is near the normal of the atmospheric.

This certainly can not be considered a surprising discovery, nor have the experimenters produced any appreciable modification on amphibians by means of differences in the amount of oxygen.

The development of tadpoles can be considerably retarded by scanty feeding, so that they may be kept in the gill-breathing stage for over a year; but if they survive they still retain their potentialities for becoming normal adults. This is shown by an interesting experiment of de Varigny's. He describes it thus:

> I have myself kept toads in the tadpole state for over two years, merely by feeding them very scantily. They were born in the spring of 1889, and remained all the time in an aquarium in the laboratory, having water enough at their disposal, being always sufficiently provided with aquatic plants, and enjoying heat enough; but it can by no means be said that their evolution was arrested by the cold of winter, as often happens in mountain ponds, when the cold of autumn sets in before the tadpoles have achieved their development, so that they become frogs or toads only in the course of the following year. In the

[28] Davenport, "Exp. Morph.," p. 306.

case of my tadpoles, it seemed that the completion of development was due to my imprudently feeding them in spring of 1891 on the very substantial flesh of their congeners; and in the course of some three weeks at most the limbs were evolved, the long tail disappeared gradually, the very color and appearance of the skin underwent considerable change, and my superannuated tadpoles became toads at last.

Modifications of this sort are shown in the experiments of Kammer.[29] *Salamandra atra* acquires yellowish white spots through higher temperature and moisture. Low temperature and dry conditions make *Salamandra maculosa* more black in color with a diminution of the yellow spots.

The amphibians show good powers of regeneration, but their faculty in this direction is neither more nor less than is warranted by their position in the phylogenetic scale. This is well indicated by Przibram.[30] In their younger and lower types they belong in the fourth class of animals, or those which can regenerate not only the tail, but also limbs, sense organs and other portions of the body as long as the central nervous system is not removed. More adult and higher types lose some of this power and then may regenerate the tail only or only certain tissues.

The general conclusion from all these experiments on amphibians involving artificially induced changes in the condition of temperature, light, gravity, salt, electricity, oxygen and food is that when we arrive as high in the phylogenetic scale as the amphibians very little can be done to permanently modify the predetermined forces of the germ-plasm. As among fishes the most striking permanent changes are concerned with the pigmentation.

Reptiles

In powers of regeneration the reptiles show their higher phylogenetic rank. The lizard can regenerate the tail, but not the limbs. It is interesting that the new tail is not composed of bones, but is a cartilaginous tube attached to the half of the broken seventh caudal vertebra.[31] Snakes and turtles will not regenerate their tails.

Modification experiments, other than those concerning regeneration, are not numerous or suggestive. I find only reference to the well-known pigmental response of the chameleon.

Birds

As we ascend the scale we not only find that modification experiments are less striking in character, but also find fewer experiments recorded. Noteworthy modifications of birds are almost entirely con-

[29] *Arch. für Entwickelungs Mechanik*, XVII., pp. 165–264.

[30] "Regeneration," Leipzig, 1909, Taf. XVI.

[31] Morgan, "Regeneration," pp. 6, 198.

cerned with questions of their plumage, and especially with the coloration of the same. A good summary of this knowledge is contained in Vernon.[32]

The effects of certain foods on the plumage of birds is well known to bird fanciers. Thus, hemp-seed causes bull-finches and certain other birds to become black. Cayenne pepper mixed with the food changes the yellow color to an orange red. This color change can only be effected by feeding the very young birds; with adults there is no effect whatever. Sauermann found that all races are not equally susceptible to the abnormal diet, some being changed to crimson, others to a beautiful orange, whilst others remain absolutely unaffected. He found also that canaries are not alone in their susceptibility, for on feeding some white Italian fowls, eight weeks old, with the pepper, orange stripes appeared on the breast feathers, and the breast had become red. One other fowl also developed a red breast, but the remaining ten showed no change whatever. The doses of Cayenne pepper given were enormous (50 gm. daily), so that the conditions were absolutely unnatural.

More remarkable than these observations are the facts ascertained by A. R. Wallace, and communicated by him to Darwin. Thus he states that

The natives of the Amazonian region feed the common green parrot (*Chrysotis festiva*) with the fat of large Siluroid, fishes, and the birds thus treated become beautifully variegated with red and yellow feathers. In the Malayan archipelago the natives of Gilolo alter in an analogous manner the colors of another parrot, namely, the *Lorius garrulus*, and thus produce the *Lori rajah* or King Lory.

Artificially produced alterations in the pigmentation of American birds are shown by the experiments of C. W. Beebe.[33] These experiments demonstrate that the effect of a very humid atmosphere is to increase the dark pigment in the three species studied, namely, the wood thrush, the white-throated sparrow and the inca dove. Beebe mentions that in a state of nature, where the dark forms have been isolated by geographical barriers (and where, of course, natural selection, or other adaptive forces, have been at work for generations), other structural differences are to be found. "With this darkening of the skin structure is frequently correlated a distinction in point of size, either of the body and skeleton as a whole or superficially, as of larger or shorter feathers of the wings or tail." Since Beebe mentions no structural changes of the body as a result of his *artificially* produced humidity, one infers that the changes were confined to the pigmentations.

In the early stages of embryogeny, heat and light, especially heat, affect the rate of development,[34] but there is nothing, as far as I know,

[32] "Variation in Animals and Plants," pp. 293–294.

[33] Amer. Breeders' Assn., Vol. V., 1909, pp. 392–394.

[34] Morgan, "Exp. Zool.," pp. 261, 262, 459; and Davenport, "Exp. Morph.," p. 459.

to show that the birds when adults exhibit any variation as a result of all these manipulations.

It is noticeable that the range of temperature (within which any growth is possible) is more restricted for birds than it is for the lower animals.

The comparative difficulty of producing a modification in birds is exemplified, in another interesting way, in the elasticity which the hen possesses of producing a shell when carbonate of lime is absent. This was referred to earlier in this article when commenting on the modification produced in crab-shells.

Regenerative powers, as is well known, are very slight in birds. In two forms at least, the stork and the fighting cock, the beak will regenerate. This fact[35] has been discussed by Weismann and others in connection with the theory of "regeneration and liability to injury," but it does not appear to have been noted that the beak is an integumentary structure and that of all tissues the epidermis is one of the easiest to modify. Neither the wings nor feet of birds will regenerate.

Mammals

In mammals, as in birds, the chief modifications are concerned with the skin and its appendages.

There is good evidence that changes in climatic surroundings directly affect the color of the hair of some of the mammalia, though at the same time it is evident that others remain unchanged. To a certain extent the white winter coat of the Hudson Bay lemming, and changes in the coloration of hares and rabbits, must be due to direct influence of temperature.[36] Many arctic animals, however, do not change their coat color with the season. Changes in the amount and quality of the hair of various quadrupeds on transportation from one part of the world to another are abundantly recorded.[37]

Other well-known modifications associated with the integument are thickening of the human epidermis by pressure and friction, and darkening of the skin by the action of the sun's rays. The effect of sunlight on the higher animals appears, however, in regard to the vital functions, to be merely superficial. We have, for example, many instances where prisoners have spent long lives in darkness or have perhaps been freed after years of confinement and have then resumed their normal activities. Working mules have been kept in mines for long periods of time, as much as twenty years, "and beyond temporary sensitiveness of the eyes no effect was perceptible."[38]

[35] Morgan, "Regeneration," pp. 95, 97, 106.

[36] Vernon, pp. 243, 330, 331. Morgan, "Exp. Zool.," p. 13.

[37] De Varigny, pp. 88–91.

[38] E. Davenport, "Principles of Breeding," p. 244.

On the other hand, it is said that arctic explorers experience sluggishness of the mind during the long winter night, as a direct result of the darkness. I do not know how far this is true, but in order to show that this is contradictory to my generalization it would be necessary to prove that the effect is greater upon the minds of men than upon the minds of domestic animals, and greater upon the minds of the leaders of the parties than upon the crews. It would seem improbable that such is the case. Moreover, I am informed by Captain Bartlett of the *Roosevelt,* that if the men are busy with duties, and if their minds are occupied to the usual extent, no such depressions occur.

With regard to the influences of direct contact on different tissues, I have already noted that pressure produces an easy modification upon the outer skin. Prolonged pressure will also produce noticeable changes in the shapes of growing mammalian bones, but it is probable that even greater modifications might be produced on the skeletons of lower animals. Normally, bone like the epidermis is being constantly remade by proliferation of young cells from the growing layers. In this respect it differs from nerve tissue, the cells of which cease division in early embryonic life.

Boas has recently announced that he has found evidence that the head forms of the children of Hebrew and Sicilian immigrants who come to the United States tend to approach the American type, as a direct result of some mysterious influence of the environment. This he assumes to be of suggestive value to the psychologist and sociologist. He fails to take into account the great anatomical and embryological differences between bone tissue and cerebral nerve tissue. The real deduction from all this work (if indeed it should be confirmed) is that it is easier to modify a bone than it is a brain.

If we consider the effects of different kinds of feeding upon higher animals, as contrasted with the lower, it is evident that the modifications brought about in this way are much less striking among the higher. The linear dimensions of lower organisms may be altered from two to twenty fold. On the other hand, there appears to be an inherent tendency for mammals to grow to a certain definite size within narrow limits. Minot[39] has shown that the *rate* of growth of guinea-pigs may be artificially altered, but that there is nevertheless a strong tendency for guinea-pigs to grow to a certain size, and that they make up in later stages what they lose in the younger; or if there is an extra increment in the younger stages this is compensated for, later on. This is confirmed by F. B. Sumner for the white mouse.[40] Our general knowledge concerning human twins supports this view. Very fre-

[39] "Senescence and Rejuvenation," *Journal of Physiology.* Vol. XII., No. 2, 1891.

[40] *Jour. of Experimental Zool.*, 1909.

quently twins differ much in size at the time of their birth, even when they are afterwards known as "identical twins" and are difficult to distinguish apart. The puny twin must have been at a disadvantage during uterine life, but this has no permanent effect and is all made up in the end.

It is well known that lecithin given in small quantities in the food will increase the rate of growth of mammals. But it has not been shown, as far as I know, that the ultimate sizes of the adults are thereby made to vary. Let us see what proportionate change in rate of growth has been effected by experiments of this sort.

The communications of Hatai[41] shows that guinea-pigs, rabbits, dogs and rats, after from one to two months' treatment with lecithin, have their rate of growth so altered that the amount of growth is increased from 1.29 to 4.60 times the normal growth during this period. The total weight of the animals is, however, but slightly increased. The animals are merely rendered about two to five per cent. heavier than they normally would have been during the same period of time. Hatai, in referring to the experiments of Danilewski on the eggs of frogs, states that frogs' eggs placed in water containing 1 to 1,500 by weight of lecithin, gained in fifty-four days, 300 per cent. more in weight than those reared in ordinary water.

This would give one the impression that the changes were about the same in ratio for mammals as for tadpoles since the amount of actual additional growth in mammals may be fully three times as much with lecithin as without it. On looking up Danilewski's[42] original paper I find, first that the proportion of lecithin used was not 1 to 1,500 but 1 to 15,000 for the frogs; and second, what is more important, that the gain of 300 per cent. refers not to the portion gained during the interval when lecithin was given, but to the total weight of the organisms. Thus tadpoles may be made to vary 300 per cent. of their *total weight,* mammals about two to five per cent. At the same time it seems that the tadpoles are nearly doubled in linear dimensions. It is evident that the mammals are but slightly altered in linear dimensions.

Thus the experimental work of biologists indicates, when we take a comparative bird's-eye view of modification, that environment will be found to be working upon human brain and nerve tissue at its minimum of efficaciousness. Let us see what direct statistical experience has to say on this important problem.

Mental and Moral Traits

The direct researches which have essayed to separate the environment and heredity factors in the higher human traits, and measure

[41] "The Effect of Lecithin on the Growth of the White Rat," *Amer. Journal of Physiology,* 1904.

[42] *Comptes Rendus,* CXXI., 1895.

approximately their relative influence, are all in substantial agreement. The first light thrown on this question comes from Galton's "History of Twins,"[43] published as long ago as 1883. The traits under discussion were physical resemblances, diseases, mannerisms of action, mental disposition, temperament and tastes. The data are not given in completeness, nor in statistical form, but the conclusion seemed to him warranted that, as regards such mental and physical differences as were under discussion, nature prevails strongly over nurture, within the limits which Galton is careful to assign to the latter. This belief was arrived at from a comparison of thirty-five pairs of very similar twins with twenty pairs of dissimilar twins.

Those twins who were similar when young remained so in general, as they grew older; but more significant than this, there appeared to be no tendency for similarities in education and home life to render those originally unlike any more similar with advancing years. The conclusion from Galton's "History of Twins" seemed to be that if the environmental differences are slight no appreciable effect is produced at least upon innate mental differences which are themselves comparatively slight or unimportant, such as differences in tastes, temperament and disposition. This would of course not prove that the more important human differences, such as are represented by success or failure, vices and virtues, are not profoundly modified by environment if the differences in surroundings are considerable.

The history of royalty offers just these remarkably wide differences of an environmental nature. This is somewhat surprising because one might assume that the surroundings would be uniformly superior, as all are of the highest social rank. But for various reasons the individuals have developed under the greatest variety of good and bad influences as regards the atmosphere of their home life, their educational advantages, and opportunities for distinction. Besides, they have lived in different countries and in different eras. Yet, in spite of the fact that the environments show wide variations, these appear to be negligible factors in the production of successful achievement or in the creation of virtuous or vicious types.

That successful achievement is almost entirely due to differences in germ-plasm and is little influenced by environment is the necessary conclusion from the complete analysis of two separate groups of royalty. One of these is the great interrelated group of 3,312 distinct persons in Lehr's Genealogy. This book contains many repeated names, because the same individual appears as an ancestor of different lines, owing to intermarriages. Thus the total number of cases for statistical purposes is much greater than 3,312. It is in fact 32,768, for this book contains eight "families" with 4,096 in each family. Out of the 3,312 different persons there were sixteen who came up to

[43] "Inquiries into Human Faculty," 1883, pp. 216–243.

a certain objective standard of distinction and 3,296 failed to do so. The environmental influences must have been mostly distributed at random throughout the group. Yet this did not cause any random distribution of the distinguished persons. Fifteen out of the sixteen were closely related to other distinguished persons.

The second group of royalty contained all the close connections of twenty-three reigning historical dynasties. This group was obtained by a different method, but in part overlaps the other group. Here detailed analysis was made not only of the question of intellectual distinction but of mental and moral variations. Environment was shown to be of little or no consequence in the production of important differences.[44]

The third research to appear on the problem of nature *versus* nurture is that of E. L. Thorndike,[45] on the origin of mental differences among children attending the public schools in the city of New York. Thorndike, like Galton, used the records of twins to support his argument, but went into the matter with far greater scientific analysis and published all the details of his measurements. He presents:

> (1) The results of precise measurements of fifty pairs of twins from 9 to 15 years old in [eight physical and] six mental traits and (2) their bearing upon the comparative importance of heredity and environment as causes of human differences in intellectual achievement. They will be found to give well-nigh conclusive evidence that the mental likenesses found in the case of twins and the differences found in the case of non-fraternal pairs, when the individuals compared belong to the same age, locality and educational system, are due, to at least nine-tenths of their amount, to original nature.

In concluding his research Thorndike says:

> It shows such likeness and differences in environment as act upon children living in New York City and attending its public schools are utterly inadequate to explain the likenesses and differences found in the traits measured, and are in all probability inadequate to explain more than a small fraction of them. The arguments concerned the lack of differences in the amount of resemblance (1) between young and old twins, (2) between traits little and traits much subject to training and (3) between mental and physical traits, and also the great increase in resemblances of twins over ordinary siblings [brothers and sisters].

Thorndike's research appears to be very conclusive and confirmatory as far as it goes. Of course one might contend that after all the

[44] For the arguments which support this belief see POPULAR SCIENCE MONTHLY, August, 1902–April, 1903 (Vol. LXI., pp. 375, 453, 455, 457, 507, 508; Vol. LXII., pp. 84, 268, 423, 426, 497, 500–503). Same in reprinted form, pp. 9, 17, 19, 21, 26, 27, 41, 65, 73, 76, 79, 82–85. Additional arguments of a generalized nature may be found in "Mental and Moral Heredity in Royalty: a Statistical Study in History and Psychology." New York, Henry Holt, 1906, pp. 276–298. The arguments drawn from intensive analysis of small groups may be found on pp. 6, 56, 81, 119, 123, 170, 222, 224, 231, 246–247, 248–249, 253–254, 271.

[45] "Measurements of Twins," *Arch. of Philosophy, Psychology and Scientific Methods*, New York, The Science Press, 1905, pp. 64.

environmental differences which are experienced by children in the public schools of New York are not very great and that the traits concerned are not really important ones. Such important traits as normal healthy body and mind for a long life of valuable achievement, and a clean bill of character, can only be determined as present or absent, in their varying amounts, after the race of life has been completely or nearly run, and the records of success or failure, of distinction or obscurity, of vices or virtues, have been left behind. The boy is father to the man but our knowledge of biometry already teaches us that this does not mean identity; it merely means a correlation.

The study of children may lead us to wrong conclusions for other reasons. It has already been shown in this article that, other things equal, the young can be more easily affected by surroundings than the adult, and also that there is a great tendency for the higher organisms to equalize in time what they have gained or lost in youth, and to grow after a predetermined plan. For these reasons even the discovery of actual modifications produced among children would not show that the grown men and women, who will be freer to pick and choose their congenial environment, will not follow the same paths that they otherwise would have done.

Pearson and his pupils have recently attempted, by the comparative study of children, to differentiate between the relative influence of heredity and environment. Their results are confirmatory for the special traits studied. In a memoir on vision and sight[46] the authors write as follows, with regard to the effects of environment.

> As far as the admittedly slender data of this first study reach, there is: (1) No evidence whatever that overcrowded, poverty stricken homes, or physically ill-conditioned or immoral parentages are *markedly* detrimental to the children's eye-sight. (2) No sufficient or definite evidence that school environment has a detrimental effect on the eye-sight of the children.

At the close of the paper the authors make the surprising statement that their own research is "the first eugenic study which has endeavored to compare the inheritance and environment factors. We anticipated finding them to be far more comparable in magnitude." If the authors had read a little of the earlier researches on the question of the relative influence of heredity and environment they would neither have spoken of their own eugenic study as the first nor have expressed wonderment at the result.

In "The Relative Strength of Nurture and Nature," Ethel M. Elderton[47] analyzes the above investigation on the eye-sight of children, and also her own study on "The Influence of Parental Occupation and

[46] Amy Barrington and Karl Pearson, "A First Study of the Inheritance of Vision and the Relative Influence of Heredity and Environment on Sight," London, 1909, pp. 61.

[47] "Eugenics Laboratory Lecture," Series III., London, Dulau & Co., 1909.

Habit on the Welfare of the Offspring," together with a research of Heron's on "The Influence of Home Environment and Defective Physique on the Intelligence of School Children." These researches "show clearly the small influence of environment." The author on page 28 writes:

> The whole subject of the influence of environment, owing to its complexity, is a fascinating one, partly because we are only just beginning to apply modern statistical methods to this side of eugenics, and the results we obtain are often very unexpected, perhaps we may say wholly contrary to current belief.

That they are contrary to current belief I do not deny, but to say that they are unexpected shows little grasp of the whole biological question of modification or knowledge of results of earlier workers. In fact it will be very surprising if any one succeeds in demonstrating an important environmental control acting on psychological differences, exhibited in mental and moral traits. All the evidence that we possess renders it highly improbable that any of the ordinary differences in human environment, such as riches or poverty, good or bad home life, have more than a very slight effect in modifying these complex and high organic functions the improvement of which is the hope of the altruist and the reformer. Not only do the collected facts indicate as much, but the reasons for the same are not difficult to understand if we consider the laws of diminishing environmental control.

Each organism, whether high or low in the scale of evolution, has from the time of conception and beginning of cell-division and segmentation onward through embryonic and post-embryonic life an *expected* environment. In other words, it *expects* to develop and live under conditions which are essentially similar to those which surrounded its immediate ancestors at each stage of *their* career.[48]

If the expected environment is altered, then the modification which will accrue will in general diminish, (1) in proportion as the change from the expected is less and less in amount. This will follow as a

[48] Since writing this I have received a letter from a distinguished student of heredity containing some remarks on the question of environment *versus* inheritance. This gentleman, like so many others, does not see that although a result may be due to a complexity of forces we may, nevertheless, measure the relative value of the different components. I refer him, for his encouragement, to the opening chapters of any text-book on physics where the "Laws of Motion," "Parallelogram of Forces" etc., suggest helpful analogies. One illustration which the correspondent gives may serve to make my own standpoint clearer if I answer it here. He says "the question of whether nature or nurture plays the greater part does not arise. As well might we ask whether the locomotive or the steam plays the greater part in transporting the train." My answer is, that by all the needs of a suffering humanity or the development of a rational understanding of the present, past or future of this same species, *Homo sapiens*, the question does arise; and second that the illustration from the locomotive will do as well as any other. Here, it is the locomotive, not the

matter of course. Its only interest for us lies in the fact that most alterations in the surroundings that are brought to bear upon human beings are probably not very great in actual differences. They are at least not great in comparison with the experiments of the botanist and zoologist. (2) Environmental influence diminishes with increased phylogenetic rank. (3) Environmental influence diminishes with the evolutionary rank of the tissue affected. (4) Environmental influence diminishes in proportion to the age of the tissue affected. The contents of this paper have been chiefly brought forward to support these second, third and fourth laws. Artificial modification then appears to be easiest upon tissues that are either young or simple, or in a condition of cell subdivision and growth. It must be remembered that the brain-cells, even of a child, are, of all tissues, farthest removed from any of these primordial states. The cells of the brain ceased subdivision long before birth. Therefore, *a priori,* we must expect relatively little modification of brain function. We next have to consider the question of the possibility of escape on the part of the organism from a novel and perhaps unwelcome environment into its natural one again. (5) Environmental influence diminishes with the organism's power of choice. This may be the chief reason why human beings, who of all creatures have the greatest power to choose the surroundings congenial to their special needs and natures, are so little affected by outward conditions. The occasional able, ambitious and determined member of an obscure or degenerate family *can* get free from his uncongenial associates. So can the weak or lazy or vicious (even if a black sheep from the finest fold) easily find his natural haunts.

In psychological matters we are dealing with a totally different class of cases from the zoological experiments referred to in this paper. It is a point often forgotten, yet one that should be constantly born in mind, that there are these two kinds of environment from the standpoint of an organism. There are surroundings from which there is no escape, let the creature try his best, and there are also environments from which escape is possible if the inheritant desires impel it. All the modifications on lower animals alluded to in this article are of the first kind, or have been brought about by imposed conditions from which there was no escape. Psychological environment can scarcely be placed in the same category. Therefore the inference is that not only is the brain little influenced by surroundings owing to its high

steam, which is the essential thing. The purchasing agent pays the highest prices for the very best machine because he knows that having got his best machine he can easily get his fuel and his water. *He expects* to get these. These form the expected environment which may differ some in quality and effect, but after all, from the practical standpoint, the essential thing is the quality of the machine. It is just so with the human mind. Nature is the great decider because nurture is expected.

organic rank, but also because most of the varying environments within any one civilization are not absolutely imposed upon the individual, as are experiments upon the lower organisms. This is not meant to imply that differences between one historical age and another, or any other imposed environment from which there is no escape, may not be found of considerable importance in relation to certain sociological and historical facts. For instance, the total number of eminent men in western Europe probably increases too rapidly from the fourteenth century to the sixteenth not to be in part due to the force of circumstances.[49] Also I have statistics in the course of compilation which indicate that there is evidence that women are advancing in noteworthiness of achievement in the United States with each elapsed decade. These imposed and unescapable conditions, which change with the course of history and affect entire races or great groups of people, must be clearly distinguished from the class of environments that exist within any one age and in any one state of civilization.

There are doubtless other ways in which man and other mammals are directly modified by their environment in an essential and lasting way, but to enter into a discussion of these questions is useless in connection with this generalization. Such are the modifications produced by poisons, diseases of a bacterial or other nature, which the individual accidentally encounters. The necessary knowledge has not yet been gained for any generalization, from a comparative point of view, in regard to these complicated processes, so that we should be able to say that these changed conditions affect higher organisms more than lower Moreover, the same poison may be for one kind of protoplasm a great change and for another a slight one, and we have already seen that the proportionate amount of change in the outward conditions is necessarily of prime importance in determining the end result.

These chemical questions do not fall within the literature contained in text-books of experimental zoology, which, to review and rearrange has been the chief purpose of this article. The entire analogy of such experiments, as well as the results of special studies on the relative influence of heredity and environment, can lead to but one conclusion, and that is, that the value of modification diminishes as evolution proceeds.

I know that to generalize is dangerous and exceptions may be found which seem to conflict with the laws or principles which are here set forth, but often apparent exceptions find explanation in the light of further knowledge. I put these laws forth with some hesitancy, yet feel that enough is known to take a step beyond hypotheses and trust that the future will confirm their essential truth.

[49] This would be the conclusion from Cattell's "Statistical Study of Eminent Men," POPULAR SCIENCE, February, 1903, and Ellis's "Study of British Genius," p. 12.

THE LEADING SCHOOL OF TROPICAL MEDICINE

BY EDWARD NELSON TOBEY, A.M., M.D.

NO plan for improving American medical education has been more widely advocated the past year than the establishment of a department of tropical medicine in our medical schools. Although we now have such possessions in the tropics as Porto Rico, the Canal Zone, the Philippines, the Hawaiian and other islands of the Pacific, not to mention our semi-tropical southern states, instruction in tropical diseases and conditions has not kept pace with the increased need. The founding of a school of tropical medicine in the United States was first suggested by the *Boston Medical and Surgical Journal* in the same year that two schools of tropical medicine were planned for England. Since England was the first to establish such a school, let us look toward that country.

Up from the Jewish quarter of the city, on the crest of Brownlow Hill, stands Liverpool University, famous, as some one has said, for its zoologist, its physiologist and its professor of tropical medicine. Entering beneath the tall Victoria Jubilee Tower with its clock and Latin inscription, and crossing the yard, one comes to the row of buildings containing the Thompson-Yates and Johnston laboratories, the former and present homes of the Liverpool School of Tropical Medicine. It was the work of this institution which caused a New York physician, when describing the advantages a medical student can get abroad, to write, "Liverpool leads in tropical medicine."

Although the school was founded a few months after the plans for its rival in London had been published, it was, nevertheless, the first to begin work. Its opening days were not darkened by any unfortunate incident, yet they were clouded by the lack of those favorable circumstances which have made the London school what it is to-day. The institution at Liverpool was not founded by the government, it had no grant nor assured income, nor even government recognition, hence it could not expect to get as many students as its rival. Some of these obstacles were removed later, yet they were important in determining the lines along which the school must work. A school which could not hope for much through excellence in teaching must look for recognition through research.

The necessity for conducting successful research was met by the appointment of Major Ronald Ross as professor of tropical medicine. The researches of Major Ross prior to his appointment at Liverpool

The University of Liverpool.

had disclosed the life history of the malarial parasite in the mosquito. That the mosquito was in some way connected with malaria was known as early as the fifth century, B.C., when Empedocles, a Greek philosopher of that period, delivered the people of Selinus, Sicily, from a pestilence by draining the neighboring marshes. Yet it was not until 1878, when Sir Patrick Manson observed the presence of the little worm, filaria, in a mosquito that there were any experiments to prove that mosquitoes carry disease.

In 1895, Major Ross, inspired by Manson, began to study the fate of the flagellating bodies which were first observed by the French army-surgeon, Laveran, at Constantine, Algeria. A few years later, being so situated as to be unable to continue his work on human malaria, Ross took up the same line of work in the malaria of birds. In July, 1898, he followed the development of the malarial organism from the pigmented cells found in the stomach of the mosquito to the rod-shaped bodies in the salivary glands. He then exposed birds free from parasites to the bites of such infected mosquitoes, and fourteen days later these birds had parasites in their blood. In this manner were demonstrated the development of the malarial parasites in the mosquito, the mode by which they were transmitted and the fact that not every kind of mosquito will transmit the microscopic animal which causes the disease. Although it was in birds that the complete life-cycle of the organism was first followed, the pigmented cells which were a clue to the discovery were first seen in man.

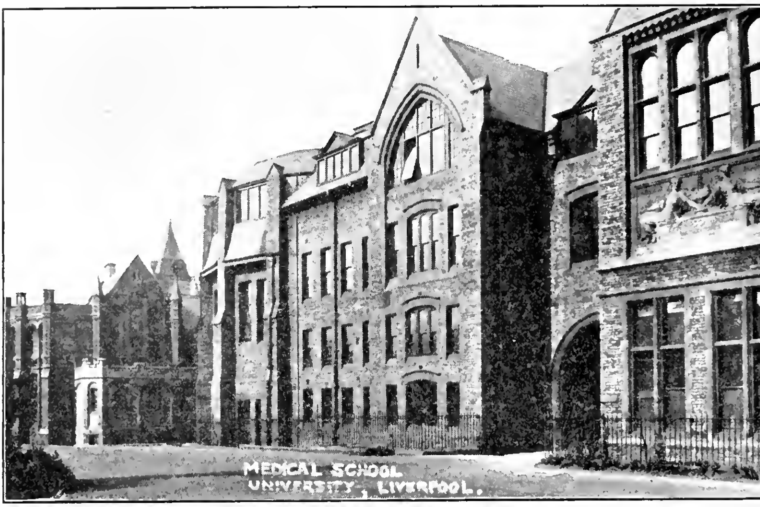
A few months after his appointment at Liverpool, Professor Ross left England for Sierra Leone, Africa, on the first of those expeditions which have made the school famous. The purpose of the expedition was to study still further the subject of malaria, but this time in the human being. Mr. Austen, of the British Museum, accompanied him for the purpose of collecting and studying the various kinds of mosquitoes and noxious insects.

This first malarial expedition was followed by many other such expeditions; and the value of the four measures for the prevention of malaria advocated by Professor Ross may be seen in the results that followed the expedition to Ismailia in 1902. Ismailia is a town of under 6,000 inhabitants, situated close to the Suez Canal and controlled by the Suez Canal Company. The number of cases there rose from 300 in 1877 to 2,250 in 1900. An active campaign of first detecting, isolating and treating the sick; second, segregating the healthy; third, mechanically protecting the well from mosquitoes; and fourth, reducing the number of mosquitoes by drainage or other treatment of their breeding places, begun in 1902, reduced the number of cases from 1548 to 37 in 1905; and all the old cases of 1905 were cases of relapse.

In 1902, Professor Ross received a Nobel prize for his researches on malaria. In 1906, he went on a malaria expedition to Lake Copais, Greece, and in 1907, he was sent at the request of the Government of Mauritius to give advice on the prevention of malaria in that island of the Indian Ocean. It will thus be seen that the work of Professor Ross is not only of scientific value, but thoroughly practical as well.

Another malady closely associated with malaria is blackwater fever. The classical description of this disease has been written by another teacher of this school, Dr. Stephens, who, next to Professor Ross, has done so much to spread a knowledge of malaria and tropical medicine. In 1907, Dr. Nierenstein, a chemist of the school, discovered certain etiological factors in this malady; and in July of the same year, the nineteenth expedition was sent to Africa to study blackwater fever.

A second disease conveyed by mosquitoes is yellow fever, which is distinctly American in origin. Found by Cortez in Mexico and un-



THE MEDICAL SCHOOL OF THE UNIVERSITY OF LIVERPOOL.

known in Europe until after the discovery of America, it has been epidemic many times in the United States, in places ranging from Pensacola to Boston. An excellent account of the last epidemic, which occurred in New Orleans, in 1905, has been written by Sir Rubert Boyce, the Dean of the Liverpool School.

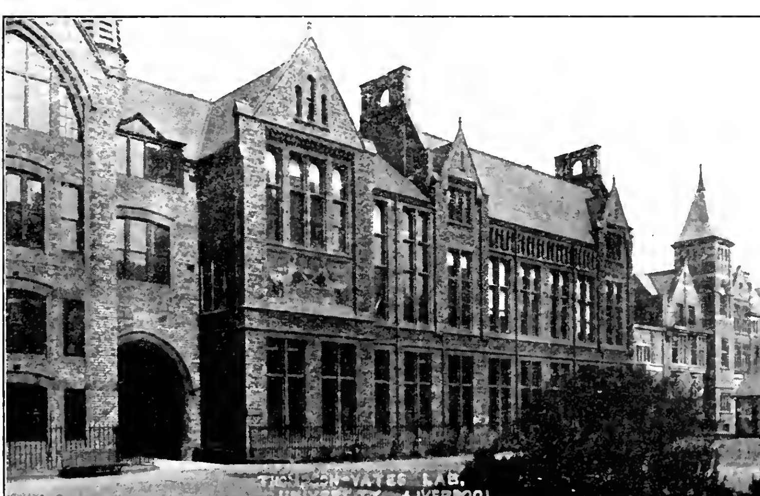
Three expeditions have been sent from Liverpool to study yellow fever, and all the members of both expeditions to Brazil were stricken with the disease. Dr. Walter Meyer, a member of the first expedition, and a young man of great promise, died of the fever. One of the members of the second expedition had a severe attack of the disease, followed by disagreeable and disfiguring complications. His misfortunes did not end here; for, during convalescence, the river boat on which he was being carried sank and he barely escaped with his life, only to meet still further disasters in another land. Dr. Thomas, the other member of this expedition, has succeeded in conveying the disease to the chimpanzee by the bites of infected mosquitoes, thus affording a lower animal to take the place of the human sacrifices made to discover the cause, and also offering a hope for a cure.

A third disease spread by mosquitoes is filariasis, a worm infection of the lymphatics and of the blood. The work of the school in this direction has been to describe a number of new species of filaria found in birds. This work is said to be in large part due to the observations of the late Dr. J. Everett Dutton, who so soon afterward made such important discoveries concerning two diseases of Central Africa.

The first of these African diseases, sleeping sickness, is spread by one of the biting tsetse flies. The cause of the infection, which had escaped detection during a century of its existence known to Europeans, was at last seen by Dr. Forde, in 1901. It was Dutton, however, who first recognized that the little flagellate in the blood of Dr. Forde's patient was a trypanosome, similar to those which cause disease in lower animals. Dutton was the first to give full details regarding the character of the organism, to describe the symptoms produced by it and to give it the name it still holds.

The Liverpool school has sent four expeditions to study sleeping sickness. The experimental work which was carried on in England was begun in 1903 with material brought back from the Gambia by Dutton. At first the researches were conducted in Liverpool, but as the work expanded and the material increased, it became necessary to find a place in the country where the work could be more fittingly carried on. Such a place was found at Crofton Lodge and Cottages in Runcorn, a town sixteen miles from Liverpool. There, in a roomy rambling old country house beside a sunken road, with two tall holly trees guarding the entrance, might be found at one time research workers from India, Russia, Austria, Canada and the United States, who kept at their work from early morning until nearly midnight, and occasionally all night.

The most important experimental work of the laboratories in Liverpool and in Runcorn has been the search for a cure for sleeping sickness. These investigations were begun by Dr. Thomas, who was the first to use and recommend atoxyl, the remedy which Koch used later in Africa with so much temporary success. Although the little animal disappears from the blood and the fever subsides after the use



THOMPSON-YATES LABORATORIES, UNIVERSITY OF LIVERPOOL.

of atoxyl, there is later likely to be a recrudescence; and it was for this reason that two chemists at Liverpool, Professor Benjamin Moore and Dr. Nierenstein, conducted still further research for a better remedy. These men found that although atoxyl killed most of the organisms, a resistant form was able to withstand the action of the drug. A second remedy was then given during this resistant stage, and success seemed assured. The disease may continue for many years, however, so it is too early to know how effective the double remedy is in man.

It is interesting to observe that as in malaria the complete life-cycle of the parasite was first followed in bird malaria; so in sleeping

Crofton Lodge, University of Liverpool.

sickness what is apparently the complete cycle has been worked out in trypanosome infection of the frog. It was observed by Dutton in the Congo that the frog trypanosome undergoes another cycle of development outside the frog; and the recent experiments of Kleine in German East Africa seem to point to another cycle of development of the trypanosome of man in the tsetse fly. Thus the study of infections in lower animals may be of the greatest assistance in solving the problems of disease in man.

The other of these two diseases of Central Africa is tick fever. This infection was first described by Dr. Livingstone, the famous explorer, who found the disease in Portuguese South Africa, and attributed it to the bite of a tick. The discovery that spirochætes could be found in the blood of every patient ill with tick fever was first published by P. H. Ross and Milne, though there has been some doubt whether their work antedated that of Dutton. However, Dutton was not only able to say that the cause of the fever was a spirochæte, but was able to prove by experiment that the spirochæte was conveyed to the healthy subject by the bite of a tick, the *Ornithodoros moubata,* and that the larvæ hatched from eggs laid by an infected tick, could convey the infection at their first feed.

Dutton's work in the Congo, on tick fever, was interrupted by the illness of both members of the expedition. This occurred at the time that Ross and Milne published the results of their discovery in Uganda. In February, 1905, three months later, Dutton died in Africa.

Further experiments were carried on in the laboratories at Runcorn, where it was found that the spirochæte of African tick fever was a new parasite, quite different from a similar organism which causes the relapsing fever of Europe. By common consent this new parasite was called *Spirochæta duttoni,* in honor of the hero who gave his life in an effort to relieve suffering humanity.

Such have been the results gained by the school in a study of five parasitic diseases conveyed by mosquitoes, flies and ticks. There are many other investigations of importance to the physician and scientist, but of less general interest. How valuable the work of the school may be in lines not strictly medical was recently demonstrated in the West Indies by Mr. Newstead, the entomologist of the twenty-first expedition.

This institution, great as it is, has been supported chiefly by annual subscriptions, as the school has no endowment. Foremost among those who have contributed most liberally is Sir Alfred Jones, who founded it. Another benefactor, who has shown his appreciation of the work done in the Congo, is the King of Belgium; and recently the English government has given its support. Much of the work has been planned and the interest in it aroused by the Dean, Sir Rubert Boyce.

This school, in the short space of ten years, has accomplished more than many an older institution.

THE GROWTH OF A LANGUAGE

By Dr. CHARLES W. SUPER

ATHENS, O.

WE now and then come across the statement that Shakespeare uses about fifteen thousand words and that he is the most copious writer in the English language in the matter of vocabulary. It is not difficult to count the number of words in an author after they have been registered in a concordance, but the statement as to Shakespeare's copiousness is misleading if not positively erroneous. It is safe to affirm that Sir Walter Scott employs more words since he has written upon a larger number of subjects. The same statement may also be made of Mr. Gladstone and of others. Besides, the mere number of different words used by an author is no test of his mental capacity, since the same word may have several different meanings and he have occasion to employ it in but one or two. "A bad case," for example, means one thing to a lawyer, another to a physician, still another to the moralist, while "case" unqualified has several more significations according to the context. It is easy to select one thousand words in any large dictionary that have five thousand different meanings. The radical sense of a word is a sort of stem from which all kinds of derivations shoot forth, or upon which they are grafted. Some of these, when used in certain cases or in a figurative sense, have only a remote relation to the original. "Case" in grammar is a good illustration. The Oxford dictionary, as far as completed, embraces, in round numbers 211,000 words. Of this number 130,000 are main words; 34,000 are subordinate words; 25,000 represent special combinations; 21,000 obvious combinations. About one fourth of the entire list is obsolete. Nearly two thousand years ago the poet Horace had noted the tendency of words to drop out of use and of others to come into favor.

> Yes, words long faded may again revive,
> And words may fade, now blooming and alive,
> If usage wills it so, to whom belongs
> The rule, the law, the government of tongues.

The vagaries of usage are past finding out. It is easy to see that when a thing passes out of use the name by which it was known is forgotten except by special students of the past. Readers of medieval history meet with many such. On the other hand, certain forms of words are discarded, current expressions become obsolete, while others are substituted because they embody a new thought and can not be dispensed with. For the former no reason can be given. For example, "afeard" is a more logical form than "afraid" because of its evident connection with fear, but it is no longer considered fit company for refined society. The history of "astun," "astony," "stun," "astonish," affords another instructive example. "Climbed" and "heated" have taken the place of "clomb" and "het," although they are longer and more expressive. Generally speaking those words that are the most used are the most irregular. Our verb of existence —am, was, been—is made up of three different stems. Our grammatical auxiliaries are very defective; the missing parts have to be supplied in various ways. We say "I must" for the present, but we can not say "I musted" for the preterit, nor is there such a verb in English as "to must" although it is found in the Anglo-Saxon. "Might" is usually classed as the preterit of "may," but in many of its uses it is not. In all the languages of the Aryan stock, and in their descendants, we find the same lack of parts and the same alien substitutions. The changes that have taken place within the historic period are just as difficult, in fact just as impossible, to account for as the earlier ones. If languages were constructed according to any system, or even according to the most elementary principles of common sense, they would differ widely from their present status. It may be said in passing that some of the languages of the Turanian stock, notably the Turkish, are to a considerable extent symmetrically built. It used to be said that many words have been modified in obedience to the general law that tends to ease of utterance; but this explanation is no longer accepted. If such a law was ever operative an inexplicable break in the continuity of the human psyche must have taken place at some remote period in the past. Such a break would be at variance with the well-established course of development. It seems probable that human speech originated at three or more points on the surface of the earth. As long as these primitive tongues were left to develop according to their innate laws the process was consistent, if not logical. But when two or more of these original stocks came into conflict, each party trying in its clumsy way to acquire the speech of the other, confusion set in. If ten crassly illiterate Frenchmen and ten equally illiterate Hungarians were placed together where they would be compelled to communicate with each other we may be sure that in two or three generations a language would be produced differing widely from either parent. We have practical examples in the mixture of Norman French and Anglo-Saxon, of Iberian with Latin, and elsewhere, although these instances are not precisely such as I have supposed above.

As the Oxford dictionary is about four sevenths completed, the entire work will include more than 350,000 words. It is claimed by the publishers of the Standard Dictionary that the latest edition contains 317,000 words. How many of these are obsolete or obsolescent can not be determined because it is impossible to draw a hard and fast line. Every successive work of this kind is larger than its predecessor, and the growth is very rapid. This is true not only of English, but of every living tongue, since all are in the process of accretion. And yet no English dictionary claims to include all the vocables that belong to the language, or at least are English. For the outlaws we have special vocabularies of localisms, dialect and vulgar terms, and so forth, which by themselves fill a number of large volumes.

We have an illuminating demonstration of the process by which word-lists grow in the case of certain compounds. In the eleventh English and the first American edition of Johnson the number of compounds with the prefix poly- is twenty-six; in the Century there are more than 550. Johnson gives no compounds with psycho-; the Century furnishes several columns. Lexicographers who aim at completeness can not exclude such compounds, yet many of them can not be classed as strictly a part of our language. With only a slight variation they may be found in the lexicons of every civilized tongue. They form a sort of international code. They are easily understood by every one who knows a little Greek and Latin, the former furnishing by far the largest contingent.

In this connection we are almost involuntarily led to ask the question, How many words does an ordinary man use? How many can he comprehend which he would not venture to use? How many words is the strongest memory capable of retaining? To the first question we have on record several answers. The late Max Müller in one of his lectures reports the testimony of an English clergyman to the effect that some of the agricultural laborers of his parish employed less than a thousand. A recent authority on the Gipsies declares that some of these people living in the villages of Sivas, in Asia Minor, although speaking a language that is clearly related to the Indic branch of the Aryan, do not have in their entire vocabulary more than six hundred words. Testimony of this kind should be received with distrust, although its falsity can not be proved. Some of the statements about the vocabulary of children before the age of five have been shown to be far too low. A person of fair natural ability, but of limited education, can comprehend a long list of vocables which he would not venture to use. There is no doubt that the popular audiences to whom Cicero addressed his Catilinarian orations followed him understandingly and with a fair degree of appreciation, although they were utter strangers to the beauty of his diction. Most persons understand preaching and popular lectures, even when the exact signification of many of the terms used by the speaker is not clear. The general run of the discourse has always a great deal of influence on the meaning of the separate words used by the speaker or writer.

Languages in which a written literature is not much developed, and a people among whom the art of writing is not much in vogue, take the factor of personal presence into account. Men who are familiar with the Turkish have noted a marked difference between its colloquial and its written form. It makes conversational sentences concise to the verge of obscurity, because in case of doubt the speaker can be asked to explain, whereas in writing it almost rejects the use of pronouns of the third person and employs a style like that of legal documents, full of repetitions of nouns coupled with "the said," "the afore mentioned," and so on. Discourses spoken, not read, to popular audiences are usually prolix. Every thought is elaborated; the same idea is presented in a number of different guises, as we may note in preaching, in political harangues, and especially in pleas before juries. How much the personal equation has to do with comprehension is easily realized if we read a drama, or even a monologue, and afterward hear the same from the lips of a competent actor or elocutionist. It is almost like a restoration of the dead to life. The ancient Greeks fully grasped the importance of the spoken word as compared with the dead letter of the written page. Homer's characters talk a great deal. Herodotus brings many of his men and women on the stage and lets them tell their own story. When Thucydides wishes to put before his readers the motives that inspire the different parties in their conflicts with each other he selects a representative of each, and brings him forward that he may present his side of the case in his own person. Plato traverses the whole domain of philosophy; but in order to relieve his doctrines as far as possible of their abstruse character he places before his readers a number of interlocutors in order to give them a lifelike setting. Few persons, when reading a novel, stop to think that the conversations so often reported to have taken place between two persons in strict privacy, or even soliloquies, are absurdly impossible.

The morphology and syntax of the Greek are so varied; their proper management requires such a high degree of grammatical and rhetorical skill; the precise meaning of a passage so often depends upon the nice choice and exact position of a particle; the tone of voice and stress with which it is uttered, that we can readily understand the aversion of those to whom it was native to the cold and lifeless word, even though we can not fully enter into the minutiæ of the causes which prompted the feeling. We have no means of knowing how many words with their definitions the human memory is capable of retaining.

There is, of course, a limit in practise; hardly in theory. The problem is closely related to that of the acquisition of foreign languages. There is not much difference between the ability to read several foreign languages and the ability to define the same number of words in one's own. Although the number of words in the largest English dictionaries seems greatly to exceed that in the standard Greek and Latin lexicons, the difference is apparent rather than real. English dictionaries give every form in which a word may occur, slight variations only being excepted. The so-called irregular verbs fill only a few pages in the English grammars; yet they are usually recorded in the dictionaries. The irregularities of Greek and Latin verbs can, for the most part, not be found in the lexicons, and when recorded separately, make a large book. The latest edition of Stephanus's Greek lexicon fills nine volumes folio and more than ten thousand pages, while the definitive Latin lexicon now in course of publication will be as large as the Oxford dictionary.

Languages grow by incretion as well as by accretion. A new invention or a new discovery may be named by using current words. Thus "steamboat" and "railway" are compounds of obvious meaning because the sense of the constituent parts is already known and is not changed by the combination. It is true, "railway" is slightly misleading. The first tracks were made of wooden rails; when they were replaced with iron the earlier name was retained. In most of the continental languages the term "ironway" is in vogue, as railways were not introduced beyond the channel until wooden rails had been discarded, although the French still employs the monosyllable "rail" in its English sense. But not all words that have been compounded have an obvious signification; one or all of the parts entering into the combination sometimes lose their former meaning. To this class belong such terms as "stirrup-cup," "dog-watch," "monkey-wrench," "man-of-war," "horse-raddish," and many more. A dog-fight is a fight between or among dogs, just as a cock-fight is a duel between two cocks; in a bull-fight the combatants are bulls, horses and men. When the vocabularly of a language grows by accretion it is either by the incorporation of words borrowed from others that designate the same object or by the modification of a foreign word to designate some object previously unknown. To the first class belong paper, parchment, hippopotamus and a host of others. To the second, amœba, protoplasm, biogenesis, bacteria and a long list of technical terms. Horace has observed this process in his day, for he wrote

> New words will find acceptance, if they flow
> Forth from the Greek with just a twist or so.

It is by this method that science has constructed a language which has become, in a sense, international. One needs to know very little Italian, or French, or Spanish, in order to be able to read a scientific work intelligently. The translator of a well-known French medical book once told me that he had a mere smattering of the language, but as he was familiar with the subject he had no difficulty in comprehending the author's meaning. If this man had undertaken to translate selections from French literature or familiar conversation he would have been swamped by the first sentence. When words pass from one language into another they are put through a transforming process before they can be naturalized. The republic of letters is, however, cosmopolitan and nationality counts for little; hence a term that is of interest only to savants needs to undergo but slight changes in order to be accepted everywhere. With popular words the case is different. An instructive example of this double genealogy is our familiar term "alms." It came into the English through the Anglo-Saxon from the Greek, in which language it has six syllables and is fairly well represented by our "eleemosynary," the form coined and introduced by scholars. The shorter word is the result of a gradual abridgment until but one syllable remains after it has been handed down by oral tradition through several centuries. If we trace this word in all its ramifications and transmutations in the languages of modern Europe we may see what strange freaks the laws of euphony play among the different nations. In Old Bulgarian it becomes *almuzhina,* in Polish *jalmuzhna,* in Hungarian *alamizna,* in Spanish *limosna,* in Portuguese *esmola,* in French *aumône.*

The ancient Greek philosophers must have given the phenomena of human speech a good deal of thought. As some of them came in contact with many tribes speaking different tongues, it would have been strange if they had not done so. As the problem presented itself to them it was whether language is a natural product of the human psyche, or the result of convention, a sort of social contract. Their speculations are, however, all lost and we have only the dialogue of Plato entitled "Cratylus" to give us an inkling of the discussions that had preceded the time of its composition.

Plato does not seem to have had a glimpse of the possibility that language might be an organic growth. He was unable to conceive that a work of such artistic excellence could be constructed by people so low in the scale of civilization that they had no conception of art. Too little was known in his day about the primitive instinct of men. Herein there is still much that is mysterious, if facts can be so designated. We know what is; how it came to be is veiled from our sight. As for Plato, there is no evidence in his writings that he knew any language but Greek. He shared the weakness common to his countrymen. In all Greek literature there are to be found comparatively few words that give the names of objects in other languages. From the era of Alexander's conquests until that of Constantine every intelligent person in the Roman empire spoke Greek; but not *vice versa.* Although Plutarch lived for some time in Rome and delivered lectures in that city, he knew Latin very imperfectly. Plato is willing to admit that words are subject to many changes and put on many disguises.

He acknowledges that the "poor creature" imitation is supplemented by another "poor creature" convention. But he does not see that "habit and repute" and their relation to other words are always exercising an influence over them. Words appear to be isolated, but they are really parts of an organism which is always being reproduced. They are refined by civilization, harmonized by poetry, emphasized by literature, technically applied in philosophy and art; they are used as symbols on the border-ground of human knowledge; they receive a fresh impress from individual genius, and come with new force and association to every lively-minded person. They are fixed by the simultaneous utterance of millions, and yet are always imperceptibly changing. They carry with them the faded recollection of their own past history; the use of a word in a striking and familiar passage gives a complexion to its use everywhere else, and the new use of an old and familiar phrase has also a peculiar power over us. But these and other subtilties of language escaped the observation of Plato. He was not aware that the languages of the world are organic structures and that every word in them is related to every other; nor does he conceive of language as the joint work of speaker and hearer, requiring in man a faculty not only of expressing his thoughts but of understanding those of others.

Language is one of the links that carry us back, if not to the origin of the human race, at least to the first articulate-speaking man. Words are the faded images, or the battered and bruised and worn coins, that have been handed down from the remotest ages. When they have received a form in literature they become in a measure fixed so that we can see how they looked to the eye, if we do not know precisely how they sounded to the ear, millenniums ago. We usually have a mere fragment of primitive words and are almost wholly in the dark as to their phonetic value.

The connection between thought and speech has long been recognized; sometimes the priority of the one, sometimes of the other has been maintained. One fact is indisputable: language greatly influences our modes of thinking; in our early years conditions it entirely. We learn to use words with the meaning attached to them by our environment. Our first ideas are exactly those of our parents, of older brothers and sisters, of schoolmates, and so on. When we begin to learn words from books our intellectual outlook gradually enlarges. The circle of our thoughts becomes wider, but only in rare cases does it extend beyond that of our generation. To the average man his mother-tongue is a current that carries him gently, imperceptibly and slowly along; he rarely stops to consider whither he is drifting. We pass on to our successors the inheritance of words into which we have come, generally unchanged and unaugmented. Only once in a while does the deeper insight of some thinker enlarge the boundary of our intellectual horizon. He may not use a single new term, at least none of his own coinage, but he puts into those he employs a sense different from what they had before. Such terms as "evolution" and "development," and such phrases as "survival of the fittest," have now a totally different meaning from what they had half a century ago. And how pregnant with thought they are! While we have here no growth of vocabulary, we have an expansion of content that is of almost unbounded extent. We have a repetition of the same process which we find in the Greek when it began to be used as the language of philosophy. We may read page after page of Plato, knowing the radical or common meaning of his words; but if we are unfamiliar with Greek thought we get but a faint adumbration of his views. Our familiar "idea" is a good example of Plato's method with words. Its root is plainly a verb signifying "see." Herodotus says the horse can not endure the sight (idea) of the camel. In all Plato's writings it does not have reference to what is seen, but to what is mentally conceived, an archetype, or immaterial pattern of an object. In our day it is so common that everybody uses it. The colloquial forms "idee" and "idear" have grown out of it, and it may mean almost any form of intellectual activity. "Graft" is a recent and familiar example of a like process. Dictionaries ten years old do not give the definition with which we are all well acquainted. Some one made use of the word in its recent sense. Its appropriateness was at once recognized. It was copied by one periodical after another and repeated orally until now it is literally in everybody's mouth.

The usual assumption is that language represents a static fact; that it is to be found in books and in other printed and written matter; on tablets of stone and bronze. Language is, however, kinetic; all living languages are in a constant condition of flux. Through the mind of every human being from infancy until death, whether sane or insane, there flows a perennial stream of words that is interrupted only by sound sleep. When we read or listen to spoken discourse our thoughts usually run in an alien channel; but not necessarily. All languages are in a process of change which, although slow, is continuous. The English of Shakespeare or of Bacon is only a little more than three hundred years old, yet it is by no means the English of to-day. No matter how well we know current German, we can not read Luther's Bible intelligently. The same statement may be made of Rabelais's French, of Cervantes's Castilian and of Dante's Italian. It is a common error to speak of Greek and Latin as dead languages. The Romance tongues are nothing more than the latest phase of a development that has been going on since the earliest period of the Latin. If the Latin is dead now, when did the process of dissolution begin? The oldest French as preserved in the Strasburg oaths of A.D. 842 is about midway, as we may say, between the French of Hugo and the Latin of Cicero's age; a knowledge of either tongue enables one to read them with a fair degree of understanding.

The process of change is comparatively slow at present, and has been ever since the invention of printing, because readers endeavor to conform to the language of the past as preserved by the types. Albeit, we do not teach the language of Shakespeare or even of Addison, for the reason they have become archaic. What is taken as the best English of to-day contains a considerable number of expressions that are not found in Macaulay or DeQuincey, even when the matter dealt with is the same. We take as models English that is less than a century old. In some respects speech orally transmitted is more conservative than that which has been handed down in books; it represents a less advanced type of thought. The speech of the average man is not much influenced by books or by any printed matter. He repeats over and over again the formulas he learned in boyhood until language becomes his master rather than his servant. He does not reflect upon the speech he uses, but expresses the old familiar thoughts in the old familiar way; of other thoughts he has but few. At school he may have studied formal grammar, and wasted most of the time he put upon it. Grammar may give us an insight into the structure of a language, but it does not instruct us how to use it. If we take a boy into a shop, teach him the names of the tools and let him look on while others handle them without letting him do anything himself, he will never become a mechanic. Even if he has learned to manipulate the tools and machinery of a bygone era and refuses to change he is hopelessly handicapped. We can not discuss modern scientific themes with Bacon's vocabulary. There is an intersting passage in one of Herbert Spencer's essays that I have quoted more than once because it bears upon the matter of teaching the mother-tongue. Few men had a greater command of English and knew better how to make themselves understood than he. In "Facts and Comments" he gives his experience as follows:

> Down to the present hour I remain ignorant of those authoritative directions for writing English which the grammars contain. I can not repeat a single rule of syntax as given in the books, and were it not that the context has shown me the interpretation of the word when I have met it in reading, I should not know what syntax means. . . . In the absence of punishment my lessons in Latin grammar were never properly learned, and my progress was so slow that I did not master all the conjugations. Still smaller was the knowledge of the Greek which I acquired. In neither case did I reach that division which treats of the division of sentences. . . . Of the French grammar the same has to be said—I never reached the end of the conjugations. Thus neither directly nor indirectly have I received any of that discipline which is supposed to be an indispensable means of insuring correctness of speech.

This and much more to the same effect is interesting. But it would be a serious mistake to assume that the study of grammar is necessarily a waste of time. We might as well argue that because Franklin, Lincoln and others became masters of English without living teachers, schools are of no use. Spencer's remarks quoted above are followed by some logical and lucid directions as to the proper place of formal grammar in the ordinary school curriculum. If we learn to do by doing, we learn to speak and to write by writing correctly. It was in this way that the masters of Greek and Latin literature acquired their skill. They heard these languages correctly spoken; they saw them correctly written; they were taught rhetoric, but not grammar. Later the rules of the art were deduced from the study of connected discourse, among others of Homer. Here is a matter that defies analysis or explanation. We can only say that the masters of speech knew by a sort of instinct how to give their inflected words one form when occupying a certain place in the sentence and another when occupying another. Every word in the Homeric poems can be "parsed," that is, its position in the sentence can be logically and historically explained; yet they are the production of hundreds of men of whom probably not one could write. In its earliest stages language was correctly used by instinct; we later-comers are compelled to do so by a laborious process because we do not hear it correctly used. Instruction in the native tongue is a comparatively recent innovation. Why should an Englishman be taught English when he learned it in childhood? He was put to the study of Latin, and perhaps of Greek; English was left out of the account.

Bacon says:

> Words are formed at the will of the generality, and there arises from a bad and unapt formation of words a wonderful obstruction to the mind. Nor can the definitions and explanations with which learned men are wont to guard and protect themselves in some instances afford a complete remedy—words still manifestly force the understanding, throw everything into confusion and lead mankind into vain and innumerable controversies and fallacies.

That is, as speech always represents the past, those who use it are unconsciously influenced by the thoughts of those who employed it in former times. There is thus an inherent weakness in adhering to what is commonly called a classic style, the style after which the literary man strives. On the other hand, the scientist is always on the lookout for something new; he must use new terms, if not new forms of expression. While a scientist may set forth general principles in a model style, when he becomes technical and precise this is no longer possible. Thus there is a certain degree of incompatibility between the scientist and the litterateur.

In the consideration of human speech we must take into account two factors: one subjective, the other objective. They are as nut and screw, as lock and key, as hand and glove. These two factors must grow up together, so to speak; they must at least become thoroughly familiar through long association. Viewed in respect to language, the human mind may be compared to a hard substance upon which it is difficult to produce impressions, upon which impressions can be made only by oft-repeated blows. But *impressions* is merely a make shift word borrowed from the material world for lack of a better. The passive mind does not comprehend the meaning of a word or phrase until its form or sound and signification have been thrust upon it over and over again. How many thousand times are familiar expressions repeated in the hearing of the infant before it understands what they mean, at least with any degree of definiteness. The adult foreigner is almost in the same predicament. After a familiarity between sound or character and idea has been established comprehension proceeds with amazing rapidity. We can run our eyes over a printed page and get its meaning much more quickly than we can pronounce the words. Like a skillful pianist who reads an unfamiliar piece of music at sight, since only the particular combinations of notes are new to him, but not the general principles upon which the score is constructed, so the reader of the printed or written page is familiar with the words before him even when their arrangement and combination are new. Words and phrases may repose passive in the subconscious mind for many years, dead and forgotten as it seemed, when suddenly either by conscious effort or by an accident of association they spring into life. It is doubtful whether we can ever forget a language learned in childhood, although lack of practise may make us awkward in its use in after time. Sometimes we may grope, so to say, for years in the effort to recall a word, especially a proper name, when something suggests it to us at an unexpected moment. It is like the powder which lies dead as so much dust until a spark falls upon it, when it bursts into flame. The latent image, figuratively speaking again, can usually be called into life more quickly if the eye and the ear cooperate, than when only one of these two organs is called into requisition. It is, however, easier to learn a language through the eye than the ear; in fact, many languages can be learned only in this way, since they have been preserved solely upon inscribed materials. If a word is unfamiliar at first sight we can keep the eye upon it until it is either recognized or until we have convinced ourselves that recognition is impossible. A dead language is, however, a good deal like a cadaver; the important thing, life, is wanting.

A visible fact connected with the internal growth of a language is its geographical expansion. The ancient Greek furnishes a remarkable example. Four or five centuries before the Christian era it had already spread over the greater part of the known ancient world. By the conquests of Alexander it was still farther extended. In the course of time it was in some degree superseded by the Latin, at least in Europe. Albeit, Latin never became the popular speech that Greek had been, although it was the medium of communication between ecclesiastics and scholars and so continued until displaced by the modern languages of which French had for a time the precedence. The lectures in the universities were given in Latin; hence we find the same distinguished scholars teaching in succession in half a dozen different countries and their books circulating even more widely. The tradition was first abrogated in England and was longest adhered to in Germany, in which country university lectures were delivered in Latin by a few professors within the memory of the present generation. To some extent French was for a long time the most generally spoken language. Professor Fouillée, in his "Psychology of the French People," asserts that toward the end of the seventeenth century France had twenty millions of inhabitants; Great Britain and Ireland, about nine millions; Germany, nineteen millions; Austria, somewhat less than thirteen millions, and that among the fifty million inhabitants of Europe France comprised about forty per cent.[1] Besides, if a person spoke two languages, one of them was almost invariably French. In 1789, according to the same authority, France had a population of twenty-six millions; Great Britain and Ireland, of twelve millions; Russia, of twenty-five millions; Germany, of twenty-eight millions, and Austria, of about eighteen millions. France now represented only twenty-seven per cent. of the inhabitants of Europe, Russia having meanwhile taken its place among the great powers. France continued to decline until the close of the nineteenth century, when it included only about eleven per cent. of the population of Europe. Nobody knows how many persons speak Russian in the proper sense of the word, but probably a good deal fewer than one half of the citizens of the empire.

Let us now glance at the career of the Castilian tongue. At the death of Philip the Second the population of Spain is estimated to have been about eight and a half millions. Towards the close of the seventeenth century it is supposed to have sunk to about six millions, since many villages were deserted and long stretches of country lay uncultivated. Within the next eight or ten decades there was considerable improvement, so that by the beginning of the nineteenth century the population is believed to have doubled. The number of inhabitants in the Spanish American states is estimated at about thirty-six millions. Outside of these countries, and including Cuba but excluding the mother-country, there may be one or two millions of Spanish-speaking people; this makes the entire number between thirty-eight and forty millions. But so badly managed are the internal affairs of the Central American states that the best possible "guess" at the number of their inhabitants may be wide of the mark. Of this total population not one tenth, more likely not one twentieth, has received systematic instruction in any language or in anything else. Besides, the number of persons of pure Spanish descent outside of the mother-country is comparatively small. As it is reputed to be but nineteen per cent. in Mexico, the total number of Spaniards at the present day may fall far short of the above estimate: that is to say, if we credit Spain with eighteen millions

[1] Page 321. It will be noticed that if the figures are correct the per cent. can not be.

and the rest of the world with nine millions we get a total of twenty-seven millions, which is probably a liberal allowance. We are, however, here concerned with the language of the Spanish-speaking people, not with their ethnology.

Coming now to England, it is calculated on the basis of the parish registers, as no one in those days thought of taking a census, that its population, including that of Wales, at the middle of the sixteenth century was about five millions. Two centuries later it had risen to six and a half millions. At the present time the number of persons whose native speech is English, or one of them if they speak two, falls not far short of one hundred and fifty millions. There are many persons in Wales, in Canada, and in other parts of the world who use two languages with about equal facility, but who would not claim English as their mother-tongue. Probably as many as three fourths of this number have received, or are receiving, systematic instruction in the English language. It is probable that an equal, if not a larger, proportion are of Anglo-Saxon, or at least of Germanic stock.

I have spoken above of the aversion of the ancient Greeks to the acquisition of foreign languages. In modern times the French have manifested a similar reluctance. As "France marches at the head of civilization," why should Frenchmen concern themselves about those who are behind them? When almost every intelligent person in continental Europe knew French a Frenchman rarely took the trouble to learn a language spoken outside of his native country. This ignorance eventually cost the nation dear; for if Frenchmen had kept themselves informed of what was going on beyond the Rhine they would have been less eager to engage in a war with the nation that dwelt there. The same charge is frequently brought against English and American representatives of commercial houses in foreign countries. We have been told many times that the United States lose a great deal of trade because their agents will not take the trouble to learn the language of the natives with whom they desire to do business and that the Germans far outstrip them in this respect. It may be said further that the efforts of the Germans to preserve their speech in foreign countries meets with small success. The children of German immigrants rarely learn the language of their parents so well that they are able to use it as readily as that of their new habitat.

We have here what seems to be the only practical solution of the problem of a universal language. When we take note of the rapid expansion of English within the last century, it does not seem a fanciful prediction that before the end of another century all persons who wish to learn another language besides their own will choose English. German received a serious set-back by the Thirty Years war. The population of the country in 1618 is estimated at twenty-five millions. There are good reasons for believing that it had been reduced to half this number by 1648. It is therefore not putting the case too strong to say that it required almost two centuries for Germany to recuperate from the effects of that terrible scourge. It is the most impressive lesson the world has received on the folly of war; but for this one, the history of the world would probably have been widely different. There is a sense in which a detriment of this kind can never be made good. Spain's linguistic losses at home may be ultimately restored and more than restored by conquests in her colonies. Conversely, Germany has thus far not been successful with her over-sea possessions, partly owing to bad management, partly owing to climatic and other unfavorable conditions.

English is the coming language. And it is coming rapidly; for while it is difficult to learn thoroughly, in the matter both of style and of pronunciation, it can readily be acquired with sufficient correctness for all commercial and practical purposes.

THE DENOMINATIONAL COLLEGE

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THAT church and state should be separate has long been held in the United States. It is one of our proudest boasts that every citizen of our country is free to worship God in his own way. It is also usually assumed that each may have his own definition of the God he worships. Our educational system, as well as our government, is based upon this assumption that it is best for state and church to be entirely independent of each other; for, in America, as in most enlightened countries, the education of the youth is considered a duty of the state. The public schools provided for by public funds are non-sectarian. The highest branches of the system, the state college and state university, are similarly constituted and similarly provided for. Neither upon entrance in these institutions nor later is any profession for or against any religious denomination, or any expression of "attitude," demanded of boards, trustees, presidents, principals, instructors or students. Religious organizations are permitted to exist among the members of these institutions, and are accorded the same assistance and courtesies as are technical, literary or purely social clubs, but the fact that they are religious organizations does not of itself entitle them to any additional consideration.

This is apparently an ideal condition. Our educational system attends to the intellectual and technical training of our youth, and to the task of developing them into useful and desirable citizens. The church, an independent organization, gives such religious and theological instruction as each citizen desires for himself and his family. Each citizen follows his individual preference as to the kind of religious teaching he needs, and of his own free will pays for it, directly instead of indirectly, and in accordance with his own rating of his duty towards it and the value of the services which it renders.

Unfortunately, however, this apparently ideal condition exists in but a part of the educational machinery of the United States. Besides our excellent system of public grade schools, high schools, technological schools, colleges and universities, we have an enormous number of educational institutions which were not founded by public legislation, and are supported by private munificence. The entire situation may be stated as follows: (1) Our city evening schools, schools for the blind, reform schools, Alaskan and Indian schools, are entirely public institutions; (2) the miscellaneous schools (of cookery, music, oratory and various special arts), the business schools, the orphan asylums and other benevolent institutions are founded and supported as private institutions. Of the remaining educational institutions, some are public, some private. The percentage of attendance of pupils and students, as calculated from the table given on page viii of Vol. I. of the Report of the U. S. Commissioner of Education printed in 1907 (from which are taken also the general data given above, and which will hereafter be referred to simply as U. S. Report), is as follows:

Kind of Institution	Percentage in Public Institutions	Percentage in Private Institutions
Schools for the deaf	95 +	4 +
Schools for the feeble-minded	95 +	4 +
Elementary schools (primary and grammar)	92 +	7 +
Normal schools	83 +	16 +
Secondary schools (high schools and academies)	79 +	10 +
Colleges and universities	33 +	66 +
Professional schools	17 +	82 +

It will be seen that the state is doing in a tolerably complete manner what it has evidently assumed is its duty, in all but two of the classes of institutions to which it gives any attention whatever. But in the case of the professional schools and the colleges and universities the state is merely dabbling in the matter, leaving so great a proportion of the work to private enterprise that of the youth being educated in such institutions seventy-four per cent. are receiving such education through private munificence. If our postal system, or our system of criminal reformation and punishment, were carried on partly by the state, partly by private enterprise, we should regard it as a very curious condition of things, and should cast about us for a remedy. But as yet we fail to observe the anomaly in this very important matter of public education.

Let us now take up the subject from the point of the comparative number of public and private institutions, rather than from that of the total attendance of students, and confine our examination to one of the two kinds of institutions of which the state controls but an insignificant proportion. We may classify the colleges and universities conveniently through the aid of tables 29, p. 578; 32, p. 636 and 34, p. 640 of the U. S. Report. All institutions classed as schools of technology (table 36, p. 650) are omitted from this consideration, even though their official title is sometimes "College of ———." (It may be stated in passing that according to this table the national government is responsible for 2 and the states for 34 of these institutions. The source of support or the founder of the remaining 8 is not specified and has not been investigated.) These statistics may be regarded as tolerably correct, although inaccuracies undoubtedly occur. Consequently the general view of the situation which they offer is approximately correct.

Many of the universities of the east have at one time or another received appropriations from the state, and some state control has been and still is exercised. But such institutions must nevertheless be classed as private rather than public. The comparative number of colleges and universities under public *versus* private control is as follows: National, 2; state, 46; city, 4; private, 620. The total is then 52 founded and chiefly if not entirely supported by public funds, as against 620 privately founded and privately supported institutions. Some of these private colleges and universities date from the early days of American history, when the government was not yet strong enough to undertake educational work, and private organizations gave their time, energy, and money to its accomplishment. The fact that the government is now able to do its duty along the line of education of its citizens does not in the least detract from the high honor due those early pioneers who by individual effort paved the way for the accomplishment by the state of a great and necessary task.

These six hundred and twenty privately founded institutions, which still educate almost twice as many of our young men and women as do the public colleges and universities (*Cf.* tables 1 and 2, pp. 545 and 546 of the U. S. Report), are as a rule conducted in accordance with the personal wishes of their founders and, according to the three tables quoted above four hundred and seventeen of them are avowedly denominational in attitude. The term denominational is here used in its broadest sense, to include both Roman catholic and protestant institutions. These colleges and universities are, of course (though why "of course" is as yet unexplained), all exempt from taxation. This one fact proves beyond cavil that church and state are not separate in America. Exemption from taxation of an institution of learning which also gives religious instruction or brings religious influence to bear means to this extent state aid, and consequently direct connection with the state.

The citizens who at its foundation endow a denominational institution and continue to support it also pay their share of the tax which supports the state college and state university. It seems at first, then, that their right to maintain in addition their own private institution for religious teaching should pass unchallenged, and, if the denominational college were for religious teaching alone, none might object. But its religious teaching is greatly adulterated. The denominational college and university compete with the work of the state institutions, and infringe upon the right and duty of the state to attend to the intellectual training and preparation for citizenship of its youth. The specious argument may be presented that these private institutions, founded in the past to accomplish the twofold task of educating ministers for the ministry and citizens for citizenship, still exist for the sake of helping out with the educational work of the country, the great task of the state colleges and universities. But the state will not do its whole duty until the entire responsibility devolves upon the state alone. If the state does not provide enough colleges (using this general term now for both college and university), it is the state and no one else who should set about the task of providing additional ones. The state is no pauper on the hands of its citizens when it comes to a question of providing and maintaining a sufficient number of reform schools or of penitentiaries. No more should it be so in the far more vital matter of the education of its normal and desirable citizens.

Briefly, the national, state and municipal governments are not doing their duty until their citizens are offered such adequate opportunity for intellectual and technical training as to render unnecessary all such offering of opportunity by institutions founded upon a private or religious basis. This position places no difficulty in the way of private citizens or organizations who wish to give direct financial aid to institutions of learning. Their gifts would instead reflect higher honor upon them, inasmuch as they would be a manifestation of unadulterated patriotism. Those who wish to give to the cause of religious instruction would find the field as large and attractive, and untrammeled by other real or apparent motives, in the various institutions or organizations to which their donations would be made.

Moreover, the impetus in this matter must come from the state itself. The remedy will not be begun by the denominational college, for, unless something is done from without, it will continue to exist from mere inertia. The remedy will not be begun by the students, for they will in general follow the line of least resistance, and attend the institution which other members of their families and their friends have attended. They will attend the college which their parents aid materially with financial support. They feel a moral obligation to help swell its roll of attendance, and they have been taught, as were their parents before them, that the college supported by their church deserves somehow a more direct and solicitous care and interest and aid than does the college supported by their state. Yet it is the students of the denominational college who receive from it the most direct harm, along with the educational advantages of which they avail themselves. They are subjected daily to the influence of some particular denomination, in either a direct or indirect method. The denomination may be the one to which their parents belong, and to which they would also ally themselves, or have already allied themselves; but the harm consists in that they are led blindly along, instead of being left to make the choice of their own free wills, as our country in the beginning proposed every one should be. The harm consists even more in that all through their course of study they find general and religious education constantly commingled, in direct contradiction to the assumption that religious freedom exists in America. The student has no way out of the dilemma but to assume that the freedom is simply a freedom as to which particular denomination shall for him be united with the state. The list of denominations from which he may choose is a limited one, inasmuch as of the seventeen denominations represented among the four hundred and seventeen avowedly sectarian colleges, almost three fourths of them are under the control of but four denominations, as will be shown from the following table, deduced from tables 29 and 32 of the U. S. Report.

Methodist. 104 (24— Per Cent.)	Presbyterian. 75 (18— Per Cent.)	Baptist. 68 (16+ Per Cent.)	Roman Catholic. 65 (15+ Per Cent.)	Lutheran. 26 (6+ Per Cent.)	Christian. 17 (4+ Per Cent.)	Congregational. 16 (3+ Per Cent.)	Reformed. 9 (2+ Per Cent.)	Friends. 8 (2— Per Cent.)	United Brethren. 7 (1+ Per Cent.)	Episcopal. 7 (1+ Per Cent.)
Universalist. 4 ($\frac{9}{10}$ Per Cent.)	Evangelical. 4 ($\frac{9}{10}$ Per Cent.)	Moravian. 3 ($\frac{7}{10}$ Per Cent.)		Latter Day Saints. 2 ($\frac{1}{2}$ Per Cent.)			Seventh Day Adventists. 1 ($\frac{1}{4}$ Per Cent.)		Church of God. 1 ($\frac{1}{4}$ Per Cent.)	

The stigma of "godless institution" used as an epithet of reproach, is so often applied to the college of the state by zealous supporters of the private college as to actually give the student the impression that an institution which does not combine some form of religious teaching or influence, some Sunday school work, with its general instruction, is acting in opposition to the good of the country, rather than in conformity with one of its most cherished principles.

It may be that the student does not wish to ally himself with any of the religious denominations which maintain colleges, but attends one of these colleges since there is no restriction announced as to the church membership or religious affiliation of prospective students, but instead a distinct effort made to win any and all students of general good character. He will be subjected constantly to petty humiliations because he does not worship his God in the same formulas as do his fellow students. If he fail to attend even the "voluntary" chapel and Sunday services conducted by the college, not to mention the various prayer services, he realizes that his absence is noted by classmates and members of the faculty, even in the unlikely case that no comments are made. In order to escape isolation and a greater or less degree of ostracism, he finds it expedient to attend the services. He goes through with song, prayer, responsive reading, or whatever form the exercises may take, carefully concealing his lack of sympathy with them. In this way a definite species of hypocrite is developed. Our colleges, to their unspeakable shame, are full of such products. They occur among instructors as well as students, for the instructors must add to the reasons of the student the additional one that they wish to retain their positions. Consequently such instructors attend and even assist in conducting services with which they do not feel the least genuine sympathy. The fault is not that of instructors and students, for they came for educational purposes to an institution which avows that its aim is educational, and that no distinctions are made on account of religious attitude. The fault is that of the college, in bringing to bear a compulsion of such a sort that there is no resort but submission and consequent hypocrisy.

Granting, therefore, that the denominational college is a pernicious and undesirable incubus upon the American system of public instruction, it becomes advisable to define the term more exactly, and to make it more clear that in it are combined church and state inasmuch as religious education and general education are here given in combination, in an institution exempted by law from taxation. The denominational college may then be defined as follows: A general educational institution which (1) was not founded by and is not supported by the state (state in this sense including national, state and municipal governments), which (2) aims to further the cause of some one religion or of some one religious denomination, which (3) holds daily religious services during each college week, which (4) makes some limitation in regard to the church membership of its trustees, president, or teaching force.

The examples given in this article will be from protestant rather than from catholic or jewish colleges, simply because the writer is best acquainted with the protestant colleges. The statistics given are based upon those of the United States commissioner of education, who makes his report chiefly concerning protestant and catholic colleges. The conclusions drawn, however, should be the same for all religions and religious denominations.

Beginning with a consideration of the second clause in our definition, we may see the method in which this is accomplished, from the following quotations. In the original articles of incorporation of a highly reputable college we read as follows:

> The object of this institution shall be to promote the general interests of education and to qualify young men for the different professions and for the honorable discharge of the various duties of life.

In the historical statement of the catalogue of the same college we find:

The college has not lost sight of the design of its founders that it should be a thoroughly Christian institution.

In a supplementary catalogue of the same college we learn that the instructing force

may assemble the students as freely for song and prayer as for athletic associations and class parties. There are no restrictions at this point, either directly or indirectly. The atmosphere is just as religious as the teachers and students choose to make it.

The reader will note that the "freedom" here referred to lies wholly in the teachers' privilege of increasing the already existing religious atmosphere, not in any possibility of curtailing it.

Each of the three following quotations is from a catalogue of a college of excellent standing. The first reads:

In accordance with the spirit of the founder, the college is undenominational, but distinctly Christian in its influence, discipline and instruction.

The second is similarly worded, as follows:

All instruction is given from the religious viewpoint with reverent recognition of and regard for the divine wisdom and power hedging us about and with which we have to do.

These statements do not leave us to infer that religious instruction is simply coordinate with other instruction, but make the claim that the teaching is a combination of the two. A *reductio ad absurdum* would lead to the query how Christian or religious mathematics differs from secular mathematics, or how such an interpretation of Horace's "Odes" or of the "Chanson de Roland" differs from the secular interpretation, and whether Christian bacteriology differs from catholic or jewish bacteriology. A more moderate statement in this regard is exhibited in the third citation:

It is a Christian college, conducted in the belief that Christian faith is the source of the highest culture, and that, in the words of its founder, "All education should be for the glory of God"; and accordingly it uses the means which legitimately come within its province to foster a Christian life in those who are connected with it.

A rather naïve method of cooperation of college and church is shown in the following citation, again from a catalogue of a college of high standing:

The college is distinctly Christian, and recognizes Christian character as its highest attainment. It is unsectarian in its management. Inquiry is made of the students at entrance as to their denominational affiliation, and what churches in the city they desire to attend. Lists are sent to the pastors of these churches, who seek out the students and bring about them the influence of church homes.

Apparently this inquiry and resultant action is official on the part of the college. One is tempted to wonder what disposition is made of students who signify a desire to attend a church of some denomination not represented in the city in which this college is situated. Possibly a substitute is offered, with the assurance that it is "just as good." In case a student does not wish to decide upon his church affiliation until a later date than that of his entrance into college, special action is perhaps taken upon the case. Further quotation of such examples is forbidden by lack of space. Any one who will take the trouble to examine a dozen non-state college catalogues, selected quite at random, will realize that there is no scarcity of examples fully as pertinent and often even more striking than the ones cited above.

In passing to the third clause of the definition, we realize that definite and individual examples are hardly necessary. It is the exception, not the rule, if any non-state college does not hold its morning chapel, its Sunday service, and its Sunday vespers. It is usual, as will be seen from an examination of catalogues, for these services to be compulsory. Attendance is "required," with or without penalty for non-attendance, or is "expected," or "urged" or is "voluntary," which latter word may be variously interpreted. For the sake of definiteness, however, some citations may be made from catalogues:

> The principles and influences of the college are distinctively Christian, but the college has no connection with any particular denomination. A short service is held each morning in the chapel at a quarter past nine o'clock. All students are required to be present at this service, and on Sunday are expected to attend the services at the church of their choice. . . . On Sunday, vesper services are held in —.

Another example is as follows:

> Every undergraduate student is required to be present twice each week at morning prayers in the chapel, unless excused by the president. If a student at any time falls short of this requirement by four absences he must during the next two weeks attend four times in addition to the four times above provided for. Failure to comply with this rule will render him liable to suspension. Every undergraduate in residence at the university is required to attend at least one half of the Sunday chapel services each quarter. Failure to comply with this rule will render him liable to suspension.

Still another citation, from the catalogue of still a third college, is as follows:

> Daily attendance at morning prayer or an alternative duty, as described below, is required of every student, except seniors enrolled in a university professional school down town. These chapel exercises are held from 10:15 to 10:30 each morning. For every fifteen absences, a student will be required to hand in within ten days after the fifteenth absence an original theme of 800 to 1,000 words upon a subject assigned him by the chancellor touching morals and religion. This theme will be graded according to its merits, and awarded the same weight in determining the student's standing as if it were a course requiring fifteen hours' recitation. Two failures to hand in themes will be entered as a condition, being treated as a failure in a term examination. Where a student is absent from college for five or more days continuously, with a good excuse, his chapel absences will be excused also. Where a student is absent from college less than five days continuously, even though excused, his absences from chapel will be counted.

In many colleges attendance at daily chapel is not compulsory, and no penalty is imposed for non-attendance. In such institutions there often exists a "custom" which has almost the same effect as the written rule. The libraries and reading-rooms are closed during the chapel hour, and instructors are officially requested to lock their class-rooms, so that no place for work or recreation is left to the students during the session of chapel. Students who in spite of this arrangement fail to appear with due regularity at chapel are made the subject of unpleasant comment among their fellow students and often directly, while instructors who do not feel the impulse toward worship at precisely the same hour of the day as their colleagues receive from the president or some other official a gentle reminder that their presence at this "voluntary" chapel is advisable.

The last clause in our definition is an important one. The reader will doubtless think at once of one of the greatest and best universities of our country, the president of which must always be of a certain religious denomination. His personal preference as to Tennyson or Browning is not inquired about, nor is he asked whether he believes in high tariff or free trade, or is a prohibitionist or a socialist. But investigation is made as to whether he has formally subscribed to a certain creed of a certain religion, although no one thinks for a moment that he will make a better executive on this account, or even did think so when the ruling was made. That all or a certain number of the trustees of a college shall be members of a specified church is likewise a familiar state of things, hardly needing illustration. For instance in the historical sketch of a certain college founded by a private citizen, it is mentioned that this gentleman was of a certain religious denomination "and he provided that the trustees of the institution should be members of that body." In the catalogue of another college we find this statement concerning its charter: "It provides that the number of trustees shall never be greater than seventeen, seven of whom shall be clergymen and ten laymen."

No one who has given the matter slight attention would be inclined to believe that the point in our definition concerning church membership of the instructional force applies to but an inconsiderable number of institutions, and is the exception rather than the rule. The contrary, however, is the case. Proof from a different source than the college catalogue is at hand, and has the advantage of being absolutely disinterested in its origin. Such proof consists in the blanks of teachers' agencies. These blanks almost invariably, and probably always, contain the items "church membership" and "church affiliation" in the list of "qualifications for teaching" to be filled out by the prospective teachers. This information would not be asked for were it unnecessary. Moreover, the writer has the opportunity of quoting from letters written in a most kindly attitude by teachers' agencies of high standing, concerning registration blanks in which membership in orthodox churches had not been indicated. The first extract is as follows:

> It will not help you . . . that you are a member of the Universalist church. . . . Sometimes employers will go so far as to state that they want a member of the Methodist, Congregationalist, Presbyterian, or Baptist church, these four being the most common of the so-called orthodox churches.

It is of interest to note in passing that this agency discovered by business experience what we have above shown by statistics, as to what denominations control most of the colleges. In our statistics, Methodists, Presbyterians and Baptists lead, Roman Catholic, which evidently does not employ the aid of agencies, or of this particular agency, to any noticeable degree, being fourth. In our statistics Lutheran and Christian come next, followed by Congregational. The reason that Congregational seems to this agency to rank with the three first quoted will doubtless appear from the latter part of this article. Another extract from a similar letter is as follows:

> It is likely, however, that you will be handicapped there, as you will be handicapped in most colleges, by your lack of church membership. Have you never been a member of a church? You understand that most colleges are directly or indirectly connected with some church, and as a general rule the president insists upon membership in some church.

An extract from a third letter reads as follows:

> You are handicapped for the majority of positions for which you would otherwise be eligible because you are not a member of a church. We had a letter to-day from . . . that is in no way sectarian and yet they absolutely demand in the teacher they desire a member of some protestant church. Frequently the denominational schools make no requirement as to a particular church but do demand membership in some church.

Let us now return to a statistical consideration of the private educational institutions. We have noted that of the 620 such colleges, listed in the U. S. Commissioner's Report, tables 29, 32 and 34, 417 are avowedly denominational. Of the remaining 203, 99 are quoted as non-sectarian, while four are not specified. In the catalogues of three of these four, the claim is made that they are non-sectarian, thus bringing the number of such colleges up to 102. From the definition of denominational or non-sectarian college which we have accepted, it follows that any college which conforms to all or even half of the four clauses of this definition may not be called non-sectarian. Stating this affirmatively, we find that: Any college which (1) was founded by a private citizen or organization of citizens, and which (2) conducts devotional exercises at least five days in the week at which student attendance is "required," or "expected" or "urged" or not distinctly stated as "voluntary" in its catalogue, may not rank as non-sectarian, in spite of any claims it may make to that effect, but must rank as a denominational college. In case a college was privately founded, but states in its catalogue that all religious exercises which it conducts are "voluntary," such college shall not be classed as sectarian unless some stated restriction exists concerning the church affiliation of its president, or all or a part of its board of trustees.

Of the 203 colleges to be considered with reference to the above definition, the catalogues of 62 have been examined. No investigation has been made of the colleges of secondary rank listed in table 34 of the U. S. Rep. as "Colleges for women, Division B," of which 32 claim to be non-sectarian and one is not specified. The conclusions to be drawn for these 33 would doubtless be similar to those which we shall deduce from the remaining 70 colleges which claim to be non-sectarian. An examination of the catalogues of 63 of these 70 colleges gives the following results: In accordance with our definition, 16 of these institutions may fairly rank as non-denominational colleges. The remaining 47 out of 63, that is to say, 75 per cent., of the colleges examined, must be classed as denominational. It may be of interest at this point to state that all of the quotations made above from college catalogues, for the purpose of illustrating "denominational" practises of colleges, have been made from the catalogues of colleges disclaiming in those very catalogues that they are denominational colleges.[1]

Subtracting these from the number of non-sectarian institutions given in the U. S. Rep. and adding it to the number of sectarian ones there given, we then obtain the following more nearly correct statistics concerning the total 672 colleges and universities of the United States:

Public (52)			Private (620)			
National	State	City	Non-sectarian	Sectarian 461		Not Investigated
				Sectarianism admitted,	Sectarianism denied,	
2	46	4	16	417	47	Thirty-three women's colleges of secondary rank.
($\frac{3}{10}$%)	(7%)	($\frac{3}{5}$%)	($\frac{1}{5}$%)	74½%		Seven colleges of primary rank.

What are the general conclusions to be drawn? It is evident that one of two things must be done. The denominational college must be entirely supplanted by the state college, placed in as numerous and methodical branches over the United States as are the high schools and grade schools at present. In each community of a certain number of

[1] The references for these quotations are as follows: Iowa College Bulletins, Vol. V., No. 2, pp. 7–8; No. 3, p. 4. Wellesley College Calendar, 1905–6, p. 21. Wabash College Catalogue, 1906, p. 11. Colorado College Catalogue, March, 1907, p. 120. Smith College Official Circular, Series 1, No. 2, 1905–6, p. 11. Western Reserve University (College for Women) catalogue for 1906–7, p. 59. Princeton University Catalogue, 1906–7, p. 255. New York University Catalogue, 1905–6, p. 179. Bryn Mawr Program, 1906–7, p. 45. Amherst College Catalogue, 1906–7, p. 6.

inhabitants there should as regularly be a good public college as there is now a public high school in each similar smaller community. Besides federal and municipal institutions there should be national ones, not of the same grade, but for entrance to which graduation from a federal institution might be a prerequisite. Whether these suggested institutions should come into existence by taking over the "plants" of the present denominational colleges or by some other method need not be worked out in this article. Ways and means can always be discovered when an act is recognized as a necessary one.

If this is not done, there is but one alternative. If the denominational colleges continue to exist, and to combine general training and education for citizenship with religious instruction, basing such religious instruction upon the contents of the accepted book or books of any religion, or the interpretation of these books by any church or personal interpreter, or propound any more definite monotheism than the motto on our coins, "In God we trust," and if these colleges continue to be exempt from taxation then we must at once and forever abandon the pleasant fallacy that in the United States church and state are independent.

THE TRIAL OF AN OLD GREEK CORN-RING

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LITTLE Greece contributed to civilization the most precious thing in the world—fearless freedom of thought. That novelty, it is true, kept the various city states from uniting as a mighty power, but that same disunion made the individual man and the individual mind superior to the dead level that saps the genius of progress. That active principle of the pioneer the Greek infused into his jurisprudence with the same telling success that stamped his efforts in the other departments of human advancement.

Though the system may have occasionally miscarried from its own weight, failure to protect the life, liberty and property of its citizens was not one of the faults of the Hellenic democracy. When Solon, in the sixth century before Christ, originated at Athens his system of trial by popular courts of jurymen-judges, he not only laid the foundation of national law but discovered the real secret of democracy, which is and has been the keystone of European and American institutions; for the hope of a free people lies in the possession of its courts.

Down through the brief but brilliant period of their political prestige, the Athenians laid many a wreath at the feet of the lawgiver, Solon, but probably never more reverently or more gratefully than when the commonwealth fought that still unfinished fight with the speculator and monopolist of the food-products of the nation. So that this review of the legal principles and procedure in the prosecution of an old Athenian corn-ring may be of interest and even of value to the historian and economist, the lawyer and patriot.

The oration with which this review deals is a speech for the prosecution, numbered 22 in the ordinary collection of speeches by Lysias, the celebrated Athenian speech-writer, and dates from the early part of the fourth century, possibly 387 B.C. To get a sympathetic setting, it is advisable to recall the appointments of the old Greek court, the laws and legal customs, as well as the peculiar, though not necessarily unique, conditions that dictated the legislation on which the prosecution relies.

Though no actual law has come down to us, the whole procedure in the Athenian courts—to say nothing of the evidence of Quintillian—shows that the law required every citizen to plead his own cause.

And this was no harsh provision before the birth of rhetoric and logic when natural eloquence alone existed and professional oratory was not dreamed of. The establishment of the popular courts and the above requirement changed the literary vehicle from poetry to prose, as a mode of expression better adapted to argument and logical treatment, and finally the professional rhetorician came into the field just after the death of Pericles, that eloquent political "boss" of Athens. At this time, Gorgias, the famous Sicilian orator, showed the Athenians, as embassador, the miraculous possibilities of their language and it at once became the style to cultivate oratory as a fine art. The ordinary man was now severely handicapped in a contest at court with a pupil of the professional rhetorician and lack of time, inclination or ability forced the suitor, if himself unskilled, to hire a logographer or speech-writer to prepare his speech for delivery.

The logographer wrote the speech and gave his client (if we may so call him) some instruction in general delivery. He was not a lawyer, in our sense, his duties ceasing when the case came to court; though at intervals, we find a "next friend," who serves as assistant speaker without pay. The speech-writer did not appear in a professional capacity and the delivered speech disclosed no identity which suggested a violation of the laws on pleading and practise.

The first logographer who wrote for pay was the orator, Antiphon, the master of criminal law. Isæus has left us an extended collection of his speeches, drawn up for suitors in inheritance cases. Demosthenes, after being looted by his guardians, took to speech-writing as a livelihood and laid the foundation of a greater fortune than the one he had lost. Lysias, a reduced metic (resident alien) at Athens, whose property had been confiscated by the "Thirty Tyrants," was probably the most famous and cleverest speech-writer of his times, if we can take Plato's word (Phædrus 228A). His character-study of the manners and mannerisms of the actual suitor was so thorough that the delivered speech became the apparent thought and word of the pleader himself. Not being a citizen, Lysias was practically out of politics and political speeches and so confined his attention to the remunerative preparation of the private speeches of those who wished to win their case. The senator who prosecutes the grain-dealers evidently considered that, in obtaining the services of the expert Lysias, he was doing all in his power to aid the public weal and to protect and enhance his own civic and political reputation.

While undoubtedly Lysias was "for the prosecution,"—whether that word is interpreted to mean the unknown senator or the state—we know nothing of the counsel for the defense—unless we have a right to infer that the corn-ring employed the regularly, though stealthily, retained, "corporation" defense-writer.

The case against the corn-ring was tried in one of the ten Heliastic (jury) courts, located in the market place at Athens, to the north of the Acropolis and Areopagus, those hills dedicated to religion and homicidal law. These courts of sworn jurymen-judges were higher courts and though apparently no appeal would lie from their decisions, some revisory power did exist, at least in the way of bringing new suit and being allowed a new trial before new jurymen-judges, on discovery of false testimony that had influenced the verdict, excusable defaults, etc.

An apparently large number of cases was settled by private and public arbitrators, the parties in interest ordinarily binding themselves to abide by the decision given. Besides family and friendly arbitrators, whose services were most widely sought and employed, there was a regularly established system of public arbitration, whose officials, chosen annually, by lot, were over fifty years of age. To these officials magistrates could refer any private suit, though from their findings appeal and recourse to a regular jury-trial in the higher court could be claimed. A fee was charged on each party. Criminal and public prosecutions, like the present, would not, from their very nature, come before the arbitrators, but be brought, in regular course, before the Heliastic jury, as noted below. The orators are continually emphasizing their offer of arbitration or criticizing their opponent's lack of it and it appears to have been a legal principle and honored custom to avoid litigation by attempting to settle all possible cases "out of court."

Such procedure would tend to greatly relieve congestion of cases, so that the "Law's delays," so fertile a source of modern criticism, would be reduced to a minimum, which must have become practically *nil,* when the statute became operative which limited the trial of a case to one day's time. There was, apparently, some fault found with this limitation; for Plato, in the "Apology" (37A), makes his beloved master, Socrates, say: "I don't believe I have intentionally wronged any man, but I am not persuading you of that; for we have been conversing with each other but a short time. But, as I think, if you had a law like other men, that the verdict in capital cases was not required to be given in one day but many days were allowed for the trial, you would have been persuaded."

But such extreme limitation seems no unhealthy prohibition, philosophers to the contrary notwithstanding, especially when we realize that at the preliminary hearing (the anácrisis) before a magistrate, all the evidence that each side had to offer—laws, decrees, documents of all kinds, oral testimony of witnesses, affidavits of commissioners, evidence of slaves given under torture—was reduced to writing and deposited, under seal, by the magistrate, in the "Hedgehog Box" (*bristling* with documents), to be kept in safety till the sacrifice and herald's prayer opened the trial on court-day. So that the speeches for the prosecution and defense and the decision of the jury virtually comprised the whole trial. This evidence, previously reduced to writing, was merely read by the clerk before the witness who stood on the speakers' platform and acknowledged his testimony. The direct and cross examination of the witnesses at the trial proper, was thus avoided and the time consumed in putting questions to one's opponent, who was obliged by law to answer, was but a small set-off to the time gained by thus preparing material beforehand. The prompt decision of a higher court, especially in a case so vital to the interests and even life of the citizens as this against the corn-ring, would be of immense benefit and must have been a procedure resulting from years of carefully considered legal and political experience.

And too, a prospective prosecutor might well hesitate to bring a public suit when he considered the penalties to which he would be liable if he failed to prove his case. Our senator, however, could be fully assured of the sympathy of the public and of enough votes from the jury to relieve him of anxiety in regard to obtaining the necessary one fifth of the total vote cast. Failing to receive the required number of votes, payment of all costs and expenses was exacted together with a fine of 1,000 drachmæ or $180, which would purchase ten-fold more than at the present day. Add to this, the partial loss of citizenship, so far as the right to again bring similar suit is concerned, and we realize the seriousness of a public indictment for the plaintiff, as well as the effort of the Athenian legislator to prevent litigation among a people with such a mania for law that a character in Aristophanes's comedy did not believe that the country, pointed out on the map, was his native Attica because he couldn't "see any lawsuits going on."

As breaking the corn laws was a crime against the state no "summons" like that in a private suit was required, but the accusation was first laid before the president of the Boulè or unicameral senate,[1] who referred the matter to the senate, in session, which then held a "hearing" which took the place of the "preliminary hearing" in the private case before the magistrate, noted above. If the senate favored the accusation, a resolution was passed to that effect, and the clerk notified the Thesmothetæ of the result of the "hearing," submitting therewith the evidence of which the latter might take official notice. It then became the duty of these officials to bring the case for actual trial before a jury. The Thesmothetæ, who were associated with the chief magistrates of the nation, were a board who had the supervision of the whole judicial system at Athens and, in that capacity, examined and noted defects in the laws and kept a record of judicial decisions. These six junior archons presided at the trial in great public cases like the present

[1] Lysias, Oration 22, Sec. 2.

one, but only as formal chairmen, and did not in any way assume any of the functions of the jurymen-judges, whose decision covered both law and fact. The senate could not legally deprive a defendant of a trial by a jury of his peers, and no instance occurs of the assumption of such powers, except under the constitution-breaking "Thirty Tyrants" or by some patent violation of the legal rights of the citizen, though it was the ultimate court in public cases settled by a fine.

The jury, in the present case, would differ from our common law jury to-day not only in its wider function of judging both law and fact, but in the number of its members and the mode of rendering its decision. Any full-fledged citizen who signified his desire to serve by placing his name on a list of would-be jurymen, was entitled to be enrolled as juror, if he was over thirty years of age and the lot chanced to fall on him.

At the beginning of each official year, five thousand jurors were selected by the Thesmothetæ by lot. The jurymen were sworn in immediately after this general list was drawn, before being assigned to any particular case. The exact nature of the juror's oath, at the time the suit against the corn-ring was brought, is uncertain, though it probably did not differ materially, if at all, from that preserved in Demosthenes's speech, "Against Timocrates"[2] a generation later. The following is a careful translation of that interesting legal relic, with its searching appeal to the juror and citizen, who swears to defend the constitution.

Oath of Dicasts (Jurors)

I will vote in accordance with the laws and decrees of the Popular Assembly of the Athenians and of the Senate of the Five Hundred.

That there should be a tyrant I will not vote nor an oligarchy; nor, if any try to abolish the Popular Assembly of the Athenians, or speak or put to the vote aught contrary to these things, will I hearken to him.

Nor a cancelling of private debts, nor a redistribution of land or houses of the Athenians.

I will not recall those in exile nor those on whom sentence of death has been passed. Neither those who are abiding here will I banish contrary to the existing laws and decrees of the Popular Assembly of the Athenians. I will not do so myself nor suffer others so to do.

I will not confirm an office so that a man hold it while still liable for his audit for a former office, whether one of the Nine Archons or Sacred Recorder or whatever offices are balloted for the same day with the Nine Archons, whether herald, ambassador or deputies.

I will not vote that the same man hold the same office twice nor that the same man hold two offices in the same year.

I will receive no gifts on account of my service in court, neither myself nor any other man or woman for me, if I know it, by any means or contrivance whatsoever.

I am not under 30 years of age.

[2] Demosthenes, Oration 24, Sec. 746.

I will listen to the plaintiff and defendant both alike.

I will give my vote on the question at issue and none other.

I swear by Zeus, Poseidon, Demeter; I invoke utter destruction on myself and my household, if I transgress any of these things and many blessings, if I keep my oath.

The jurymen, thus drawn and sworn, were divided into ten panels of five hundred each. Each person, drawn, received a ticket of boxwood or bronze inscribed with his own name, that of his father, his residential district (the three essentials required for the legal designation of a free citizen) and the number of his panel. Such tickets of bronze, with the Gorgon's head and the omnipresent, Athenian owl—the official bird—are still extant.

Each panel was made up of members of all ten Athenian tribes, thus reducing to a minimum religious and residential prejudice and favor. The smallest number on any one case mentioned by the classic authors is two hundred, but we find cases with five hundred (trial of Socrates), one thousand, two thousand and even as high as two thousand five hundred jurymen-judges. An odd man seems generally to have been added to break a tie vote, though from some remarks dropped by the orators, we can infer that an even vote would mean the defendant won. The number which sat on the jury in the prosecution of the corn-ring is not known, but from the number assigned to other cases of similar importance there must have been a jury of a thousand or even two thousand men, as in the political trial of the informer, Agoratus, by the restored democracy after the expulsion of the aristocrats.[3] The theory underlying these great juries was that they were the largest possible representative committees of the whole Athenian democracy, with the delegated powers of the body-politic, the nearest approach to trial by the whole people. And, too, large juries were safer as a protection against bribery—that nightmare of the Athenian patriot. With the American reluctance to serve on the jury in mind, we instinctively ask how such large panels could have been obtainable. The answer is found in the fact that the Athenians were the most litigious people in history, loved the popular law-courts as the safeguard of their constitutional liberty, and were furnished by Pericles and the great political bosses after him with sufficient pay for their services to provide a living to the poor Athenian from jury service alone, to say nothing of becoming the political equal of the richest or most aristocratic citizen. The Athenian seemed to realize, in unique fashion, that the hope and redress of a free people lies in the possession and use of its courts, and they were so eager to attend trials and serve on juries that the conservative Aristophanes satirized the typical Athenian disease of law-mania. In the "Wasps," the comic poet, in trying to ridicule popular juries, especially those of the paid and

[3] Lysias, Oration 13, Sec. 35.

democratic brand, has given us an amusing study of the law-frenzy of the old juryman, Philocleon (Boss-Lover), who could not be kept away from court, though his son and two slaves net the house, from which the infatuated juror tries to escape through the chimney, by the rain-gutter, concealing himself under an ass that is being driven to market. The chorus of elderly jurymen come to "Boss-Lover's" assistance and finally compromise the matter by having the old man go back home and hold a private trial of the dog, Labes (Snap).

The case and the court house, in which any particular panel was to serve, was unknown till early in the morning of the day set for trial, when our jurors presented themselves and their bronze tickets, showing they had been drawn on the general list, and were then assigned by lot to their work for the day. The corn-ring jury then went to the "Middle Court" or the "Red Court," or "Hole and Corner Court," "Music Hall Court," to the "Painted Colonnade," or to one of the other five courts, all with different names and door-ways of different colors. On receiving his assignment, the juror took the staff of the proper color and was immediately escorted to the court to match and, at his entrance there, gave up the staff, getting in exchange a check which, at the close of the day, was good for his fee of three obols or nine cents, which slave labor and low costs of living made many fold more than the mere amount indicates.

The appointments of the court room consisted of an altar for sacrifice, raised platforms for the presiding officials, for the parties to the suit and the witnesses. A statute of Lycus, patron-god of jurors, a water-clock to time the speeches and a table with the two voting-urns thereon probably completed the furnishings at the period when our case came on. Order was kept in court by Scythian slaves, detailed from the regular police.

After the speeches were made, the case was given to the jurymen-judges, who always rendered their verdict without leaving the court-room but, however, with the utmost secrecy. The mode of voting was simple and, though secret, was open to the fullest scrutiny on the part of the spectators. A person, chosen by lot, distributed bronze discs, pierced by protruding axles, all exactly alike, except that the ballot for the plaintiff had a hollow axle and that for the defendant a solid one. Specimens of these ballots, marked "public ballots," are still extant. The herald proclaims "hollow ballots for the plaintiff; solid ones for the defendant"; hence hollow ballots meant condemnation, in the prosecution of the corn-ring, and solid ballots meant acquittal. Our juryman concealing the ends of the axle with thumb and forefinger, at the herald's notice, proceeds to the table and deposits in a bronze urn the ballot with which he wishes to record his verdict, casting the unused ballot into a wooden urn. The ballots are counted by the presiding officials and the result is immediately announced by the herald. Under the system, to say nothing of the natural feeling in this case, there were no delays resulting from the failure of the jury to agree; for a majority-vote decided the verdict.

The penalty, in this case, was fixed by law—which did not always happen—and, in default of a fixed penalty, not only actual damages but the penalty also was a matter for the jury to assess.

Athens and the Attic country-side, bounded by the mountains and the Greek seas, were practically insular when the supply of wheat was considered. A little nation, with only half the area of Rhode Island but equal in population to that thickly settled commonwealth, would thus present problems in plenty and corn-laws galore. The unproductive, light soil caused Solon early to forbid the exportation of any farm product except olive oil: while the export of native grain was absolutely forbidden by law, with the consequent encouragement of the importation of cereals. Bread-stuffs must, in the main, come from abroad and the fertile fields of Egypt and Sicily, to say nothing of Rhodes and Cyprus, and, above all, the Black Sea country of modern Russia were drawn on. The great problem in war, as well as in peace, was to keep open a way for the corn-merchantmen, especially to that north country; and on the failure or success in that vital work lay the hope or despair of the Greek admiral or ruling statesman. Foreign princes wooed the Athenian populace with presents of corn and Harpalus, afterwards treasurer of Alexander the Great, won citizenship at Athens by a gift of corn.

Forced importation of grain was a cardinal principle of Athenian economics, politics and law. The speeches of the "orators" are full of regulations, restrictions and enactments, rigorously and mercilessly enforced, against the dreaded day when city-folk and farmers alike might see starvation at their doors. Both Athenian citizens and metics (resident aliens) were forbidden to ship grain elsewhere than to Attic ports or to lend importers money on vessels unless the mortgaged cargo was to put in to the Piræus, harbor-town of Athens. Another law required that at least two-thirds of the cargo of every corn-ship that touched at the port must be carried to the city. The popular assembly called for reports and demanded provisions for a supply of grain at its monthly sessions.

Among the numerous corn-laws, one, intended to prevent speculation and the artificial raising of the price of grain, went directly to the heart of the traffic by prohibiting retail dealers, on penalty of death, from buying more than fifty *phormoi,* or baskets, at any one time. The *phormos* was a measure equal to about a bushel and a half and the consequent seventy-five bushels—to the purchase of which each retailer was limited on any one day—was probably a sufficient stock in trade and, if enforced, a reasonable safeguard against "a corner in corn." The severity of the penalty imposed in this case by the law of the land, is remarkable, especially as the Athenian law seldom imposed the death-penalty at all; banishment, disfranchisement, etc., being preferred as potent purifiers of the body-politic. If the evil was driven out of the state, the state was the better for it. The control of such a small nation by a "ring," guild or corporation of tradesmen was easy, by virtue of its narrow boundaries, and, for that reason, heavier penalty and more rigorous control is imperative. The easier the violation, the greater is the temptation and consequent danger to the commonwealth. A twenty-nine million dollar fine would have been impossible, but the death-penalty was a more direct and persuasive inducement to respect for the public weal; and though the risk was still run by greedy speculators, as our speech informs us, the law, made by the people, for the protection of the people, was enforced by a jury of the people, though they must in the discharge of their duty send the guilty to the fatal draught of hemlock.

A special board of ten corn-commissioners, elected annually by lot, had charge of the enforcement of the above law, under which our senator prosecutes the "corn-ring." It was the duty of the board to see that the unground grain was for sale in the market at a fair price; that the millers sold the meal at a price proportionate to that of the corn; that the bakers sold bread at a price proportionate to the price of wheat and made their loaves of bread of a weight fixed by the corn-officials.[4] These officers were also required to keep an account of all importations of grain.[5]

The grain dealers or retailers were the middlemen between the people and the great wholesalers or importers, and we may trust them to evade the law by secret understanding with the importers in regard to buying in bulk; by combining with each other to buy low, hold and sell high; by raising the price by circulation of news of war, storm, wreck, etc., as we learn from the orations of Demosthenes and Lysias. Such are the legal principles, laws and procedure underlying the case which our senator brings in his prosecution of the Athenian "corn-ring" for illegal speculation.

The senate, in such cases, ordinarily chose a public prosecutor to defend the interests of the state. Our senator may have been glad to assume that position as a willing choice, as he intimates, to clear himself of the suspicion of being "in with the Ring."

The speech itself is brief and logical, clearly stated and forcibly argued, and sticks closely to the point at issue—a proceeding that did not always obtain in the Greek law suit, though that blemish is not entirely unheard of in our modern courts, at least by inference, which

[4] Aristotle, Resp. Athen., 51, 3.

[5] Demosthenes, Oration 20, Sec. 32.

sometimes gets in where direct statements fail to enter. The speech, a master-piece for a conservative, public-spirited business man, is a fine example of Lysias's character-study. The defendants admit their guilt and apparently try to avoid the consequences by pleas in confession and avoidance. The pleas in excuse were (1) that the corn-inspectors suggested that the dealers buy up the corn; and (2) that their action had benefited the public by obtaining for it a supply of grain. Our senator replies (1) by showing, on evidence, that the corn-inspectors never made any such suggestions and that if they did it would not excuse such an open violation of a plain law; and (2) by showing that the rôle of public benefactor could not be very seriously assumed by men who "dodged taxes" and the other patriotic contributions and raised the price of corn in one day many fold higher than the law allowed.

Liberal extracts of the speech itself in the words of the old Greek senator follow:

Many have come to me, gentlemen of the jury, wondering at my accusing the grain dealers in the Senate and saying that no matter how guilty you thought they were, you would nevertheless consider those who made speeches against them, blackmailers. Now I want, first of all, to tell you why I was compelled to accuse them. When the presidents brought the charge before the Senate they were so indignant with the dealers that some of the speakers said they ought to be turned over to the "Eleven"[6] and put to death without a trial. But I, thinking it was a terrible thing for the Senate to get in the habit of doing such things, got up and said that it seemed to me that the grain-dealers should be tried according to law, considering that, if they had done things which deserved death, you would give them their just desserts just as well as we; but if they had done no wrong there wasn't any need of our putting them to death without a legal trial. And although the Senate was persuaded of this, some tried to accuse me, saying I made my speech to save the grain-dealers. Now before the Senate, when the "Hearing" was held, I made a practical defense against these charges; for when the others kept quiet I got up and accused the dealers and made it clear to everybody that I had not spoken in their behalf but for "due process of law." Now I started in this affair for the reasons I have described (from fear of the charges against me), but I consider it disgraceful to stop till you have voted what you wish to do with them.

The plug is put in the water-clock and the flow of water, which regulates the time for speaking, is stopped, while one of the defendants is put on the stand.

First you come up and take the stand. Tell me, are you a metic [resident alien]? Yes. Do you enjoy the privileges accorded to the resident alien on condition that you obey the laws of the city or with the understanding that you do whatever you please? On condition that I obey. Don't you expect to die if you have done anything in violation of the laws for which the penalty is death? Certainly. Now tell me if you admit that you bought up more than the seventy-five bushels which the law provides as the limit permissible? I bought at the bidding of the officials.

[6] Board of prison and police commissioners in charge of executions, etc.

After this, rather evasive, reply the water-plug is removed, the water runs anew and the senator replies to the first plea, noted above:

If he can show, gentlemen of the jury, that there is a law which requires the corn-dealers to buy up corn because the officials bid them to, vote to acquit them. But if he does not, it's only just that you vote condemnation; for we produced the law which forbids any one in the City buying up more than seventy-five bushels of corn. Now this accusation ought to be sufficient, since this man admits he bought it, the law clearly prohibits it and you have sworn to vote according to the laws.

However, to persuade you that they are lying about the officials, I must speak more at length about them. Now when these fellows put the blame on the officials we summoned the officials and questioned them. Four said they knew nothing about the matter and Anytus said that during the previous winter, when corn was high and these fellows were bidding against each other and fighting with each other generally, he advised them to stop their wrangling, thinking it to the interests of you who buy from them, that these dealers should buy as low as possible; for they've got to sell it higher than cost, if it's only a penny more. Now to prove that he did not order them to buy up corn and store it away but did advise them not to bid against each other, I will furnish Anytus himself to you as witness; and to prove, too, that he spoke these words under the former Senate and that these fellows appear to have bought it up this year. "*Testimony* (Read and acknowledged)." Now you've heard that they did not buy up the corn on orders from the officials. But I think, if they are really telling the truth about the corn-inspectors, they will not be defending themselves but be accusing the officials; for in matters which the laws have expressly provided for, why shouldn't both those who fail to obey and those who incite them to act contrary to the laws, pay the penalty?

The senator then replies to the second plea in excuse which admitted that they had "cornered" the supply but held their action had really benefited the people. This prototype of the modern trust-lover's argument is logically decapitated and the disguise of public benefactor is torn off in brief but telling language which exposed variation of price in a single day—the most charitable explanation of which was that the price changed as the "bulls" or "bears" respectively controlled the market. The senator also took the opportunity to impress on the "corn-ring" that obedience to the laws and willingness to make the patriotic contributions the nation called for was a condition precedent of loyalty and that charity in trade may be allowed as a supplement, but not as a substitute for the performance of duty to one's country and fellow citizens.

But, gentlemen of the jury, I don't think they will get any pity for such talk. And perhaps they will say, as they did in the Senate, that they bought up the corn out of good will towards the state, so that they might sell as low as possible. But I will offer you the greatest and most evident proof that they are lying. For if they did do it for your sake they would have appeared selling for many days at the same price, until the corn they bought up gave out; but now, as a matter of fact, at times on the same day they sold at a drachma [18 cents] higher than at other times—just as if they had bought by the bushel and not by bulk. And I furnish you witnesses to prove it.

And it seems to me an awful thing that they don't want to contribute to the war-taxes, when necessary—and that's a thing everybody is going to know about—and plead poverty; but where there was a death-penalty and it was to their interests to keep things "dark," this they say they did in defiance of the law out of love for you. And you all know that such talk as that does not become them at all; for their interests and those of other people are radically different. For they make their biggest profits when they sell corn higher to the State on some report of evil. And so glad are they to see your mishaps that they know about them before other people and make up stories and circulate them themselves, saying that the ships in the Black Sea have been wrecked or those which have put to sea have been captured by the Spartans, or the ports have been blockaded, or the truces are about to be annulled; and have come to such a pitch of hostility that they plot against us at the same critical period that the enemy does. For when you especially need grain these fellows "snap it up" and refuse to sell so that we may not haggle over the price but may think ourselves lucky if we get off with buying from them at any price whatever; so that sometimes, even in time of peace, we are besieged by them. . . . Frequently, before now, you have inflicted the most severe penalties on the officials—and that too, though they were citizens—because they could not control the rascality of these men. What, pray, ought the malefactors themselves to suffer at your hands when you killed those who were unable to guard them?

Calling upon the jurymen to regard this as a "test case"—as the people surely will—to chastise the guilty and protect their victims, with an appeal to justice and an argument to catch the crowd, our senator closes this speech of such vital interest to the people of constitution-loving and law-enforcing Athens.

You ought to consider that it's impossible for you to vote acquittal; for if you acquit men who confess they "combined" against the merchants, you'll seem to be plotting against the importers yourselves. But if they had made any other defence no one could have found fault with a jury who acquitted them; for "it's up to you" to believe whichever party you wish. But now, won't you seem to be doing something awful if you let men go scot-free who confess they violated the law?

Now, gentlemen of the jury, I think it's clear to everybody that law-suits on such matters are of the most general interest to the citizens, so that they will learn what opinion you hold about them, thinking that if you condemn these fellows to death, the rest will be more orderly and law-abiding, but should you let them go scot-free, you will be voting them full immunity to do whatever they please. You ought, gentlemen of the jury, to chastise them, not only for the past but as a warning for the future; for in that case even, they will be barely endurable. . . . And should they beg and implore you, you would not justly take pity on them but far more on those of the citizens who are dying through their rascality, and on the importers against whom they have "combined," whom you will please and make more zealous if you punish these fellows. But if you do not, what opinion do you think they will have when they learn that you acquitted the hucksters, who admitted they conspired against the importers?

I don't know what more I ought to say; for about other malefactors, when they are on trial, you must get your information from the accusers, but all of you know the rascality of these fellows. At any rate, if you convict these men you will "do the square thing" and you'll buy your corn lower; but if you don't, it will be higher.

THE POPULATION OF THE UNITED STATES

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Of all branches of statistics, those which relate to the population of a country or city are of most general interest. The interest felt in the question of our national population culminates every ten years when the census is taken. To be sure, no great importance is to be attached to mere numbers; yet we can not help feeling a little pride if we belong to the biggest religious denomination, the biggest university, or the biggest country.

The plots in Fig. 1 represent the growth in population of various countries as indicated by the census of 1900. The curves were made by Mr. W. R. Wilcox and were printed in the census report for that year.

An examination of these curves shows that for the most part the growth of a country is constant; for example, the lines representing France, Spain, Sweden and Norway, Turkey and Italy, are nearly straight. This indicates that while the population of those countries is increasing slightly, there is no great gain from year to year. The population of the United States is represented by a curve which is well known in mathematics. In the chart below I have redrawn this curve, and with it one which is a true parabola.

It will be seen that these two are strikingly similar. Now if the population of the United States increased in such a manner as always to follow this parabolic form, the census enumeration would be unnecessary, as one could predict the future population from the past. Unfortunately, however, this is not the case; and it is only by a somewhat tedious method that we are able to predict the future population with any degree of certainty. There are two kinds of formulæ—rational and empirical. A rational formula is one which is mathematically true under all conditions. The fact that the volume of a cylinder equals π multiplied by the square of the radius, multiplied by the length, is a fact that does not depend upon any external circumstances whatever. On the other hand, the value of the acceleration due to gravitation is not a constant quantity, but differs with the latitude and altitude of the observer. This latter is one of the most important physical constants in nature and a great deal of time and money have been expended in determining its value. While there is no mathematical formula that expresses this value, an empirical formula has been devised in which, if one substitutes the latitude and altitude of the place of observation, a close approximation of the value of this constant may be obtained. To take another illustration: The relation between the velocity of water flow to its depth below the surface in a river is not a constant one, but

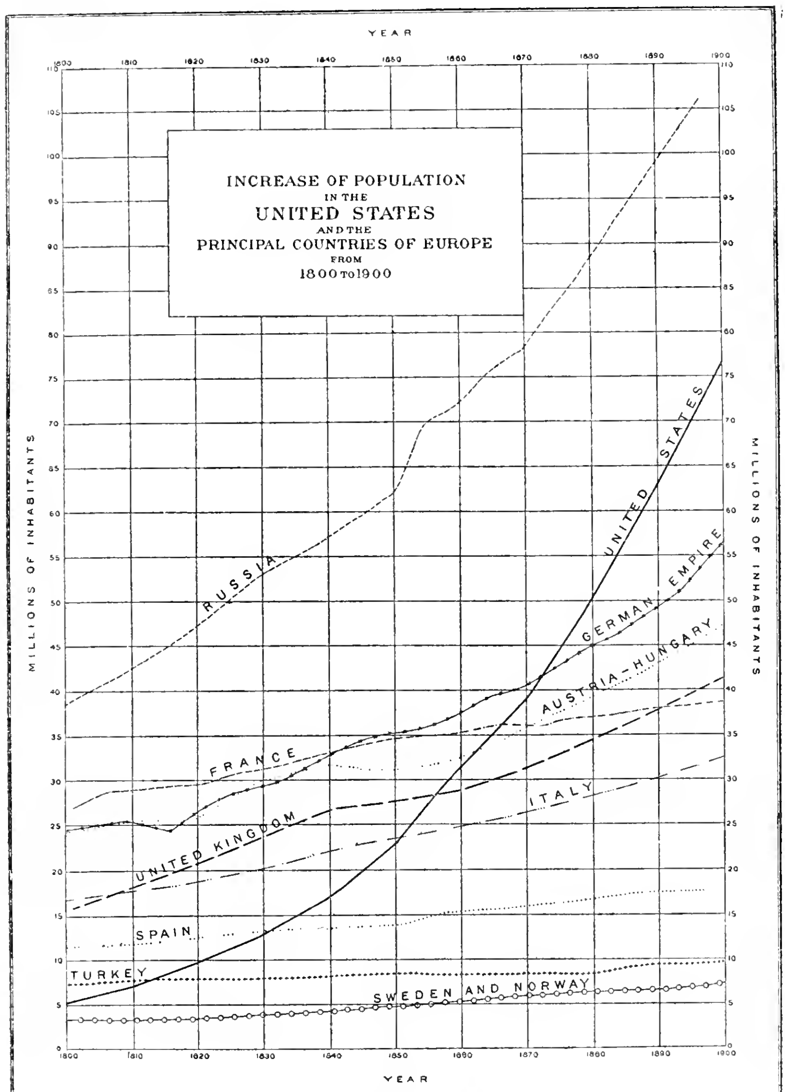

FIG. 1.

repeated measurements have shown that by the use of an empirical formula containing certain constants, this relation may be quite well established. On the other hand, the relation between the space passed over by a freely falling body and the time of its fall is a perfectly definite one, and may be correctly expressed by saying that the space passed over varies as the square of the time.

These illustrations will be sufficient to make clear the distinction between mathematical and empirical formulæ. It will be hardly necessary to state that the growth of a country in population follows the latter rather than the former. In order to predict the future population, it is necessary to determine what kind of a curve the previous numbers representing the population will plot. As has been stated above, this curve comes out a parabola and the equation for this parabola is

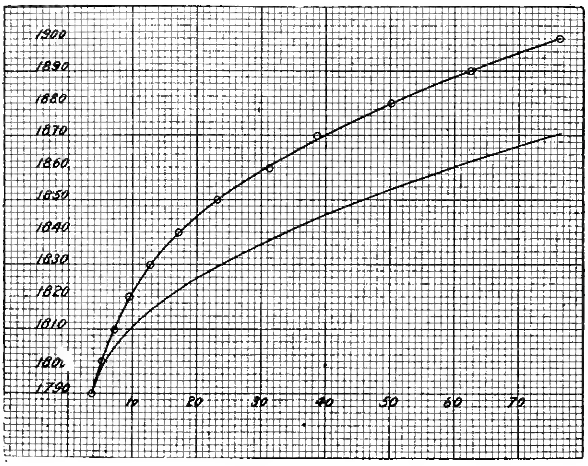

FIG. 2.

$$P = S + TX + UX^2.$$

There are also certain terms of higher orders which may be omitted. In this equation, P represents the population at any time, X the number of the decade and S, T and U are constants, which are to be determined. The determination of these constants involves a somewhat technical process, which may be briefly stated as follows: We first write down the population of the United States for each decade since the census began to be taken.

Year	Population	Year	Population
1790	3.9 millions	1850	23.2 millions
1800	5.3	1860	31.4
1810	7.2	1870	38.6
1820	9.6	1880	50.2
1830	12.9	1890	62.6
1840	17.1	1900	76.3

From these observations we form what are called "observation equations" by substituting for P and X their proper values.

These observation equations follow:

1	$3.9 = S + 0 + 0$	7	$23.2 = S + 6T + 36U$
2	$5.3 = S + T + U$	8	$31.4 = S + 7T + 49U$
3	$7.2 = S + 2T + 4U$	9	$38.6 = S + 8T + 64U$
4	$9.6 = S + 3T + 9U$	10	$50.2 = S + 9T + 81U$
5	$12.9 = S + 4T + 16U$	11	$62.6 = S + 10T + 100U$
6	$17.1 = S + 5T + 25U$	12	$76.3 = S + 11T + 121U$

Normal equations for each constant are formed from these observation equations by multiplying each equation by the coefficient of the constant concerned in the equation and adding. This gives us three equations containing three unknown quantities. These unknown quantities are determined by any method and substituted in the general formula for S, T and U, respectively. For example, in 1900, before the census returns for that year were available, the process above outlined yielded the following equations:

$$261.7 = 11S + 44T + 286U$$
$$1669.5 = 44S + 286T + 2026U$$
$$12324.1 = 286S + 2026T + 15334U$$

When these equations are solved, it is found that

$$S = 6.08, \qquad T = 0.690, \qquad U = 0.622.$$

If we substitute these in the formula, we get

$$P = 6.08 + 6.9 + 62.2, \qquad \text{or} \qquad P = 75.2 \text{ millions},$$

which is the forecast for 1900.

(It should be observed that in this work the year 1790 was considered — 1, and 1800 was taken as the origin.)

This estimate proved somewhat low, as the census returns reported 76.3 millions for 1900. This indicates that the population of the country is growing a little more rapidly than would be indicated from its past history.

While the government authorities are at work on the census for 1910, it will be interesting to try this method of forecasting, and to see how well our results will compare with those to be announced later on. I have made a number of equations which are supposed to represent empirically the growth of the population of our country. These have been made in various ways, but all depend upon the parabolic formula, and the method outlined above.

A. $P = 5.13 + 0.358X + 0.666X^2$

B. $P = 5.30 + 0.49X + 0.65X^2$

C. $P = 4.90 + 0.45X + 0.66X^2$

D. $P = 5.30 - 0.20X + 0.73X^2$

E. $P = 5.40 + 0.12X + 0.70X^2$

F. $P = 39.1 + 10.45X + 0.65X^2$

The equations yield the following values for the census of 1910:

A. $P=89.7$	C. $P=89.7$	E. $P=91.4$
B. $P=89.3$	D. $P=91.4$	F. $P=91.3$

It will be observed that these forecasts fall into two classes, in one of which the numbers run between eighty-nine and ninety millions and the other a little over ninety-one millions. The former are based more strictly upon the formula as it stands, including the entire set of observations. In the latter, greater weight is given to more recent observations, as it is supposed that they represent more nearly the present rate of increase in the population. The last formula (F) is based upon three observations only, those for 1880, 1890, and 1900. It is probable that while the formulæ yielding the lower results conform more nearly to the population of our country in the past, the results which are yielded by the other set of formulæ are more correct for 1910. As an illustration of the closeness with which the formulæ conform to past conditions, we will determine the results for each census by means of formula:

$$P=5.13+0.358X+0.666X^2.$$

Year	P (Census)	P (By formula)	Difference
1800	5.3	5.3	0.0
1810	7.2	6.2	1.0
1820	9.6	8.5	1.1
1830	12.9	12.2	0.7
1840	17.1	17.2	0.1
1850	23.2	23.6	0.4
1860	31.4	31.3	0.1
1870	38.6	40.3	1.7
1880	50.2	50.7	0.5
1890	62.6	62.4	0.2
1900	76.3	75.4	0.9
			6.7

The formula published by Dr. H. S. Pritchett, in THE POPULAR SCIENCE MONTHLY, of November, 1900, agreed more closely with the results of past censuses than the one used here. It will be noted that while the sum of the various deviations resulting from each application of the formula is 6.7 millions, that from Dr. Pritchett's formula is only about 4 millions. This formula, however, does not seem to fit the future conditions so well as the one employed here, for it gives a population of 77.5 millions for 1900, while the census returns show it to be 76.3 millions.

As a method of determining the population of the United States during the coming decades, the application of these formulæ is interesting. By the use of formula E—

$$P=5.4+0.12X+0.7X^2$$

we obtain the following forecasts:

1910	91.4 millions	1970	209.7 millions
1920	107.6	1980	234.4
1930	125.3	1990	260.4
1940	144.3	2000	287.8
1950	164.7	2500	3,443.8
1960	186.5	3000	10,099.8

Since one of the factors used in the formula is a square, it is noticeable that the increase is quite a rapid one as the years go on. In the year 2270, which is not so very remote, the estimate is 1,557 millions, which is about the population of the globe at the present day. The predictions reached by this formula are somewhat smaller than those given by the formula of Dr. Pritchett in the article referred to. An interesting point in the curve is noticed for the year 1870. It will be observed that the population for this year differs more widely from that of the predicted population than that for any other year. This is probably due to two causes. In the first place, the effects of the civil war are shown in the reduction of the population, and, secondly, it is probable that the census of 1870 was not so accurately taken as that of any other decade. This latter reason is given by Mr. Robert Porter in the Census Bulletin No. 12, 1890.

There is another method of forecasting the census, which depends upon reported estimates of the population in various centers. "The World Almanac," for example, secures the best available data from government and other officials, and each decade estimates the census which is to be taken. In January, 1900, this estimate was 79.4 millions, while the census enumeration showed 76.3 millions. This was about 4 per cent. too high. In January, 1910, the estimate is given as 92.3 millions. If this is reduced in this ratio, it gives a result of 88.8 millions for the year 1910.

In conclusion, it may be stated that the results of empirical formulæ, unlike those of the mathematical formulæ, are never perfectly reliable or correct. It is, therefore, impossible to predict the population for 1910 with any such degree of certainty as one can predict the free fall of a body in a given interval of time. It is to these empirical formulæ, however, that science owes much of its progress, and the governments of civilized countries are spending thousands of dollars in order to bring the constants in these various formulæ a little nearer the truth. In its application to the problem before us, it may be stated that if the population for 1910 shall be found to conform to the general trend of increase in the population since the first census was taken, we may feel certain that it will come out about 89.7 millions. If, on the other hand, it shall be found to conform more nearly to the growth made in the last few decades, it will be about 91.3 millions. Of course, there is always the possibility that the case may be an abnormal one and that the growth of our country will be found to conform to no formula which represents its past growth. In such a case, all empirical methods are helpless. It should be added that the formulæ used in this article are anti-expansion formulæ—that is, they do not include the insular possessions of the United States.

PRESERVATION OF THE FISHERIES ON THE HIGH SEAS

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THE fishery resources on the high seas can not be regulated and conserved by municipal or national laws, and the governments of the world are in a just sense the trustees for the management of this great wealth, this common field, where all reap and none sow, where all harvest and none plant.

It is to the common interest of all nations to prevent indiscriminate depletion of these resources. Useless destruction is a crime against posterity. Doubtless a century hence no policy of our great president will add more largely to his fame than his efforts toward preserving the natural resources, and no branch of these calls for more prompt international consideration than the resources of the high seas.

Upon the subject of the preservation of these resources so that their yield may continue undiminished, so much is appropriate to be said that one is lost in the abundance of it. The animal and vegetable products of the seas differ almost as widely in their characteristics and needs as those on land, and equally diversified and complicated are the problems concerning the most favorable conditions of their production and development.

Fortunately, the problem of sewage pollution, doubtless the greatest destructive factor in the inland and the coastal fisheries, has little or no existence in a consideration of the resources of the areas under consideration.

From the standpoint of protective needs, the fishery products of the high seas may be roughly divided into four general classes, viz.: (1) the migratory species, such as herring, mackerel, bluefish, etc.; (2) the bottom or ground species, such as cod, haddock, flounder and flatfish, which are less migratory in their habits and remain in the same general locality; (3) those products which are fixed to the bottom and are to some extent susceptible of ownership, as sponges, pearl oysters, etc.; and (4) the aquatic mammals.

As regards the migratory fishes, there is an increasing belief that serious impairment of these species is beyond our present demands on them, and that the destruction effected by man is but child's play compared with nature's work in that direction. Many states from time to time have enacted restrictive legislation with a view to preserving them, but estimation of the beneficial effect of these regulations is generally discredited.

Since this legislation interferes with the established uses and customs of the fishermen, the burden is upon those who advocate it to prove that the benefit will outweigh the inconvenience. Ever since the influential voice of Huxley was lifted in its defense, the policy of unrestricted capture of the migratory species has continued to grow, this view being strongly supported by many eminent authorities of the present day.

With respect to the bottom fishes, cod, haddock, flatfish, etc., our present knowledge of the remedial effects of fishery restriction is so slight as scarcely to furnish a satisfactory basis even for national waters, much less for complicated international restrictions.

For the purpose of determining the best regulations for preserving the fishery resources with the maximum extent of their utilization, it is not easy to exaggerate the importance of systematic research in marine biology and the effect of fishing operations. Excellent work of this nature has been done and is yet in progress in many countries where the fisheries are of great extent.

International restrictions have been of two general classes, the one for preserving the resources and the other for the maintenance of good order among the fishermen and for preventing the destruction of property. To the former class belong the Bering Sea fur seal regulations, and in some particulars the Anglo-French regulations of 1843; while all the remaining conventions and regulations, the North Sea Conventions of 1882 and 1891, the Anglo-Denmark Convention of 1901 and the Sub-marine Cable Convention of 1884 are of the second class. A review of the history of these regulations shows that the arrangement of joint action is a tedious and difficult matter and ratification of the convention is always uncertain. Indeed, except so far as concerns the police of the fisheries, it does not appear that great practical benefit has resulted from the regulations already enacted for the fisheries in the international waters.

For the preservation of the coastal fisheries by means of municipal regulations, as well as for the more important matters of national defense and safety, the opinion is growing that the three-mile limit of the territorial waters is too narrow and that it should be extended considerably beyond the present distance.

This limit had its origin in the range of cannon, which determined the distance over which a nation was able to exercise jurisdiction from the shore. Since the efficiency of cannon has greatly increased, and is now considerably more than three miles, it is urged that the width of the maritime belt should increase correspondingly. In recent years most of the writers on international law have expressed views favorable to this increase.

The extension of the marginal belt was discussed by the Institut de Droit International at its meeting in Paris in 1904. The general opinion was that such an extension was desirable, and it was agreed without a dissenting vote to recommend an increase to six miles, after the proposal to extend it to ten miles had been rejected by twenty-five votes against ten.

However, in view of the approval which the three-mile margin has received in international conventions, legislative bodies and judicial tribunals, the indefiniteness of centuries ago has become the vested rights of to-day, the once plastic cement which the workmen molded has now become so set and solidified with the passage of time that it is useless to discuss an extension of the distance of exclusive jurisdiction without absolute international agreement.

It can not be denied that such an extension would be vigorously opposed by some influential interests. Doubtless one is safe in stating that the trawl fishermen of Great Britain, for instance, would unquestionably object to it, and for very practical reasons. Exclusive of the White Sea and the Baltic, the trawling area outside the three-mile limit of northern and western Europe approximates 450,000 square miles. An extension of the marginal belt to six miles would place 81,000 square miles of this area within the territorial jurisdiction of continental countries, and an extension four miles further would exclude British fishermen from 135,000 square miles of the best trawling grounds, an area nearly equal to that of the North Sea. As the British trawling fleet greatly exceeds that of all the continental countries, the fishermen of Great Britain would have much to lose and nothing to gain by the extension.

On this side of the Atlantic, acceptance of the extension would depend very largely on how it would affect the rights and treaty privileges of the United States along the shores of the British provinces, which probably more than any other factor has influenced the present firm position of this government respecting a marginal belt of a marine league only.

More important from an economic point of view than several miles increase in the width of the marine belt is a clear and unquestioned international recognition of vested rights in attempts to exploit and develop definite areas of ground under the high seas, as in the cultivation of sponges, corals, pearl oysters, etc. There is a distinction in law as well as in fact between such an industry and a fishery dependent on the pursuit of free swimming fish in the ocean. Oysters, sponges and the like represent a peculiar kind of property. They are not *feræ naturæ,* as they do not stray nor do they require taming, hence ownership may be acquired in them.

It can not be affirmed that this extension of territorial jurisdiction to cultivated sea bottoms has ever been made the basis of any treaty or agreement, or has even been the subject of diplomatic discussion. With the single exception of Vattel, the older writers on international law were silent on this matter, and even Vattel seems not to have clearly distinguished it from the exercise of jurisdiction over migratory fishes in the seas near the marginal belt, a doctrine which has long since been discredited.

Very natural was the silence of the older publicists on this subject, since there was no occasion for recognition of this view until a very recent period. The spirit of scientific investigation and of industrial development is everywhere, and in few directions have these made greater progress in the last score or two of years than in the possibilities of cultivating the sea bottoms. Millions of dollars' worth of oysters are now grown on areas which thirty years ago were barren wastes. Biologists are obtaining excellent results in sponge culture in the Gulf of Mexico, and are investigating coral growth in the Mediterranean. Careful observers are awakening to the possibilities of pearl culture, not simply to raise the mollusks which yield pearls fitfully and at rare intervals, but to insure and to increase the yield of pearls within these mollusks, and thus to obtain remunerative returns without the arduous toil and the element of hazard inseparable from pearling as now prosecuted.

And must the work of these investigators, must the enterprises which they stimulate, be restricted to the bounds of the marine league while the broad areas of shallow bays and gulfs remain barren? Must we plant and harvest but along the wave-washed shores of the maritime belt and leave the rich meadows of the sea bottoms to waste? Must the work be handicapped by the refusal of international law to concede to these enterprises the elements of ownership, which must be wholly lacking unless territorial jurisdiction apply to the areas which they exploit?

Numerous instances exist in which fisheries for pearl oysters, etc., prosecuted beyond the marginal belt, are the subject of fostering care on the part of a government or its people. By careful supervision as to close seasons, size limits, etc., and in some cases special preparation of the bottom and even removal of predaceous enemies, the output from these areas is conserved and increased. Instances of this kind, under state authority or recognition, may be regarded as an occupation of the bed of the sea, and territorial jurisdiction should rightly extend to them even though they be carried on beyond the marginal belt ordinarily recognized by international law. Even Grotius's *Mare liberum* is founded upon the old doctrine of Roman law that there can be no property in anything without occupation. And while the vagrant waters of the ocean can not be subjected and occupied, the sponge beds and pearl reefs can be even as the hills and the prairies.

This view is founded not only on justice, but likewise on necessity.

Man's eagerness has so nearly exhausted the easily exploited resources that fostering care is essential to the best development and use of the sea bottom. Left to the chance of nature and subject to despoilment by every one without hindrance, these areas would remain barren wastes. Law and government are for the benefit of humanity, not to foster waste. The aim of international law is the welfare and happiness of the general society of mankind, and this would not be promoted by a policy which would keep the sea bottoms forever unproductive. The reason for the freedom of the high seas is the freedom of intercourse and commerce between the states, the seas being the common highway; and a recognition of the occupancy by an individual nation of so much of the sea bottom as it may actually improve and develop does not impair the perfect freedom of navigation by vessels of all nations, as this occupancy is subordinate to the right of navigation and fishery and can not be exercised in derogation thereof.

Necessarily in the recognition of this extension of jurisdiction, the interests of the various states must be carefully guarded, and especially of those near the areas to be exploited. Within general limits, the right of exploitation and development must be reserved to the nation within whose sphere of influence the particular area is situated, for it would be manifestly unjust, indeed extremely unwise, to establish a principle by which a nation could appropriate to itself a resource off the shores of a less enterprising country. The privilege of exploiting the sea bottom in the whole of the Gulf of California, for instance, should undoubtedly rest with the Mexican people; Ceylon and British India should have control of that in the Gulf of Manar, and the riparian states should possess those in the Persian Gulf and the Red Sea.

However we may view the protective needs of the migratory and the bottom fishes, the situation is quite different with respect to the great marine vertebrates, the seals, walrus, manatees, sea otters and many species of whales. These animals are approaching practical exhaustion with great rapidity, and prompt action seems necessary if they are to be preserved from extinction.

This is not the language of exaggeration. Under the influence of the bounty of $25 which industrial use offers for the life of a fur seal, $300 for a sea otter and $8,000 for an arctic whale, these animals are passing away far more rapidly than is generally realized, the entire annual product of sea otters throughout the world now approximating only 200 and of arctic whales less than 100 each year. The timid whalebone whales have been swept from the navigable seas and are nowhere to be found except in the most remote ice fields of the frigid zones.

The walrus are almost exterminated in the seas north of Europe; and where they were formerly so plentiful in Bering Sea, they are to be found only in one small herd, which hauls out in the spring and fall on the islets off Port Heiden, on the Alaska Peninsula.

It is shocking to contemplate the indifference with which the civilized world has witnessed, nay, not only witnessed but encouraged the slaughter, almost to the point of extinction, of highly organized animals evidencing traits of affection and devotion which would do honor to human beings. Everywhere, in every sea, it is the same story, destroy! destroy! destroy! What more pathetic sight in the whole range of man's ruthless destruction than the thousands of nursing fur seals starving and dead on the shores of the Pacific islands as a result of the inhuman butchery of their nurture-seeking mothers in the waters of Bering Sea and the North Pacific. At the present rate of decrease the day is not far distant when they will have become as extinct as the buffalo of the American prairies.

Let it not be understood that our sympathy for the highly organized creatures of the sea would withhold them from industrial use. The slaughter of animals under proper safeguards, whether they be in the seas or under domestic care, does not in itself constitute needless cruelty, for the end of every individual, beast or human, is pathetic, whether it result from sudden accident or through the waste of years. When this slaughter is so conducted that it is conservative utilization, with due care for the welfare and perpetuation of the species as a whole, it is but the most intelligent application of nature's wisest law of the survival of the fittest. The preservation which we would extend to these animals is largely for the purpose of their greater use. We would surround them with such protection and take them only under such conditions as would tend to increase their numbers and thus make them of far greater value to the hardy fishermen whose industry has won renown in all ages. It is hoped that the wide public interest attracted to the preservation of our natural resources will result in preventing the now imminent extermination of these species, whose zoologic and philosophic worth far exceeds their economic value.

It is beyond the limits of this paper to outline the proper direction of the efforts to preserve these resources. But in view of the fact that the fisheries on the high seas represent the greatest economic resource which the nations of the world hold in common for their joint use, it seems that there might be wisdom in a general treaty or international union for their consideration. Already there are several treaties of this nature with special international offices for the purpose of satisfying economic and other nonpolitical interests, such as the Universal Postal Union, established in 1874, the Union for the Protection of Industrial Property in 1883, and the Union for the Protection of Works of Literature and Art in 1886. More closely allied to our subject is the convention in behalf of the preservation of wild animals, birds and fish in Africa, which was signed in London on May 19, 1900, by France, Germany, Great Britain, Italy, Portugal, Spain and the Kongo Free State.

And at this time when the preservation of natural resources is receiving so much attention, what subject more worthy of consideration than the economic conservation of the resources of the seas? A brotherhood of great nations arranging not the partition of nature's inheritance among themselves for speedy waste and despoilment, but the preservation of that inheritance for beneficial use in common by all the people of the earth: each to draw upon that storehouse of wealth only in accordance with the common welfare of all, for the sustenance of its citizens, for the comfort of its people and for the advancement of civilization throughout the world.

Fig. 1. General View of the Tortugas Laboratory from the northwest in 1906.

THE RESEARCH WORK OF THE TORTUGAS LABORATORY

By Dr. ALFRED GOLDSBOROUGH MAYER

MARINE BIOLOGICAL STATION OF THE CARNEGIE INSTITUTION AT TORTUGAS, FLORIDA

NEARLY seventy miles west of Key West, out in the Gulf of Mexico and in the most isolated situation occupied by any islands off our coast, lie the seven small keys of the Tortugas. Between them and the Cuban coast flows the great current of the Gulf Stream, and to the eastward of them lie forty miles of open water beyond which are their nearest neighbors, the Marquesas Keys of Florida. The Tortugas are the most westerly and southerly and the newest geologically of all those coral and limestone islets which are strung chain-like one after another in a long graceful sweeping curve from Cape Florida southward and always westward to end in the Tortugas.

The Tortugas Keys are low, being only as high as the winds and waves can toss the shifting sea-sands which compose them, for they consist entirely of wave-broken fragments of shells with here and there the stony skeleton of a seaweed, echinoderm or dead coral. Every particle composing them was once part of a living creature in the ocean which surrounds them, and thus the islands are but the dead remains of living things that were. A stunted twisted growth of bay cedars and cactus clings to their sandy soil and defies the salt spray which in time of storm drives completely over the islands. Almost every plant surviving upon the Tortugas is tough-leaved and juicy inwardly, or it sends roots far down through the sand to the salt water, for the rain serves but poorly to moisten the loose sandy soil through which it filters rapidly. The Tortugas Keys constitute the rim of an irregular atoll enclosing a lagoon with many a coral patch rising ominously out of deep blue water to within a few feet of the surface. In the old days tradition says that its harbor was the retreat of many a pirate safely anchored in the midst of the maze of its coral reefs.

Yet the islands, although remote, are not desolate to the naturalist, for all around them lies the deep blue of the tropical ocean, its ripples flashing merrily in the brilliant sun, and looking downward through the crystal depths one floats above the richest coral reefs of the Florida region. No butterflies of an East Indian jungle outrival the brilliant fish which glide languidly in and out among the purple sea-fans bending majestically to the surging sea. Hundreds of creatures find their homes among the caverns of the coral reef, or under the great carpets of rich yellow and olive sea-anemones which overgrow the naked rock

Fig. 2. The Main Building of the Tortugas Laboratory in July, 1909.

that once was living coral; and the Gulf Stream, that greatest carrier of floating life, flows close to the Tortugas, and the southerly and easterly winds of the summer months constantly drive its dark blue waters upon the islands.

It is on account of these things that the Carnegie Institution of Washington, seeking always to promote research in fields that others can not, or dare not, venture to explore, has established a marine laboratory upon Loggerhead Key, Tortugas. The station is still young, its first season being that of 1905.

The era of finding and naming of animals which had its dawn with Linnæus and its noonday of splendor with the great French naturalists has waned into its dignified decline. Not that systematic zoology will not accomplish much in the future, but the days of its great achievement are in the past.

Therein, indeed, lies the opportunity of the Tortugas laboratory, for a new science has arisen phœnix-like above the ashes of the old. Modern biology is now but little concerned with the naming of dead things, but the study of the living has become of paramount importance. All problems necessitating the study of living animals have been neglected in the tropics, yet there in the pure water of the Gulf Stream one may conduct such experiments with extraordinary success. It is through the study of living animals that science has already discovered truths of incalculable benefit—the control of malaria, yellow fever, and the hook-worm—but a mere beginning has been made in this new science, and, if unrestricted by ill-considered legislation, its future promises far more than its brief past has given us.

As Franklin said when asked the purport of the study of so trivial a set of phenomena as those of frictional electricity—"Of what use is a baby? It may become a man." Who could predict that a reflection of the sun from the windows of the Luxembourg would reveal to Malus the secret of polarized light, and lead ultimately to the most accurate analysis of sugars. It is a reflection upon our lack of confidence that in this age one must still plead for the cause of pure science, for everywhere about us we find practical applications rendered possible only through the previous discovery of their underlying principles by students whose inducement to labor was their love of science, not the hope of financial gain. Thus it was that Henry paved the way for Morse's telegraph, Faraday's classic studies rendered possible the dynamo and electric motor, and the researches of Hertz found their practical application in the development of wireless telegraphy.

Fifty years ago Darwin changed biology into a philosophical science, but it is only recently that it has exhibited decisive evidence of passing out of the qualitative into the quantitative stage of its development.

Thus it is that in these days a marine laboratory is dependent not

FIG. 3. COCOANUT GROVE NEAR THE TORTUGAS LABORATORY.

mainly upon a rich and varied fauna, but upon the presence of animals which may be found in abundance in its immediate neighborhood, and which provide favorable subjects for experimental studies.

When we contemplate the vast numbers of so-called researches published every year, it becomes evident that science will be advanced more surely by improving the quality of these papers than by increasing their bulk. For a generation the civilized nations of the world have at great expense maintained experiment stations to improve the breed of plants and animals useful to man, but nearly all of them have labored under the false impression that researches can be produced at stated intervals. Much of that freedom so essential for research was sacrificed to the production of bulky annual reports restricted to the accounts of "purely practical" studies. It was not an accident that Mendel, laboring obscurely in his cloister garden and with no thought save but for nature and her ways, discovered the law of heredity which all the experiment stations in the world failed to find.

Anton Dohrn did well for science when he gave his fortune to build the Naples Laboratory, but he did far better when he granted to those who labored there unlimited time and boundless freedom in thought and action, and his confidence was rewarded, for at Naples have been produced many of the greatest papers known to biological science.

Concentrating its efforts solely upon research, the Tortugas is in no sense the rival of other educational institutions, its simple object being to supplement and extend the work which others are attempting, or to render possible the prosecution of researches which no other institutions can undertake. Indeed, the success of any research laboratory must depend upon the efficiency of the training which its investigators have received at institutions of both instruction and research, such as the laboratories at Woods Hole, Cold Spring Harbor, Bermuda, South Harpswell and St. Andrews.

At Tortugas some of the ablest investigators of our country have been directing their attention not only to the systematic study of the rich reef fauna of the region, but mainly to problems in physiology, ecology, regeneration and embryology. We shall have space for a review of the results of a few only of these studies, selecting such as may be of the widest general interest.

Throughout the autumn and winter one of the most desolate of the Tortugas Islands is the small uninhabited Bird Key; but suddenly on a day late in April or early in May a cloud of sea-gulls gathers from far and near, and soon more than 25,000 birds are screaming over the island, struggling for nesting space.

Undeterred by the roasting heat of desert sands, the air above which rises to at least 120° F. on every sunny summer's day, or by the ceaseless shrieks of sea-gulls, Professor Watson, of Johns Hopkins University, lived nearly three months upon Bird Key. He reared the young birds and found that they could learn their way through a maze to their food. The adults could also learn to overcome obstacles in seeking to sit upon the eggs. The noddy gull builds its nest in bushes and while

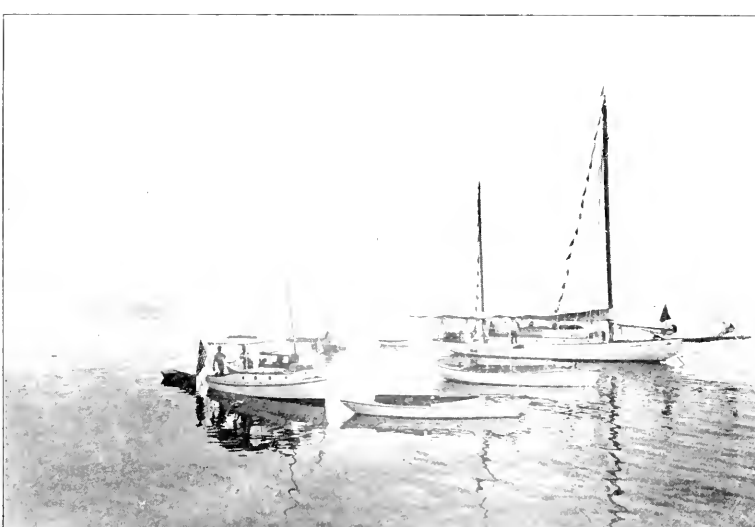


FIG. 4. THE FLEET OF THE TORTUGAS LABORATORY.
The *Physalia*, *Sea Horse* and launches.

FIG. 5. NODDY GULLS NESTING ON BIRD KEY, TORTUGAS.

so doing is quite shy, but if an egg be placed in the nest the mere sight of it causes the bird to lose all shyness, and it sits upon the egg as if it were its own. Both male and female cooperate to build the nest, but the male alone procures food for both during this period, the female constantly guarding the nest. After the egg is laid, both male and female fly away to fish and take their turns in brooding the egg at intervals of about two hours. The egg hatches after 32 to 35 days. But the noddy gull does not recognize its own egg, but will readily incubate the egg of the sooty tern or any object colored or uncolored bearing more or less resemblance to an egg. It recognizes the locality of its nest, however, and returns to the old locality if the nest be moved, but it will accept an artificial nest placed in the old nest locality without hesitation. Dyeing one of the mates in strange colors causes the undyed bird to attack it, and indeed all other birds upon the island displayed excitement at the appearance of a dyed bird.

The sooty tern nests upon the ground, and recognizes the exact locality of its nest, if, however, the nest be raised vertically, the bird, but little disturbed, alights upon it, then if after an interval it be lowered, the bird attempts to alight in the air above the nest in the place where the nest was formerly. A slight *horizontal* movement of the nest causes great confusion in the bird.

Professor Watson caused adult birds to be taken from Bird Key to Havana, 92 miles; to Key West, 66 miles, and to Cape Hatteras 850 miles from Bird Key. Birds liberated at these places returned in a very short time to their nests on Bird Key. The sooty terns returned from Cape Hatteras in five days, and as they probably flew along shore and not by the straight-line route, they must have flown at least 1,081 miles. This is a most striking experiment, for Cape Hatteras is far to the northward of the northern limit of the geographical range of these birds.

Another Tortugas research was that of Professor Reighard, of the University of Michigan, who worked upon the subject of warning coloration.

For a long time Darwin was puzzled by the fact that many animals are conspicuously colored and yet their habits are such that they openly display themselves to the view of all possible enemies. Why, then, were they not exterminated? That brilliant yet modest man, Alfred Russel Wallace, came forward with an ingenious hypothesis, now well known as the theory of warning coloration. He assumed that such con-

FIG. 6. A NODDY GULL UPON ITS NEST, BIRD KEY, TORTUGAS.

FIG. 7. GROUP ACTIVITY OF SOOTY TERNS.

spicuous animals possessed poisonous or disagreeable qualities which rendered them unpalatable, so that their enemies soon learned to recognize them as uneatable, and thus the more conspicuous their appearance, the more surely were they protected.

It has been assumed that the beautifully colored fish which swim so unconcernedly and slowly in and out among the caverns of the coral reefs were good examples of warning coloration, for over the sandy

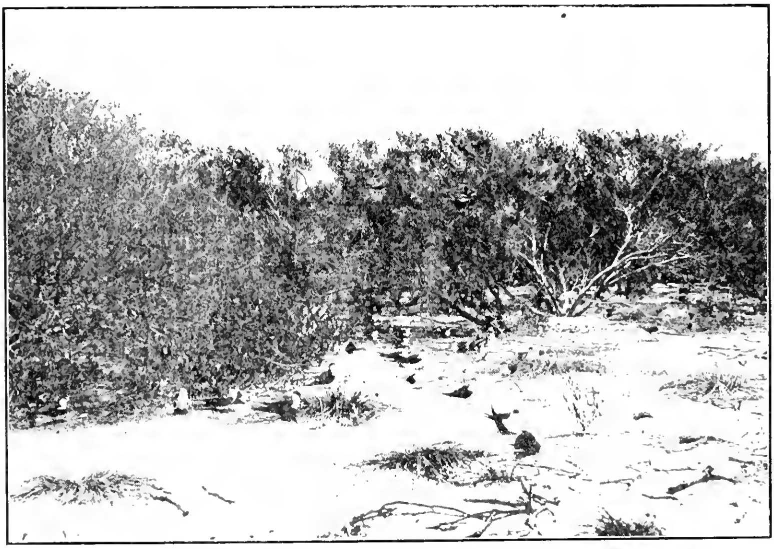


FIG. 8. GROUPS OF NESTING SOOTY TERNS.

bottom around the corals swims the gray snapper, the commonest predaceous fish of the reefs. Yet these gray snappers are not seen to attempt to devour the reef fishes. Professor Reighard found, however, that when he captured these beautiful reef fish and threw them in among the gray snappers far from the reefs they were greedily devoured without a moment's hesitation. It became evident that the gray snapper could not capture the brilliant little fishes as long as they enjoyed the protection afforded by the stings of the coral polyps, or remained near the entrances to the intricate caverns of the reefs. Hence these fishes are not warningly colored, and Wallace's hypothesis does not apply to them.

Nevertheless, Professor Reighard found that the gray snapper *could* distinguish colors, and that it could be *taught* to associate a brilliant color with an unpleasant taste.

In order to prove this, he made use of the little silvery sardine (*Atherina*) which swarms in thousands over the shallows of the reefs, and whose only office in life seems to be to supply food for all larger fishes. Reighard dyed these silvery fish a brilliant carmine red and the gray snappers devoured them without hesitation. Then, however, the tentacles of a medusa were placed in the mouths of the red-colored sardines and the gray snappers soon learned after a brief experience with the stings to avoid them; and they *remembered* to avoid red-colored sardines after an interval of twenty days had elapsed since they had last seen them, although these later red fish had no medusa tentacles in their mouths. Thus he created a warning coloration: something nature herself had not done.

Professor Reighard's experiments are by far the most convincing that have ever been carried out upon the subject of warning coloration, being performed in surroundings natural to the animals themselves. He concludes that the conspicuous coloration of coral-reef fishes is is not for warning enemies, and is the result of race tendency unchecked by selection.

Another research of interest was that of Dr. Stockard, of the Cornell Medical College, upon the habits of the walking-stick insect, *Aplopus*, which lives upon the bay cedar (*Suriana*) bushes at Tortugas and bears an extraordinary resemblance to a stick of the bush itself, while its eggs resemble the seeds of the same bush. Professor Stockard finds that the habits of the insect accord perfectly with and enhance the value of its protective coloration. The insect is active only at night, or in darkness, and in daylight they may be piled one on top of another, remaining motionless as real sticks in any attitude, but if they then be placed in the dark they immediately scramble off in all directions.

In another research Dr. Stockard studied the regeneration of the claws of the snapping-shrimp *Alpheus* which lives within the cavities of sponges. This little lobster-like animal has one very large claw and one small one, and when captured it snaps the nippers of the large claw, producing a sound resembling the sudden cracking of thick glass, so that one imagines that the aquarium has broken. It is well known

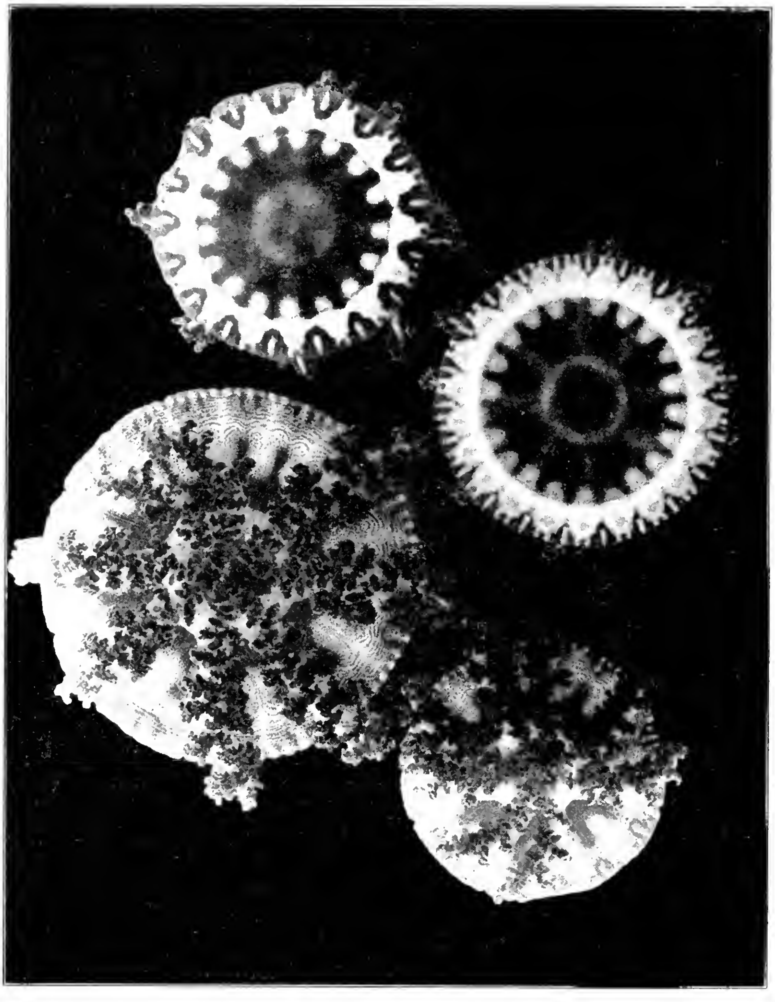


FIG. 9. *Cassiopea xamachana*, THE JELLYFISH OF THE MOAT OF FORT JEFFERSON, TORTUGAS.

from the work of Prizbram that if the large claw of *Alpheus* be cut off the small claw changes to a large one at the next molt.

Dr. Stockard finds, however, that if the large claw be removed and at the same time all legs of the *opposite* side of the body *except* the small claw be cut off, the small claw does not change into a large one and the animal acquires two equally developed small claws at the next molt. Thus a tendency toward a reversal is checked.

In another research, Dr. Stockard made the interesting observation that when a piece of a jellyfish (*Cassiopea*) is cut away and the animal starved a new piece regenerates, even though the old part of the body shrinks in size to provide it nutriment. Cancers also grow in this manner at the expense of the surrounding tissues, and thus there appears to be an analogy between the mode of growth of cancer and regeneration. Possibly, then, if we could control regeneration some similar process might be found effective to check the growth of cancer.

As is now well known to naturalists, Tower has succeeded through the influence of heat and moisture in producing a new sort of beetle which breeds true as would a newly arisen species. MacDougal has also succeeded through chemical means in effecting the same result with plants. Recently, at Tortugas, Professor Tennent, of Bryn Mawr, produced hybrids by reciprocal crosses between *Hipponoë* and *Toxopneustes,* two common sea-urchins of the reefs; and he discovered the interesting fact that if the sea-water be normal or rendered alkaline the larvæ resemble the *Hipponœ* parent, but if the sea-water be treated with an acid so as to reduce its alkalinity the larvæ resembled their *Toxopneustes* parent. He could then by changing the external conditions produce larvæ resembling either parent he choose, and thus alter the dominance of either parent at will.

No one knew what caused the newly hatched young of the great sea-turtles to crawl toward the ocean as soon as they had dug their way upward out of the sand within which their eggs are laid, but Dr. Davenport Hooker, of Yale, found that the young turtle is attracted toward the ocean by the blue color of the water. If it sees the ocean through red, yellow or green glass it does not crawl toward it, but if a piece of blue glass, or even blue paper, be placed anywhere within range of its vision the turtle at once scuttles toward it with great excitement.

If one goes out upon the ocean before sunrise on the morning of a day within three days of the time of the last quarter of the July moon, the surface will be found to be covered with actively wriggling worms, about six inches long, swimming in all directions. These are the posterior ends of the Atlantic palolo worm (*Eunice fucata*) which breaks off from the head end of the animal and swims upward from the crevices of the coral reef, to take part in the breeding swarm. Professor Aaron L. Treadwell, of Vassar College, is now studying this phenomenon, and he has discovered that if the rocks containing the worms be placed in a dark chamber upon the day preceding the night of the swarm the worms may still swarm. Hence, contrary to Mayer's supposition, the presence of moonlight is not necessary for the swarming reaction. Previous studies at Tortugas have shown that the

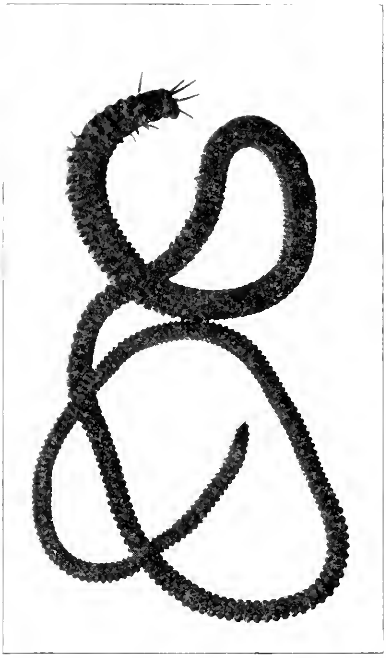


FIG. 10. THE ATLANTIC PALOLO WORM. *Eunice fucata.*

swarming is not due to tidal influences, and now the great question is —what *does* cause this remarkable response, for it appears to be some form of energy to which we are ourselves not sensitive.

Dr. T. Wayland Vaughan, of Washington, finds that the line of the Florida Keys from Soldier's Key to the southeastern corner of Big Pine Key is composed of elevated coral-reef rock. The northern end of Soldier's Key and all keys to the northward of it are composed of quartz-bearing sands mingled with broken shells. The keys from Key West to Big Pine Key, with the exception of the southeastern corner of the latter, are composed of limestone mud which long ago was elevated above the sea and changed into rock, so that now one sees a net-work of old mud-cracks in the rocky floor of the pine forest. On the continental side of the line of coral-reef keys and extending transversely to them are long shoals formed by the settling of lime mud in the slack water between the currents which flow in and out with the tides through openings between keys. These shoals become covered with mangroves, and thus finally elevated above the surface of the sea. There are many other interesting geological observations made by Dr. Vaughan which limitations of space prevent us from reviewing.

In addition to his studies of the geology of the reefs, he is making

FIG. 11. THE GHOST CRAB, *Ocypoda arenaria*. Photographed by Dr. R. P. Cowles.

the most accurate and extensive investigation of the associations, habits, rate of growth and constitution of corals ever attempted by any naturalist. He is rearing corals from the free-swimming larva, and observing their rate of growth as well as studying the growth-rate of many coral heads found living upon the reefs or in the moat of Fort Jefferson. Years must elapse before the results of these studies will be ready for publication, but he has already discovered that under favorable conditions the rate of growth of corals is surprisingly rapid, and that the free-swimming stage of the planula lasts long enough for corals to be drifted fully 800 miles by the Gulf Stream.

Professor Edwin G. Conklin, of Princeton, finds that the egg of the scyphomedusa *Linerges* consists of an outer layer of clear protoplasm, an intermediate shell of densely packed yolk spherules and a central sphere of dissolved yolk. The outer layer of the egg forms the peripheral layer of the gastrula and blastula, and gives rise to the cilia of the ectoderm. The middle layer constitutes the principal part of all of the cells of the body, while the central yolk serves for nourishment. Thus animals so low as the jellyfishes show the beginning of that differentiation of organ-forming substances in the egg which Professor Conklin discovered was so characteristic of the eggs of higher forms. He also finds that the gastrula larva in this medusa may be formed either by invagination or by unipolar ingression, thus showing the intimate relationship between these apparently distinct processes.

Dr. R. P. Cowles, of Johns Hopkins, carried out an extensive series of observations upon the habits and reactions of the ghost crab *Ocypoda arenaria,* which lives upon the sandy beaches of the Tortugas. It will be impossible to do more than present a few of his most important results. He finds that this crab can not detect color, but is sensitive to large differences in the intensity of light, and it readily perceives a moving object. The color pattern of the crab changes under different conditions of light and temperature, becoming dark and mottled in dull light and low temperature. It can not detect sound waves traveling through air, but its so-called "auditory organs" are actually organs of equilibration. The crab has memory, is able to profit by experience and can form habits.

Dr. Frank M. Chapman, of the American Museum of Natural History, discovered that the booby, *Sula fiba,* which nests upon Cay Verde, Bahamas, between February and April, lays two eggs but rears only one young bird. His observations and collections upon Cay Verde has led to the construction of a very attractive group in the American Museum of Natural History in New York illustrating the nesting habits of the frigate-bird and the booby.

Pleasurable as the task would be, limitations of space prohibit my reviewing the results of the studies of Messrs. Brooks, Hartmeyer,

The Tortugas Laboratory from the Top of the Lighthouse.

Harvey, Jordan, Kellner, Linton, McClendon, Osburn, Perkins and Pratt, all of whom have produced careful and important work.

The laboratory is very young; it can not yet claim to have been a success, for despite the fact that some of our ablest workers have seen fit to strive in its interests, the time which has elapsed since its foundation is too short to enable us to do more than to assert that with such generous self-sacrificing devotion to its cause as has been shown by those who have honored it by their labors, success will come with the years that lie before it.

THE PROGRESS OF SCIENCE

INCORPORATED CHARITIES

THE bill before the congress to incorporate the Rockefeller Foundation opens up many social, educational and scientific problems. Its objects are stated to be "to promote the well-being and advance the civilization of the peoples of the United States and its territories and possessions, and of foreign lands, in the acquisition and dissemination of knowledge, in the prevention of suffering and in the promotion of any and all the elements of human progress." The bill names as incorporators of the foundation John D. Rockefeller, John D. Rockefeller, Jr., Fred T. Gates, Starr J. Murphy and Charles O. Heydt. The amount of the endowment is not known, but it is assumed that it will be very large, as Mr. Rockefeller has already given fifty-three million dollars to one board of much narrower scope.

There should be nothing but sincere appreciation of Mr. Rockefeller's generosity and public spirit. It is quite absurd to fancy that he has sinister motives or any other wish than to do good with his wealth. This would be the right attitude even if the money had been obtained by improper methods. But there are probably not many men of affairs in America whose transactions if so fully known would be less open to blame. Secret rebates and harsh competition are the charges. There are not many clergymen or statesmen who refuse to accept rebates from the railways and competition to the limit of the law is the common method of business. As a matter of fact, there has never been a man of business who has done so much to abolish competition as Mr. Rockefeller, who will probably be looked upon hereafter as the principal promoter of socialism.

Mr. Rockefeller's corporation for charity and public service is less original and less imposing than his business corporation. It is insignificant beside the Roman Catholic Church in the middle ages or beside what is now being done by every state for charity and education. Mr. Rockefeller's wealth would scarcely support the public schools of the country for a single year. None the less a corporation of this kind will for a time have considerable power and there is some reason to fear that it will not be wholly beneficial.

Society is concerned more about the consumption of wealth than about its ownership, so long as the ownership is not used outside the ordinary methods of business. It is obvious that wealth is consumed more profitably in promoting the acquisition and dissemination of knowledge and the prevention of suffering than along the paths which lead to the divorce courts. But it is not certain that it is better to divert capital from business enterprises, tie it up in real estate and lands exempted from taxation, and use the income permanently for charity. What may happen is shown by the Roman Catholic Church, which in the middle ages acquired half the wealth of the nations and instead of contributing to the advancement of civilization became on the whole a barrier to progress.

Other corporations for public and charitable purposes are controlled by a board representing a church, the educational interests of a community, or the like, and have some definite object. This new corporation represents and is controlled by the Rockefeller family and its scope is unlimited. An emergency fund for the promotion of civilization appeals to the imagination, but it will not be easy to administer it. We have had recently experience of two such funds with more limited scope—the General Education Board and the Carnegie Institution of Washington, to which, respectively, Mr. Rockefeller has given $53,000,000 and Mr. Carnegie, $12,000,000.

The General Education Board does not even make public its activities or its accounts. It has concerned itself with agricultural education in the south, but its income has been spent in the main in contributing to the funds of colleges and universities on the condition that four times as much should be collected from other sources. It is not clear how the foundation is more useful than if the whole capital were at once distributed among the colleges and universities of the country in proportion to their existing endowments. The Carnegie Institution was established as an emergency fund for scientific research, but it was not found feasible to conduct it on these lines, and it now administers certain research institutions. Here again there seems to be no advantage in maintaining at Washington an expensive administrative office. It would be better to divide the capital among the observatories and laboratories and let them develop as they can.

Mr. Rockefeller's most useful and important benefactions are the University of Chicago and the Rockefeller Institute for Medical Research. It would probably be of greatest benefit for society if he should use his fortune to establish three or four great universities with their research institutions, libraries, museums, theaters and hospitals. Chicago could be further endowed and universities established in the city of Washington, Texas and Oregon, or, if it were preferred to make the influence world wide, the universities could be in Washington, South America, China and Russia.

THE CARNEGIE FOUNDATION FOR THE ADVANCEMENT OF TEACHING

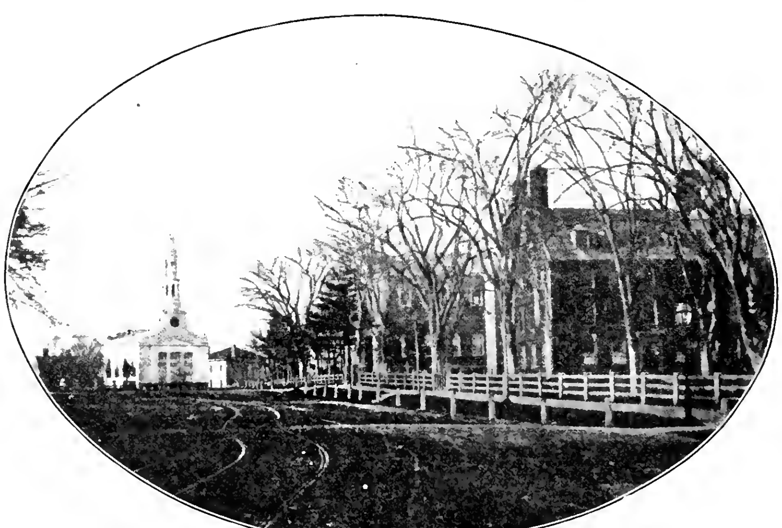
The benefits and dangers of a centralized endowment for public purposes are well shown by the Carnegie Foundation, the fourth annual report of whose president has recently been issued. On April 16, 1905, Mr. Andrew Carnegie addressed a letter to twenty-two college presidents and three business men whom he had selected as trustees, transferring to them $10,000,000 in bonds of the U. S. Steel Corporation "to provide retiring pensions for the teachers of universities, colleges and technical schools in our country, Canada and Newfoundland." He says that "expert calculation shows that the revenue will be ample for the purpose" and "I have reached the conclusion that the least rewarded of all the professions is that of the teacher in our higher educational institutions."

These college presidents drew up an act of incorporation and rules which in the main would distribute the income among certain institutions for their advantage rather than for the benefit of the individual professors. Cornell and Williams have continued to pay the pensions for which they had contracted, so their professors receive double pensions, but other institutions having pension systems have withdrawn them and diverted the money to other purposes. Professors in colleges accepted by the foundation and not having pension systems may benefit, as they receive annuities which they did not earn; but the salaries will soon be adjusted with a view to the pensions, and the income of the foundation will be distributed among certain institutions having pension systems, not at all to individual professors.

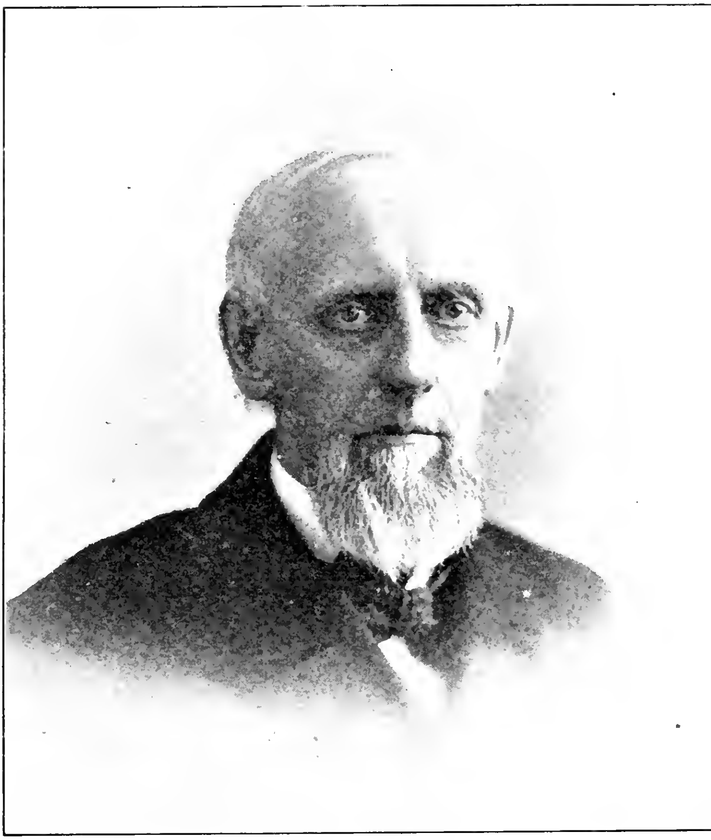
The professors benefit only if a pension system is advantageous to them. Any one can purchase an annuity, and it is doubtful whether the enforced purchase of annuities by professors combined with dismissal from their work is of benefit to them. A centralized system works especially to the disadvantage of the individual professor. If an institution had to pay a pension from its own funds, it would be much more conservative in retiring a professor who is willing and competent to stay in service. To benefit the professor, his salary should be paid for life and he should render such services as he can to advantage. The dismissal of professors on pensions throughout the country against their will may have the unfortunate effect of breaking down the permanent tenure of the professor's office, which has done more than anything else to give it dignity and to attract to it able men willing to serve for small salaries.

The act of incorporation of the Carnegie Foundation provided for two kinds of retiring allowances: (1) for long and meritorious service, and (2) for old age, disability or other sufficient reason. At the last meeting of the trustees, the retiring allowances for length of service were withdrawn, not only for the future but also retroactively from those to whom they had been promised. Dr. Pritchett, the president, states that the ground for withdrawal was that the rule worked badly; Dr. Jordan, one of the trustees, states that it was financially impossible to carry it out. Both results might have been foreseen, but neither seems to justify the foundation in breaking its engagements. The editor of the New York *Evening Post* does not hesitate to charge "a misty notion of the nature of moral obligations" and a violation of "the ordinary standards of honorable conduct between man and man."

The foundation supplies an additional income to a number of colleges and universities; but this appears to be the end of its usefulness. The attempt of an energetic president to lord it over the educational development of the country has done some temporary harm; but the money by which he can purchase submission will soon be exhausted. It has been a sorry sight to see institutions raising standards which they can not and should not maintain, freeing themselves nominally from denominational control—one has offered to establish an undenominational holding company—and most of



This photograph, showing a part of Harvard University in 1857 or 1858, is contributed to the *Harvard Graduates' Magazine* by Professor F. W. Putnam. The small square building of wood on the right of the church is the Agassiz Museum. Massachusetts Hall and Harvard Hall are shown on the right. The Agassiz Museum Building was erected in 1850. After the first section of the present Museum of Comparative Zoology was built, in 1859-60, the old Museum Building was moved to the site now occupied by the Peabody Museum. It was remodeled for living-rooms for Agassiz's students and assistants.



AMOS EMERSON DOLBEAR.

all to watch the great state universities begging the favor of a private corporation. Thirty-two state legislatures have approved the request for money, and the foundation finds that four of the universities are worthy, while the others—institutions such as California and Illinois—must be further investigated. The president tells the governor of Ohio how the universities of that great state should be administered; he says that "in nearly every state" there is "educational demoralization."

In his last report Dr. Pritchett makes all kinds of recommendations. Some are in themselves good and some bad, but all are bad in so far as they come from that source, for there is an implicit threat everywhere that institutions must do as they are told or they will not receive Carnegie money. The best thing that could happen would be for the foundation to retire its president with a liberal pension to write about education over his own signature, and then, as the Peabody Fund has wisely done, to dissolve and distribute its funds among our colleges.

AMOS EMERSON DOLBEAR

IN the death of Dr. Dolbear, for thirty-six years professor of physics and astronomy at Tufts College, America loses a man of science of a type that is now becoming rare. Born in New England in 1837, and left early an orphan child, he worked on a farm and at other odd jobs, attending the district school when he could. He became a machinist, had various adventures, and when twenty-six entered what is now the Ohio Wesleyan University. He taught natural history and the physical sciences in western institutions until called to Tufts College in 1874. He was early an inventor and later made inventions which led him to believe that had anticipated both the telephone and wireless telegraphy. He was, however, unsuccessful in his suit against the Bell Telephone Company. But Dr. Dolbear did not confine himself to inventions; he did experimental work in various directions, wrote text-books and made addresses, and in his last work, entitled "Matter, Ether and Motion," discussed the fundamental principles of his science. Dr. Dolbear, in whose personality were commingled some of the traits of the scholar, the clergyman, the mechanic and the farmer, won the affectionate regard of all who were associated with him.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Charles R. Barnes, professor of plant physiology at the University of Chicago; Dr. Henry Byron Newson, professor of mathematics in the University of Kansas; Professor J. Edmund Wright, associate professor of mathematics in Bryn Mawr College; Dr. J. A. Bergström, professor of pedagogy in Sanford University, and Dr. Charles F. Wheeler, botanical expert in the Department of Agriculture.

Lord Rayleigh has been elected a foreign associate of the Paris Academy of Sciences in succession to the late Simon Newcomb.—The Edison medal of the American Institute of Electrical Engineers has been presented to Professor Elihu Thomson.—Dr. Hugo Münsterberg, professor of psychology at Harvard University, has been appointed exchange professor to lecture at Berlin in 1910–11.—Dr. S. Weir Mitchell celebrated his eightieth birthday on February 15. On the following day he gave a lecture before the College of Physicians of Philadelphia on "William Harvey, the Discoverer of the Circulation of the Blood."—Sir William Huggins, F.R.S., the eminent astronomer, celebrated his eighty-sixth birthday on February 7 at his residence at Tulsehill.

For the meeting of the British Association for the Advancement of Science, which is to take place this year at Sheffield, beginning on August 31, under the presidency of the Rev. Professor T. G. Bonney, F.R.S., the following presidents have been appointed to the various sections: Section A (Mathematical and Physical Science), E. W. Hobson, F.R.S.; Section B (Chemistry), J. E. Stead, F.R.S.; Section C (Geology), Professor A. P. Coleman, Ph.D.; Section D (Zoology), Professor G. C. Bourne, D.Sc.; Section E (Geography), Professor A. J. Herbertson, Ph.D.; Section F (Economic Science and Statistics), Sir H. Llewellyn Smith, K.C.B.; Section G (Engineering), Professor W. E. Dalby, D.Sc.; Section H (Anthropology), W. Crooke, B.A.; Section I (Physiology), Professor A. B. Macallum, F.R.S.; Section K (Botany), Professor J. W. H. Trail, F.R.S.; Section L (Educational Science), Principal H. A. Miers, F.R.S.—The French Association for the Advancement of Science will hold its thirty-ninth annual meeting at Toulouse in August under the presidency of M. Gariel, professor of biological physics in the faculty of medicine of the University of Paris.

Columbia University has received an anonymous gift of $350,000 for a building for the faculty of philosophy.—A gift of $150,000 for the erection of an administration building and library at the Rensselaer Polytechnic Institute has been made by the Pittsburgh Alumni Association.—The medical school of the University of Pennsylvania has been given $100,000 by an unnamed alumnus to endow a chair to be known as "the Benjamin Rush professorship of physiological chemistry."—Tufts College has been made the residuary legatee under the will of John Everett Smith, and will, it is said, receive on the death of Mrs. Smith the sum of $500,000.

THE POPULAR SCIENCE MONTHLY.

MAY, 1910

HEREDITY[1]

By Professor W. E. CASTLE

HARVARD UNIVERSITY

THE conservation movement now in progress has for its end to preserve for future generations of men the natural resources of the earth. But it goes without saying that the movement is useless unless there are to be future generations of men capable of utilizing those resources. Thoughtful persons are beginning to wonder whether this is assured. Man is the product of two sets of agencies which we summarize in the terms heredity and environment. The question has often been asked which of these is the more important, but with this we need not concern ourselves. Both are indispensable. Seed and soil combined assure a harvest, but if either is lacking no harvest can be expected.

The public is awakening to the importance of providing mankind with a proper environment through the agencies of sanitation, education and good government, and this is well. This assures a suitable soil in which a crop of healthy human beings may develop. But what of the seed? This question has not yet been seriously considered. Only in England has it been more than suggested. There Francis Galton and his associates in the eugenics movement have started an inquiry as to why it is that the average physical condition of the English nation is declining although more and more attention is constantly being given to improving the environment. Likewise in Germany statistics show a steadily declining proportion of the young men fit for military service. There is a suspicion in the minds of many, that these nations are producing the new generation of citizens chiefly from inferior family and racial stocks. If this is so the remedy is

[1] From a lecture delivered before Section F, American Association for the Advancement of Science, December 31, 1909.

obvious, though how easy of application remains to be ascertained. Would a farmer expect to have full harvests if each year he saved seed from the poorest yielding plants, or could he hope to secure the best results from his herds by selling or butchering the best stock and keeping only the scrubs? Obviously not, and no more can the civilized nations maintain their present standards of manhood if they follow a like practise.

But before any serious attempt can be made to improve the human race considered as an assemblage of animals possessed of certain desirable physical and intellectual attributes, it is obvious that we must know something about heredity in general, and how in particular each of the desired physical and intellectual attributes is produced. Considerations such as these lend general interest to the study of heredity, a subject which has always been of great practical concern to farmers, and of much theoretical interest to scientists. It is my purpose to review briefly some of the problems which the study of heredity presents, and some of the results obtained from their consideration.

"Like father like son" is a homely proverb which shows how general the recognition is that children resemble their parents. Resemblances to grandparents or ancestors even more remote are also of frequent occurrence, and it is convenient to use the term heredity as including all such resemblances, whether to near or to remote ancestors. The phenomenon of heredity is of course not restricted to human society. Heredity has for the stockman and plant-breeder a well-recognized commercial value, because by a knowledge of its laws he is enabled to produce in greater number or with greater certainty animals or plants of a particular type. Indeed, much of our present knowledge of heredity has been derived from a study of the domesticated animals or of the cultivated plants, and from the same sources we may expect to continue to draw, for here alone have we an unobstructed field for observation and experiment, the indispensable tools of scientific research. Just as the sciences of anatomy, embryology, physiology and pathology progressed but slowly so long as the phenomena of the human body alone were considered, but advanced by leaps and bounds when comparative studies on other animals were undertaken, so concerning heredity in man we have learned and can expect to learn but little from the study of man alone, but much from a study of other animals and of plants and from a comparison of the phenomena in the two cases.

Every new individual arises out of material derived exclusively from its parents. This is the basis of heredity. But it does not follow that the new individual will resemble its parents merely. It may resemble remote ancestors more strongly than either parent. For it represents a combination of materials or of qualities derived from the two parents and it is possible that neither parent may manifest all the peculiarities which it transmits to the offspring. For the parent is made up of two distinct parts, its own body and the reproductive substance contained within that body, and the two may not be identical in character.

The reproductive substance has been called by Weismann the germ-plasm. He it was who first clearly recognized the fact that the germ-plasm is distinct from the body which contains it, and that the influences which modify the character of the one do not of necessity modify the character of the other. Thus he was able to show experimentally that mutilations of the body, as loss of the tail in mice, are not inherited, and to establish with a considerable degree of certainty the principle that characters acquired by the body as a result of use, disuse or other agencies are not inherited, because they have not affected the constitution of the germ-plasm carried within the body.

Weismann's two principles are of fundamental importance to a right understanding of heredity. They are: (1) That the germ-plasm is independent of the body containing it, or, as Weismann put it, that the germ-plasm is continuous from generation to generation, whereas the body dies, and (2) that acquired characters are not inherited.

The hottest biological discussions of the last twenty years have been waged over these two principles and the contest is by no means ended, but year by year the correctness of Weismann's contentions is more generally admitted.

Common experiences support both principles. Thus the independence or continuity of the germ-plasm has been shown from time prehistoric in the practise of castration upon the domesticated animals or upon man. The germ-plasm is localized in particular organs of the body, the reproductive glands. If these are removed reproduction becomes impossible, though all other functions of the individual persist. Further, it is possible to show experimentally that the germ-plasm

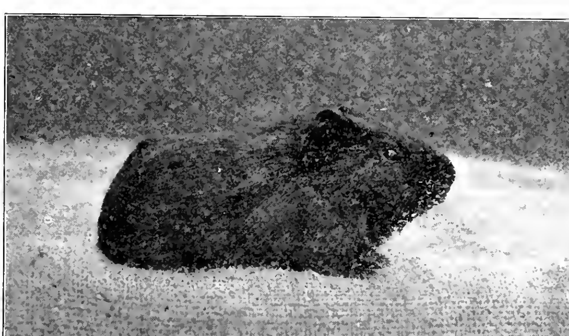


FIG. 1. A YOUNG BLACK GUINEA-PIG, about three weeks old. The ovaries taken from an animal like this were transplanted into the albino shown in Fig. 2.

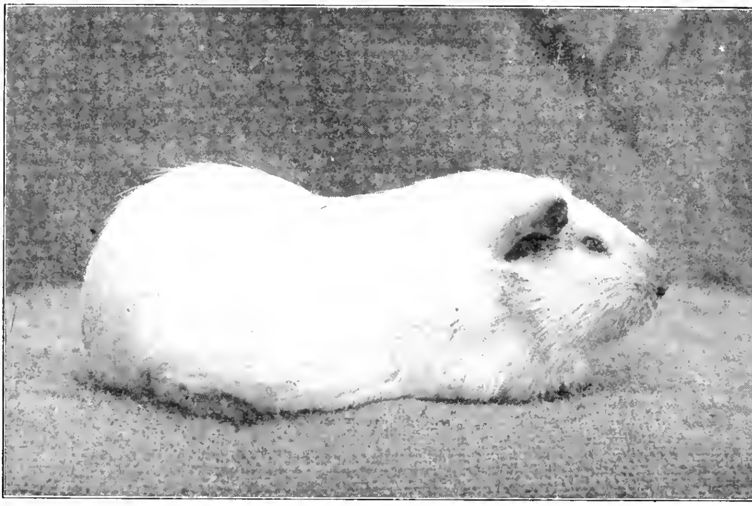


FIG. 2. AN ALBINO FEMALE GUINEA-PIG. Its ovaries were removed and in their place were introduced ovaries from a young black guinea-pig. Compare Fig. 1.

transplanted from one individual into another retains the character which it originally had, quite unaffected by the changed body with which it is associated. This Dr. John C. Phillips and the writer have recently shown in the following way. The ovaries were removed from a young black guinea-pig, Fig. 1, and these were transplanted into the body of a white guinea-pig, previously castrated, Fig. 2. The white guinea-pig was now mated with another white guinea-pig, Fig. 3. Normal white guinea-pigs produce only white offspring when mated with each other, but these two have now produced in three successive litters six young, all black. Three of these are shown in Fig. 4. Evidently the germ-plasm of the black guinea-pig retained its original character even after transplantation into the body of a white one.

In order better to understand the processes of heredity we should be familiar with what takes place when a new individual is formed. The new individual, whether an animal or a plant, has its beginning in the union of two bits of germ-plasm, an egg cell furnished by the mother and a sperm cell furnished by the father. Whether the union of the germ-plasm takes place within the maternal body or not is quite immaterial; among a great many animals it does not.

The new individual, it will be observed, is dual in origin, and to its dying day it retains a dual nature. For the maternal and paternal contributions of germ-plasm retain a certain distinctness as we shall see, and may in part separate from each other at reproduction.

Each germ-cell (egg or sperm), so far as its contribution to heredity is concerned, stands for a complete organism of its species, bears the potentialities of a complete organism, and under appropriate conditions can develop into such an organism. For this idea we have strong experimental evidence. It has long been known that the eggs of certain species of animals can develop without fertilization, *i. e.*, without having united with a sperm or male sex-cell. In such cases there can be no question that the potentialities of an entire organism are contained in the egg, for without any outside help the egg develops into a complete individual of the species. In recent years it has been shown that the eggs of many species in which fertilization normally occurs may by artificial means be made to develop without having united with a sperm. This is true of the eggs of sea-urchins, star-fishes, and of certain worms and mollusks. Such eggs artificially stimulated to development produce entire individuals, similar to those produced by fertilization, but possibly less vigorous.

On the other hand, a sperm cell may be made to develop, if it is allowed to penetrate into a fragment of an egg, even a fragment which lacks the important cell-nucleus. In such cases the entire nuclear material of the embryo is furnished by the sperm, yet the embryo so produced is complete, lacking no essential part, and similar except in size and vigor to normal embryos produced by fertilization.

Accordingly the evidence is fairly complete that each germ-cell (egg or sperm), considered as the vehicle of heredity, represents a complete organism, and that an individual produced by the union of two such germ-cells represents twice over each heritable trait of the species. In other words, the germ-cell is single, the individual is double.

This fundamental principle of the singleness of the germ in con-

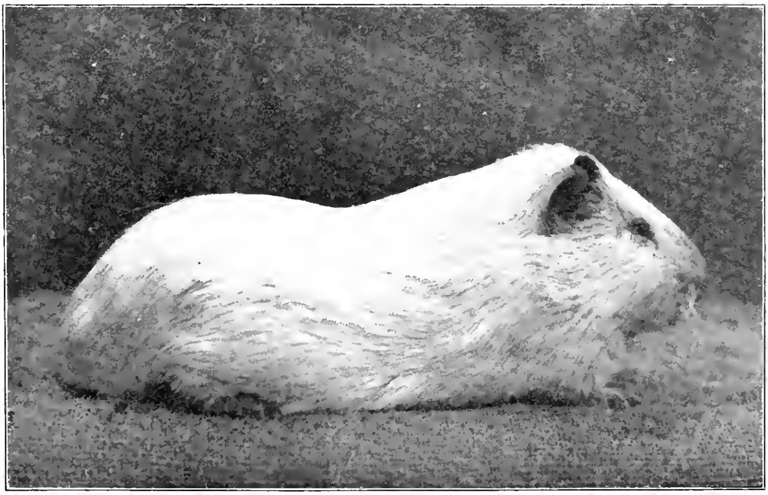


FIG. 3. AN ALBINO MALE GUINEA-PIG, with which was mated the albino shown in Fig. 2.

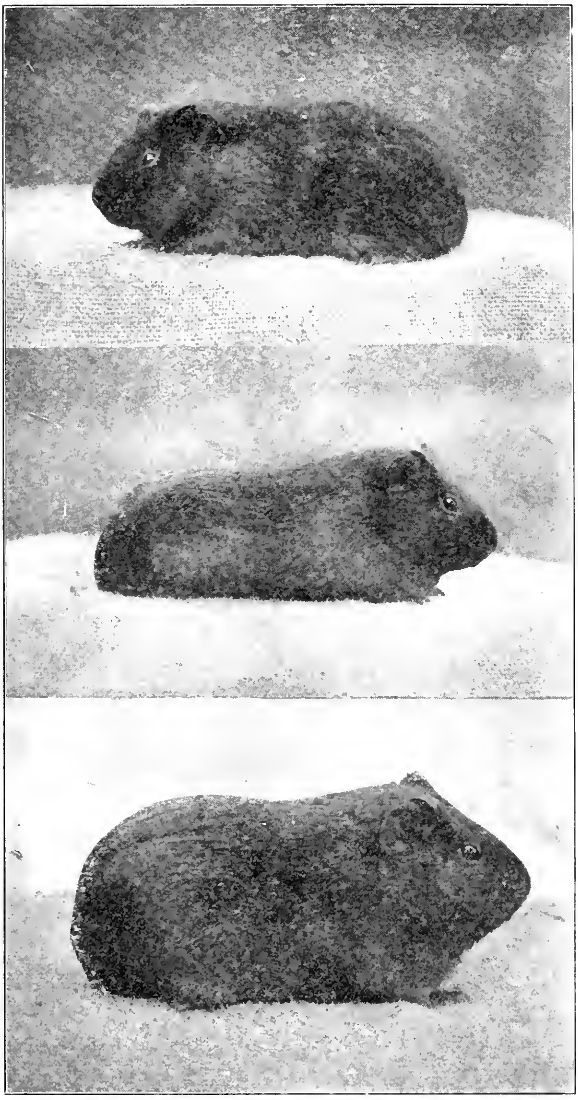


Fig. 4. A Group of three Young, produced by the pair of albinos shown in Figs. 2 and 3.

trast to the doubleness (duality) of the individual receives the fullest confirmation from experimental breeding.

If we mate a pure-bred black guinea-pig with a white one, the young are all black pigmented. This result seems to violate the principle previously stated that both parents contribute equally in heredity; in reality, however, that principle is not violated. The white parent has contributed its own character to the offspring, but that contribution is unseen in them simply because black hides it. The white will reappear among the grandchildren. In Fig. 5 we see a mother guinea-pig having a jet black coat. Beside her are four young of the same color as herself. The father too was black. In a word this black race breeds true. A female of this race was mated with the albino male shown in Fig. 6. Albinos have white hair and pink (unpigmented) eyes, the red eye color being due to the blood which shows through; they breed true among themselves, but the result is very different when they are mated with black individuals. Two children of the albino male and the black female are shown in Fig. 7. They are intensely black pigmented, as are all the young produced by this cross. Two of them when grown to maturity and mated with each other, produced a litter of four young, shown in Fig. 8. Three are black pigmented like the parents, but one is an albino similar in all respects to the albino grandsire. Here we notice the reappearance of the albino character after skipping a generation. The albino grandsire really made a hereditary contribution as regards the character hair color, but it did not show in the children, because black also was present in the children, and black obscured or dominated the white.

Applying our principle of single germ, dual individual to this case, we see that the facts observed are fully in harmony with it. The original cross brought together the characters B (black) and W (white) into an individual (or zygote as we call it, a joining together) B W, which showed only black. Two such individuals, a male and a female were now mated together. In the formation of germ-cells by these individuals there is a return to the single condition, B separates from W and passes into a different germ-cell. Accordingly, the mother forms eggs, B and W, respectively, and the father forms sperms of a like character. Now a new individual arises from a union of an egg with a sperm. Apparently either sort of sperm may unite with either sort of egg which it chances to meet. So there are formed in the next generation three sorts of zygotes (individuals), *viz.,* B B, B W, and W W, instead of B W alone as in the previous generation. The chances for the occurrence of these three sorts of unions are 1 BB, 2 BW, and 1 WW. Any individual containing the character B will be black: accordingly the BWs as well as the BBs will be black and there should be three blacks to one white. These are in fact the observed proportions. The white individual should transmit no other character, because it contains only W. Such is indeed the observed fact. Any two white individuals mated together will produce only white offspring. But, if our reasoning is correct, two thirds of the black individuals of this generation (*viz.,* the BWs) should transmit white as well as black, while the remaining one third, BB, should transmit only black. Experiment justifies both these conclusions. If we mate the black animals

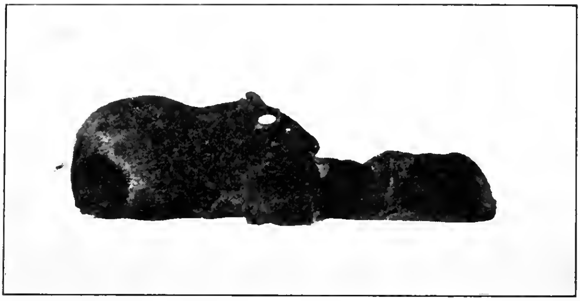


Fig. 5. A black female Guinea-pig and her Young.

Fig. 6. An Albino Guinea-pig, father of black young, like those seen in Fig. 5.

of this generation, one by one, with albinos, we find that on the average two out of three of them will produce white offspring as well as black ones, while the third one produces only black offspring.

The scientific law which governs the inheritance of albinism, and of other characters transmitted in a similar fashion, is known as Mendel's law. It applies, apparently, to all cases of color-inheritance, as well as to the inheritance of characters of many other sorts. Through its operation new combinations of the peculiar characters of individuals or of races can be obtained in the course of one or two generations. Thus when a guinea-pig showing the two coat-characters seen in Fig. 9, dark and smooth coat, is mated with one showing the combination, white and rough, Fig. 10, young are produced showing a wholly new combination, dark and rough, Fig. 11. And if these young are at maturity bred together, a fourth combination, white and smooth, appears among their young, the grandchildren. See Fig. 12. Other grandchildren manifest the combinations seen, respectively, in the parents and in the grandparents. By selection any one of these combinations may be obtained in a pure race.

Oftentimes a new combination of characters obtained through

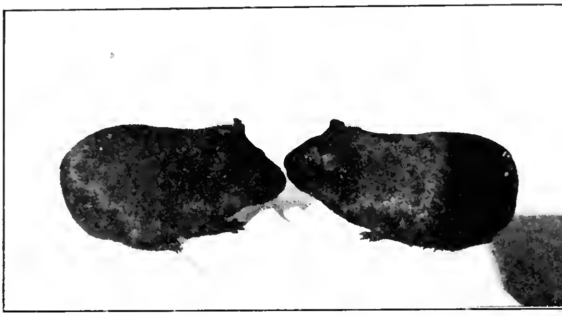


FIG. 7. TWO OF THE GROWN-UP YOUNG OF A BLACK AND OF AN ALBINO GUINEA-PIG.

FIG. 8. A GROUP OF FOUR YOUNG, produced by the animals shown in Fig. 7.

crosses coincides with a lost racial combination. Then the phenomenon is called reversion or atavism. Thus when yellow rabbits are crossed with black ones, gray offspring are obtained similar to wild rabbits in coloration. There is no longer anything mysterious about the process; it is simple recombination of different unit-characters formerly associated together in the same race, but since isolated in some of the derived races.

Very different in nature, apparently, from the Mendelian inheritance of unit-characters is the result obtained when races of animals are crossed differing in size or in the proportions of their parts. In such cases the children are intermediate in character, and the grand-parental conditions do not reappear among the grandchildren. The result may be described as a blend apparently permanent. Fig. 13 shows the skulls of three rabbits, all adult, father, mother and son. The skull of the son is shown between that of his parents, the mother's skull being at the right. Size and proportions of parts are clearly intermediate in the son. No grandchildren were obtained like either grandparent in size. The color of the coat in this same family of rabbits clearly followed Mendel's law, although the size characters blended. The practical result is that one may at will produce a race

FIG. 9. A *dark smooth* GUINEA-PIG.

of rabbits of any desired size within the known limits of variation in size among rabbits, and with any of the conceivable combinations of color factors. Size variation is apparently continuous and its inheritance blending, color variation is discontinuous and its inheritance Mendelian.

Notwithstanding the seemingly radical difference between these two types of inheritance, it is possible that they may, after all, prove to have

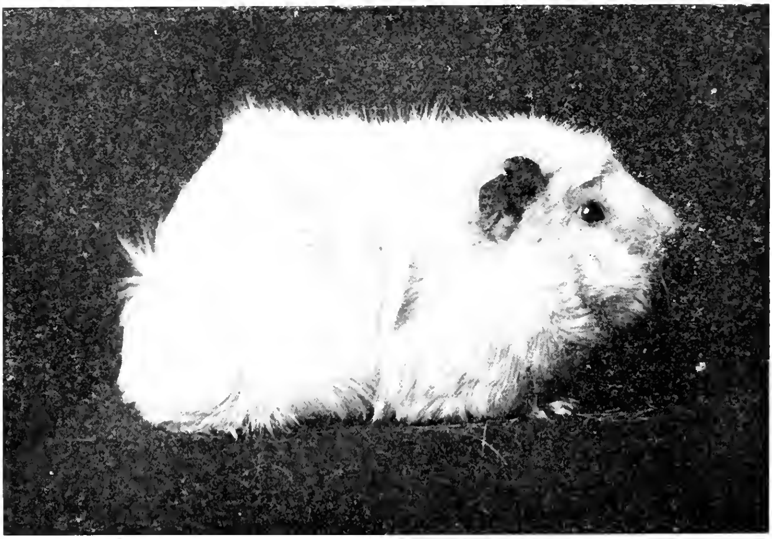


FIG. 10. A *white rough* GUINEA-PIG.

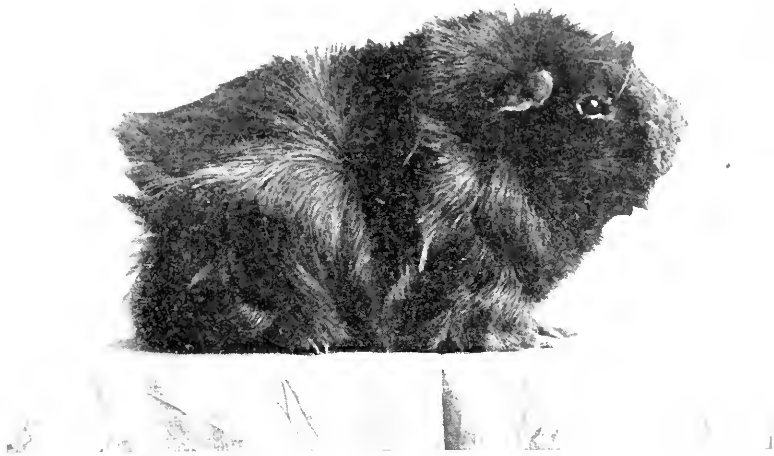


FIG. 11. A *dark rough* GUINEA-PIG, the new combination of characters obtained when animals are mated like those shown in Figs. 9 and 10, respectively.

a common basis. Blending inheritance may possibly be only a complex sort of Mendelian inheritance, in which many independent factors are simultaneously concerned. The question is one of much theoretical interest. Its solution awaits further investigation.

FIG. 12. A *white smooth* GUINEA-PIG, a second new combination of characters, but obtained first among the grandchildren of such animals as are shown in Figs. 9 and 10. Other grandchildren are like the respective grandparents (Figs. 9 and 10) or the parents (Fig. 11).

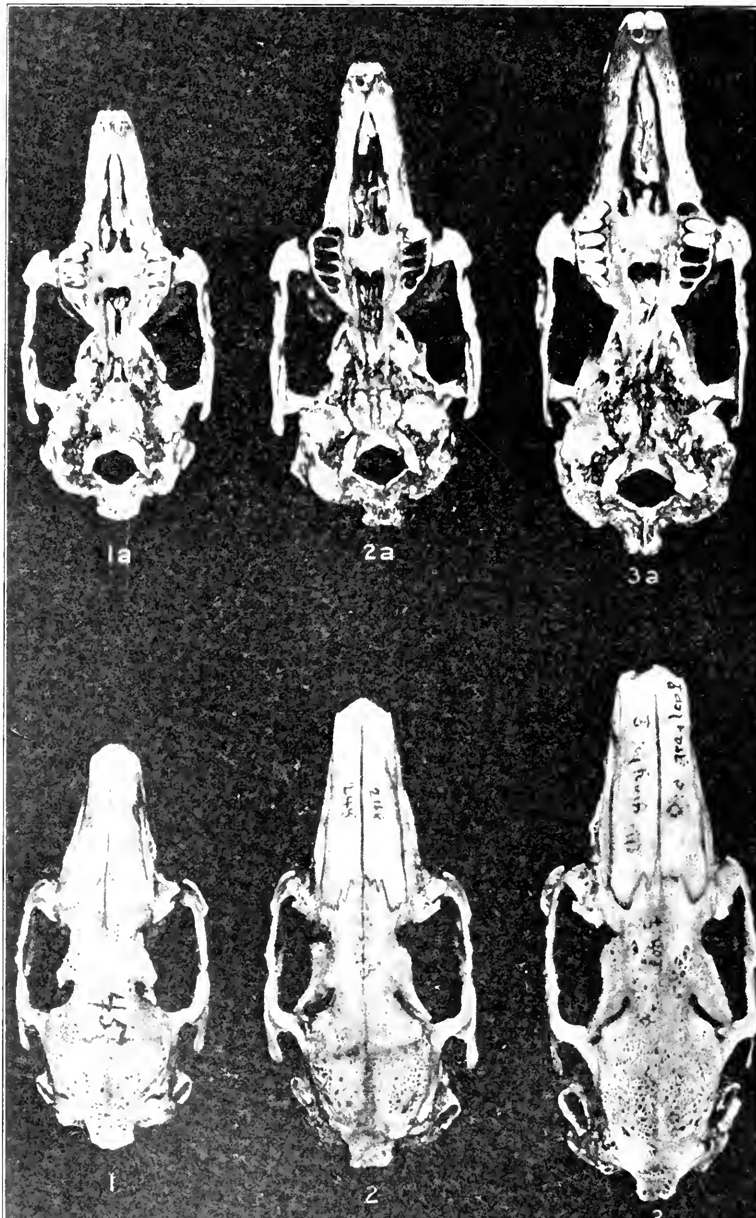


FIG. 13. SKULLS OF THREE RABBITS, mother (3 and 3*a*), father (1 and 1*a*) and son (2 and 2*a*). From Publication No. 114, Carnegie Institution of Washington, by permission.

What has already been accomplished in the study of heredity gives us a hopeful outlook for the future. We are gaining a fuller knowledge of its processes, and a knowledge of processes is a first step toward their control.

SNEEZING, SEA-SICKNESS, PAIN

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PHYSIOLOGISTS can not lay claim to a theory of pain. Even definition is difficult. The distress of bodily wants overlaps pain on the one side; fear, anxiety and similar mental states overlap it on the other. Excessive stimulation of certain organs of special sense, particularly those for touch, temperature and hearing, leads up to it. If an attempt be made to isolate, in thought, the effect in consciousness to which the term "pain" properly applies, it may be said to be the awareness of something amiss in some part of the body, irrespective of the testimony of either of the special senses. It is a modification of consciousness, not a part of its content. We have learned to associate the receipt of the modifying influence through particular nervous channels, with its provenance, just as we have learned to associate sensations of touch conveyed by particular nerve-fibers with the contact with external objects of particular regions of the skin; but such topognosis is no more innate in the one case than in the other. It is the product of self-investigation, and is based either upon the testimony of the eye or upon experiments in moving the hand to the spot. Hence in the case of organs which are out of sight and out of reach topographical guidance is unobtainable. Since we can have no knowledge of its seat, the pain is referred to some accessible part of the segment of the body in which it occurs. A gulp of very hot water, on reaching the closed sphincter muscle of the stomach—the valve which must open before it can pass from gullet into stomach—gives rise to pain which seems to have its seat in the skin over the lower end of the breast-bone. In the same way disease of the various viscera gives rise to pain and tenderness of areas of the skin of the segments of the body in which the nerves of the viscera join the spinal cord.

From a physiological standpoint "pain" and "sensation" are antithetical terms. Sensations inform. Pain is a state of consciousness which masks sensation. Sensations are transient. Their apparent prolongation is due to repetition. They are vibratory. Pain is a condition, slowly set up, slow to disappear. Even the briefest pain is long as compared with the constituent unit—a nerve wave—of sensation. It is of the very essence of sensation that it has quality or modality; the informing value of any given sensation depends upon its excluding all other forms of stimulation. The sensation of a bright red spot of light is not susceptible of confusion in place or quality with other visual sensations. Still less is it liable to be mistaken for a sensation of hearing or of taste. Pain has no modality. If it may be justly described as stabbing, aching, burning, it owes its individual character to the form of its onset and to its duration, and these in turn depend upon either the vascular condition of the part affected—the pumping of blood through the vessels of a tissue free to expand, or packed in a bony case—or they are due to the effect upon the inflamed or injured part of muscular contractions. If the injured part be inaccessible, pain has no "local sign." If it be on or near the surface of the body the pain felt in it has or seems to have a topographical meaning; but it is very doubtful whether the mind can localize the source of pain in the absence of evidence simultaneously afforded by the nervous apparatus of the sense of touch. Many instances are on record of disease or injury to the central nervous system resulting in complete loss of sensitiveness to pain, whilst sensitiveness to touch and pressure remained undiminished. But there are no recorded cases, so far as we are aware, of complete paralysis of the mechanisms of touch and of the recognition of heat, of cold and of pressure, with the retention of normal sensitiveness to pain. Such a condition, if it were established, would make it possible for an investigator to ascertain whether skin-pain, by itself and unsupported by collateral evidence, has a topographical meaning, or "local sign"; and whether the expression pain-spot may be legitimately used, as meaning a sounding spot in the midst of a dumb area, and not merely a focus of sensitiveness at which the weakest stimulus which can evoke pain is effective.

Dr. Henry Head caused the large cutaneous nerve of the thumb-side of the forearm and hand to be cut in his own arm, in order that he might study carefully the revival of sensations which follows on nerve repair. He found that, long before he regained the ability to distinguish degrees of warmth, to feel as separate the two points of a pair of compasses, or to recognize a touch with cotton-wool, he regained his power of recognizing stimulation by agents that do harm—hot things, cold things, pricking with a pin—but his power of localizing the spot injured was extremely vague. Trotter and Davies have made similar experiments in their own persons on a still more extensive scale and have confirmed and amplified Head's results.

Investigations with the aid of new histological methods has shown that the epithelial tissues are supplied with nerve-filaments in inconceivable abundance. It is probable that the conclusion is justified that every cell of the skin, of the mucous membranes, of the lining epithelium of the air-chambers in the lungs, of the pleural and peritoneal cavities, of the various glands, is connected with a nervous thread. It is certainly true also of every muscle-fiber in the walls of the alimentary tract, of ducts and of blood-vessels. By these filaments the cells of the body-surfaces both external and internal, the central nervous system and all motile organs, are bound together.

Superimposed on this basal system are the various specialized systems of nerves which originate in organs in which their ends are so modified and so enveloped as to render them sensitive in the highest degree to one particular order of stimulus, whether of smell, sight, taste, hearing, touch, heat, cold, pressure or traction, and inaccessible to stimuli of every other class. These nerves, with the chains of neurones which link them to the muscles, *via* the spinal cord and brain, stand out as a pattern on the basal system, like the pattern formed of thicker fibers and coarser knots on a sheet of lace.

In a book recently published, "The Body at Work," I have endeavored to present a picture of the nervous system and its activities, which, although not original in any of its details, is new in their grouping and in its comprehensiveness. It is based upon the teaching that the two great functions of the nervous system, notwithstanding that they grade one into the other, must, for purposes of analysis and description, be considered apart. By the basal system of protopathic nerves all the cells of the body, with the exception of those of the connective tissues, bones, tendons and so forth, are bound together into a continuous inseparable whole. No change can occur in the nutritive condition of any part of the skin or of an internal epithelium without the induction of a nutritive change in the central nervous system and thence, onward, in the plain muscle-fibers of arteries and other structures of the segment of the body in which the inducing change occurs. As contrasted with the influence which spreads through this basal system the "impulses" which travel up the nerves of special sense are peculiar in kind or, at any rate, in intensity. In order that they may overcome the resistance of a chain of neurones they have a certain potential, and progress in pulsations or waves.

Pain is explained as due to the setting up in a particular segment of the axial nervous system of a focus "pain-conditioned" sympathetically with the injured tissues. Consciousness of pain depends upon the direction of attention to impulses which ascend through the pain-conditioned segment from end-organs of nerves of special sense. If the seat of injury be the skin it is through the specialized nerves of the injured spot that modified impulses reach the cortex of the brain. If the seat of injury be an internal organ no effect is produced in consciousness until the pain agitation of the spinal cord has become sufficiently intense, and sufficiently wide-spread, to modify impulses which ascend to the cortex from skin areas of the segment in which the viscus is situate. The pain in angina pectoris is felt on the left side of the breast bone at its lower end. This shows that the nerves of the aorta have their centers in the same region of the spinal cord as the cutaneous nerves of this area on the surface of the chest.

To give an illustration of the difference of mechanism of pain and of sensation. In a railway station lavatory I recently observed a man who absent-mindedly placed his fingers on a free-standing iron stove to ascertain whether it was hot. It was a frosty morning in November. Obviously, the stranger had a strong prejudice that the station-master would not have thought it necessary to order a fire to be lighted so early in the winter. As nearly as I could estimate, three seconds elapsed between the touching of the stove and the ejaculation which announced with unnecessary emphasis that the man had obtained the information he desired. Had he, expecting to find the iron hot, directed his attention to the modification of his skin sensation he would have withdrawn his fingers in one seventh of a second.

One of the characteristics of incipient pain is exaltation of reflex actions. I can not by any effort of will prevent my muscles from withdrawing my hand from hot iron (although the resolute withdrawal of attention from pain-modified sensations and the forcing of a conviction that it does not exist, has in certain cases a remarkable effect in suppressing pain). Equally characteristic of established pain is the inhibition of action. A whitlow abolishes all temptation to shake the finger.

Physiologists can not investigate the phenomena of pain, although they make elaborate studies of its threshold value and of the distribution of "pain spots." It would take us too far were we to consider the evidence of a degree of specialization in the protopathic nerves of the skin which is held by some to justify the use of the expression "pain-nerves," and of the allied question of neuronic conduction of incipient or threshold pain along pain-tracts in the spinal cord.

The chief interest of the hypothesis of structural continuity through the protopathic nervous system, with its corollary of sympathetic nutritional change, lies in the explanation which it affords of the influence upon reflex action of the establishment of a pain-condition in the axial nervous system in circumstances in which, consciousness not being affected, there is no "pain."

Pain-condition which inhibits reflexes due to impulses which start in the damaged organ or skin area, greatly increases in many instances the conductivity of the portion of the nervous system which it affects for impulses which do not come from the damaged part. Such a reinforced reflex is the attack of sneezing to which many persons, most monkeys, and some breeds of dogs are subjected when the eye is stimulated by a bright light. When the gaze is directed towards a bright cloud, excessive stimulation of the retina sets up a pain-condition in the mid-brain. In the progress of evolution this portion of the cerebrospinal axis has undergone great changes. Its sensory nerves with their protopathic constituents have been drawn backwards into the great bundle of the fifth nerve, which joins the hind-brain, whilst the nerve from the retina has established a secondary connection with the mid-brain. The mid-brain receives in consequence the protopathic nerves of the eye. But the nose being the real tip of the body and anterior to the eye the sensory fibers of the skin which lines it although bound up with the fifth nerve, extend forwards within the cerebrospinal axis to the very front of the mid-brain. A remarkable state of affairs is thus established. The mid-brain receives the protopathic nerves of the eye and the root-fibers of the sensory nerves of the nostrils. When excessive stimulation of the retina by bright light sets up a pain-condition in the mid-brain the every-moment impulses ascending from the nostril acquire undue importance. It is as if they had been increased in intensity by a pinch of snuff. Their urgency causes the reflex by which irritating substances are expelled.

Some persons merely feel a tickling in the nose when they look at a bright light, but do not sneeze. This phenomenon is extremely interesting. It proves that stimuli "adequate" to impress nerve-endings are not necessarily "adequate" to arouse consciousness. External forces incessantly press the button with sufficient energy to make contact. At each pressure a bell rings in the chamber of consciousness, but, if it is to attract attention, it must ring more loudly. The stimuli which gave rise to a tickling feeling were not originated nor intensified by the light which fell upon the retina. The mid-brain through which impulses passed to reach the cortex was rendered more conductile.

In normal conditions no pain results from stimulation of the retina, however severe; because the nerve-fibers which convey visual impulses from this highly specialized sense-organ, are connected, not with the mid-brain, but with the optic thalamus and the occipital cortex. It would stultify so highly specialized a sense, were its news admixed with, or modified by any influence or information not directly connected with its proper function.

Sea-sickness is another illustration of the effect upon reflex action of central agitation due to impulses which do not appear in consciousness however voluminous the sensations may be of which they are the indirect cause. The nerve which is concerned with the adjustment of the position of the body is a constituent of the auditory nerve. It comes from the semicircular canals. Never under any circumstances do the impulses which originate in these organs of orientation enter consciousness; but when a ship begins to roll, or worse, to heave, they churn up the gray matter of the hind-brain until its conductivity is so affected as to demonstrate their urgency beyond misunderstanding. Root-fibers of the vagal nerve traverse the hind-brain much in the same way as root-fibers of the fifth nerve traverse the mid-brain. Habitual, every-moment impulses ascending from the stomach by the vagal nerve, for the routine regulation of its purely domestic functions, acquire, when the hind-brain is pain-conditioned by impulses from the semicircular canals, a terrifying import, causing the explosion of numberless motor neurones. The stomach sneezes, with the zealous support of muscles of the throat, chest and abdomen. In the early stages of the malady the same cause leads, no doubt, to reflex derangement of the secretion of the stomach involving nausea. Disturbances of vision add to the victim's discomposure, and in some small degree precipitate the stomachic catastrophe; but the effective cause is, I take it, the agitation, by impulses from the semicircular canals, of the gray matter of the hind-brain.

Hiccough, again, is an exaggerated reflex due to increased conductivity of gray matter. A child takes a cold drink, or he rapidly fills his stomach with insufficiently masticated food. The ends of the vagal nerve in the stomach are irritated. They convey an influence which sets up the pain-condition in a portion of the gray matter through which nerve-fibers from the lungs extend their roots towards the nucleus of the phrenic nerve. The diaphragm sneezes.

It would carry us beyond the proper sphere of this journal were we to consider the phenomena of inhibition of some reflexes and exaggeration of others which the modification of the normal conductivity of gray matter due to the establishment of pain-conditioned foci, brings about in hysteria, angina pectoris and many other morbid conditions.

The pain of headache is as truly "referred" as is the pain of angina pectoris, although it must be assigned to a different category. Medical men tell their patients that their headaches are in their scalps and not within their skulls. The patient finds it difficult to understand how this can be, when there is nothing the matter with his scalp; but agrees with his doctor that, were it otherwise, it would be impossible to explain the beneficial effect of a cold wet rag. Again as in sea-sickness the vagal nerve is at the bottom of the mischief. Indeed, in many persons, intolerable headache takes the place of sickness on the sea. Impulses ascending the vagus agitate the gray matter of the hind-brain. Into this pain-conditioned gray matter the nerves of the scalp pour a constant stream of impulses. Myriads of fibers connecting the scalp with the brain twang ceaselessly with messages to which, under normal circumstances, consciousness gives no heed—until a draught of cold air or the tickling of a fly's feet accentuates a certain group. Let the gray matter through which they pass be pain-conditioned, the vibrations traveling to the cortex from innumerable spots on the surface of the head produce a widely diffused dull ache which has no sensational quality, because no particular group of nerve-endings is being especially stimulated by external force. Vascular changes in the scalp due to the same cause, the exaggeration of impulses during their transit of the gray matter of the hind-brain, making believe that the scalp is injured and needs more blood, react upon the nerve-endings increasing the illusion of injury. The pain is no illusion. It is impossible to decide whether vascular changes are the first effect of vagal agitation and therefore the immediate cause of pain or whether they are merely subsidiary results of the exaggeration of sensory impulses from the scalp. A cold compress by constricting the blood-vessels reduces the din of the multitudinous messages shouted into consciousness by the sense-organs of the scalp. If completely successful it subdues their chorus to its habitual murmur, too faint to secure attention. Long continued, and therefore damaging, contraction of the muscles which move the eye-ball, and particularly its elevator, sends through their protopathic nerves a stream of influence to the mid-brain, with which these nerves are connected, which causes frontal headache in just the same way as the influence which ascends the stomach nerve.

Would doctors be more logical if they said that the headache was in the hind-brain—the region which contains the agitated gray matter which gives pain-value to the impulses from the scalp—or if they said it was in the stomach? The irritation of nerve-endings in the stomach is the origin of the trouble, seeing that it sets up the pain-condition in the hind-brain.

Psychologists base their science upon conspicuous sensations—sensations of sufficient prominence to stand out in the field of consciousness. They can do no otherwise. But the terminology in which they have expressed the results of their analysis hampers physiology. In the process of conduction a physiologist can distinguish no stages intermediate between stimulation and muscular response. In reactions to which consciousness is adjunct, as judged by self-feeling, or, when outside oneself by attribution of self-feeling, the nerve-current may be termed a sensation, and sensations may or may not provoke attention. Nothing is gained by classifying the sequence of events into stimulation, passage of impulse, sensation, perception. Such terms are machinomorphic. The nervous mechanism is infinitely vibrating. "I always hear my clock stop" can have but one meaning. Every tick of the clock produces an answering vibration of the auditory nerve, however little attention be given to the message; and attention carries with it the idea of something which attends. Pain, as pictured in this essay, is the interpretation which the ego gives of hitherto unperceived sensations when they are increased in volume without definition. Pain is developed when impulses, without informing attributes, are raised in urgency to the level of attention.

The passage of a gall-stone from the gall-bladder to the intestine is the cause of intense pain, "referred," in the first instance, to the skin which overlies the liver. Yet the gall-bladder is insensitive. As surgeons have long been aware, the liver, stomach and other viscera may be cut, burned, scarified, without arousing pain. Laying stress on these two well-known facts, (1) the insensitiveness of the viscera and (2) their liability to become the source of referred pains, James Mackenzie has defined pain as "a disagreeable sensation due to stimulation of some portion of the cerebrospinal nervous system and referred to the peripheral distribution in the body wall of cerebrospinal sensory nerves." When a viscus is the seat of origin of pain the impulses which ascend its sympathetic nerves excite the centers of sensory nerves in the spinal cord.

The theory which I have attempted to outline in this article is laid on the same basis, somewhat broadened. All pain is "referred"—to the right spot, if its source be in the skin; because the skin is elaborately supplied with place-defining nerves—to an organ or part, skin, muscle, joint, which the ego, during the progress of self-investigation, has discovered in the same segment of the body, if its source be in a viscus.

The body is permeated with a felt-work of nerves, unprovided with specialized nerve-endings, conveying no definite information, and in consequence without precise distribution in the seat of consciousness. This non-specialized system which binds the various parts of the body together is the mechanism through which the caliber of blood-vessels, erection of hairs, secretion of glands, contraction of the walls of ducts and of the intestines, and many other domestic adjustments are effected. It is also the medium through which the gray matter of the cerebrospinal axis is affected sympathetically with damage to the tissues. The resultant altered conductivity of the gray matter leads to modification of the only kind of impulses with which consciousness is concerned—impulses which inform. We infer that the damage which is giving rise to a feeling of pain is in the part from which the modified impulses come.

When attempting to formulate the theory of pain it is necessary to discard the prejudice that there need be a proportional relation between the intensity of pain and the magnitude of the physiological changes which condition it. A heavy blow hurts more than a light one. Yet a change which could not be detected by any piece of apparatus in use in a physiological laboratory, if it affect the nerve-tissue of a tooth, may give rise to more pain than is caused by a crushed limb.

Another prejudice, from which it is difficult to shake free, attributes to the mind an innate knowledge of the topography of the body; an innate knowledge, that is to say, of the distribution of its news-agents, the sensory endings of nerves.

Thirdly, it is necessary to remember, when investigating the machine, that the machine is the man. It is not sufficient to design a scheme of telephone wires requiring for its use a listening ear at its center, the brain. The ear is a part of the machine. There is no need to picture a system of pain nerves, carrying news of damage to an attentive mind. A departure from the normal in the functioning of the sensory apparatus is pain.

THE CIRCULATIONS OF THE ATMOSPHERES OF THE EARTH AND OF THE SUN

By Professor FRANK H. BIGELOW
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The Two Causes of Circulation on a Non-Rotating Earth

Gravity, Temperature and Pressure

It must seem rather ambitious to attempt to treat so great a subject as that of the circulation of the atmospheres of the earth and the sun in a single lecture. It is true that if it should be discussed fully, in the technical way, it would require a great many lectures, but of course there are at the same time certain fundamental principles which are common to all circulations that can easily be studied, and then illustrated by the known facts of the circulation in these two atmospheres. All circulation depends upon two primaiy causes, the first being the attraction of gravitation, by the laws of the action of the earth upon its atmosphere or the great body of the sun upon its atmosphere; and, secondly, the difference of temperature which exists in different parts of a given atmosphere. If we had an earth standing still in space without rotation upon its axis and the sun were withdrawn for a considerable time, the atmosphere of the earth would gradually settle down into a quiescent state, which may be described as consisting of a series of concentric shells, each shell having a certain fixed temperature passing around the earth at the same distance from a center, as if a balloon were floating at the same height above the surface, where will be found the same barometric pressure and the same temperature in all latitudes and longitudes. If the balloon falls from one shell to another it would pass into layers of greater density, and if it rises, into layers of less density. The boundary of each shell may be conceived as a surface having the same force of gravity acting upon it, and this is called the gravity level. In this case the surfaces of equal pressure or the isobars, and the surfaces of equal temperatures, isotherms, both coincide with their own gravity levels. Everything is quiescent and there is no circulation. It is quite important to secure a clear idea of the fact that the isobars, isotherms and gravity levels coincide wherever the layers in the atmosphere have the same temperature. As a matter of fact the earth is not without rotation, and the sun is shining upon it, sending enormous masses of heat which fall upon the tropics, and it is our problem to study the effect of this heat, at certain layers in the earth's atmosphere, upon the circulation of the entire mass.

To illustrate the series of causes and effects we can take a long box or canal containing air at a certain temperature. Now if heat be applied at one end, it is evident that the air at that end is displaced in proportion to the amount of heat. The effect of heating the bottom of a column of air is to expand the lower layers of it and this produces less density in each of the lower layers, while at the same time the entire mass is lifted, provided the bottom rests upon a solid surface. Take water in a tube, heat the lower part of the tube, and the whole column will seem to rise in the tube, but the lower parts, being hotter, will necessarily have a smaller density. A common case of the power that can be produced by heat is seen in its effects in the steam engine. Similarly, the air when heated in certain localities, as over the tropics, begins to work practically like the steam engine. The air is expanded, the upper part is elevated and the lower part is rarefied. Now the effect of lifting a column which is heated in the lower part is to raise the isobar above the gravity level which is occupied before heating, and in the lower part the isobar is depressed below the position which it had before it was heated. It is now readily seen that isobars, instead of coinciding with the gravity levels, have a slope, the upper ones trending downwards towards the cold end of the canal, and the lower one sloping downwards to the warm end of the canal. Under the action of gravity a liquid or a fluid which rests on a slope of any kind tends to run down hill, just like water in a brook or a railroad train on a grade. The part which is above the gravity levels tends to get down to it, in order to destroy the slopes which nature abhors among its gravity levels. The force of gravity tries to make all the temperature and pressure levels coincide with the gravity levels, and in order to do that it is clear that currents of circulation are set up. In this way there is an effort to destroy the differences in temperature which have been produced by the sun's radiation and reduce them to a uniformity; that is, a uniform temperature at the same distance above the surface of the earth.

It becomes, therefore, a fundamental point in meteorology that the air over the tropics is heated in the lower levels by the action of the sun's radiation falling upon the earth, and that the air in the tropics is also lifted above its natural gravity position; hence, in the upper levels the air flows from the tropics towards the poles, and in the lower levels from the poles towards the tropics. We will not attempt to trace out this general circulation more fully until certain other conditions have been described.

If the heat is applied at the center of a canal, instead of at one end, the same principles operate, so that the lower part, being heated, has its isobars depressed in the middle, while the upper part is lifted so that the higher isobars are elevated above their original position. In this case air flows from the center in both directions towards the cold ends of the canal in the upper levels, and from the cold ends towards the middle in the lower levels. In this figure we have therefore a general description of the primary motion of the air on the earth taken as a whole, by which the air flows from the tropics towards the north pole and the south pole of the earth, respectively, in the upper levels, and from the north pole towards the tropics and from the south pole towards the tropics in the lower levels. It should be remarked in passing that since the assumed canal is like a rectangular square box in our laboratory experiments, but as a matter of fact of a wedge shape in the earth's atmosphere, the circulation is not so easy as might be at first assumed. The meridians at the equator, which are one degree apart, converge to a point at the poles, so that the atmosphere when quiescent must be thought of as made up of a series of sectors or spherical wedges. Now the air in running from the tropics towards the poles runs from a broad end to a thin end of the wedge, and, since it can not congest, a very complex circulation is set up in order to enable it to escape unnatural compression. There are, however, many examples in the earth's atmosphere of masses of air which are arranged much more nearly in the form of a rectangular box canal, as shown when a long mass of cold air is pointing north and south, with a mass of warm air pointing from south to north and lying east of it, while another mass of cold air pointing from north to south is placed just east of the mass of warm air. While these masses may not in fact be very rectangular, yet we can study their action on the supposition that sections through them produce figures which are practically rectangular in shape. Suppose we have a warm mass lying between the cold masses, then the warm mass will be higher above and also lower below than the cold masses so far as their isobars are concerned. That is to say, at the upper surface of the sections if you want to get a mass of air at a certain density it will be necessary to go higher up in the atmosphere over the warm mass than over either of the undisturbed cold masses lying on the side, and furthermore, if one wants to get a mass of air of the same density as that lying on the under side of the cold section, it will be necessary to go down lower in the warmer mass, that is, nearer the surface of the ground, in order to find it. Applying now our principles of circulation, the action of gravity will tend to draw the upper part of the warm mass over upon the cold masses to either side, and thus tend to destroy the inequality in the elevation of the upper isobar. Similarly the cold masses will tend to flow under the warm mass from either side, and remove the discontinuity in the positions of the lower isobars. Not only do these masses of warm and cold air tend to overflow and underflow sidewise, but they seek to move, as it were, along the meridians, northward and southward at the same time; hence the long currents of circulating air are naturally produced so that the warm and cold begin to interflow among one another, as a matter of fact in very complicated curves, the purpose of this being to restore the coincidence between the isobars, isotherms and gravity levels, which had been disturbed primarily by the heat of the sun falling upon the tropics of the earth. Having considered thus briefly the general principles which would induce circulation on a non-rotating earth, we can take up somewhat more fully the effect produced upon this same circulation by the fact of the earth's rotation; that is to say, we can discuss the circulation upon a rotating earth.

The Gyrations in the Atmosphere set up on a Rotating Earth

It will be desirable to define a few terms which occur in circulation that will enable us to speak more briefly of the subject in its advanced stages. *Rotation* will be confined to the motion of a mass of matter, as the sun or the earth, which is revolving about its center. The rotation of the earth takes place in 24 hours; the sun rotates on its axis in 27 days more or less. *Revolution* is the motion of a mass about a center from which it is separated by a radius, as the revolution of the moon about the earth, or the earth about the sun, or of an ideal particle of the atmosphere revolving about a center at a variable distance. *Gyration* is a more complicated motion. It consists of the revolution of a mass about its center at a given radius while the center itself is moving in some direction. If the moon revolves about the earth and the earth revolves about the sun, each particle of the moon will describe a series of gyrations forming a looped curve which describes this motion. If a particle of air in a tornado revolves about its axis while the axis is moving over the surface of the earth, the particle will gyrate or form a looped curve relatively to the surface of the earth. *Vortex motion* is more complex still. A vortex may be described as consisting of a series of concentric tubes. The motion of the tube is such that the inner tubes revolve about the axis faster than the outer tubes. A particle of an inner tube has a certain velocity which is greater than the velocity on an outer tube, but the velocity of the inner tube multiplied by its radius is equal to the velocity of the outer tube multiplied by its radius. If a particle moves from an outer tube to an inner tube in a vortex it can do so only by increasing its velocity of rotation. If the particle moves from the outer tube towards the inner tube and at the same time ascends along the axis, the particle will move in a helix. The *helix* may be contracting, with greater angular velocity, or expanding, with less angular velocity. In the latter case the particle moves from the inner tube to the outer tube of a vortex. A *torque* is a complicated motion which applies to a mass taken as a whole. The earth is covered by a shell of air and its actual motion may be described as a torque. Take a bundle of paper rolled up about a center line and grasp it in the two ends. Now twist the roll so that the ends move in opposite directions. At some point in the middle there will be no motion of the particles, while the upper particles of the paper move in one direction and the lower particles move in the opposite direction. In the case of the earth's atmosphere, in each hemisphere, there are two great currents each constituting a torque. In the northern hemisphere the northern current moves eastward and is called the eastward drift. In the northern tropic the great current moves westward and is called the westward drift. There are really two torques in the earth's atmosphere, one belonging to each hemisphere, so that in the tropics, as a whole, the movement is westward, while north of the Tropic of Cancer it is eastward, and south of the Tropic of Capricorn it is also eastward. Instead of the atmosphere running from the tropics towards the poles in the meridional wedges, as a matter of fact it circulates in these great torques. In the northern hemisphere north of the latitude of 33° there is a great eastward drift and between the latitudes of 33° there is a great westward drift. Along the latitude of 33° approximately there is no general motion either east or west, and this corresponds with the part of the paper bundle which does not get twisted when the upper and lower ends are moved in opposite directions.

When a current of air moves in any direction it tends to break up into two *volutes* or spiral branches. If one takes a dandelion stem and splits it along the center, the two pieces will curl over in opposite directions and form beautiful right and left handed spirals. If a warm current of air ascends from the ground and forms a cloud, it can be seen that the middle of the cloud is ascending while the edges are descending in a gentle spiral of an umbelliform shape. If a southerly current of air moves northward it will tend to open up in two branches to the right and left. If a northerly current moves southward it will tend to open up in two branches to the right and left. The left-hand branch of the southerly current and the right-hand branch of the northerly current will tend to interlock or intercurl. The great current in the tropics which moves westward, instead of proceeding due west around the earth, tends to break up into two great volutes, one curling into the northern hemisphere, and one curling into the southern hemisphere. The word *curl* has several meanings, the first is that in which it has already been used; namely, a spiral rolling about a center. The second is connected with vortex motion and is really a name for a part of the helix action. If a mass of air moves in a spiral towards a center, it is evident that it can not proceed long in this way without some provision for its escape. If it moves in a spiral on a given plane it must begin to escape along a line perpendicular to that plane. If a circle is taken as a boundary in a given plane, and a certain mass of air moves into this circle on spirals, then there will be a certain amount of the air moving perpendicular to the plane of the circle. This whole action of spiral movement inward and vertical motion from the plane is called a curl and it depends upon vortex laws. In a tornado or hurricane the curl is illustrated by air which ascends as a current while the air is moved inward along certain spirals. It is also illustrated in electricity and magnetism where an electric current passing around the helix surrounds a magnetic field perpendicular to the sections of the tube along which the electric current is flowing. Electric currents and magnetic fields are also related to each other by the law of the curl, and this evidently goes back to the idea of the helix or vertical spiral.

We may now resume our discussion of the circulation of the air on the rotating earth, repeating to some extent what has been said in defining these special terms. Take a globe and in the tropics place an arrow pointing westward between the equator and the latitude of 33° both north and south. To the north of 33° place an arrow pointing eastward, and in the southern hemisphere to the south of 33° place an arrow also pointing eastward. These represent in a general way the action of the atmosphere as consisting of two great whirls in each hemisphere, thus composing a torque on a hemispherical scale. Draw a ring around the earth in latitude 33°, cutting out a section of the atmosphere. If this ring moves northward it will evidently contract, and to have the same angular momentum, that is, mass energy, it must rotate faster about the axis as it approaches the pole. This constitutes in a way an illustration of vortex action whereby a particle passes from an outer to an inner tube and consequently revolves faster about the axis. Take another section south of latitude 33°, cutting out a ring of atmosphere. If this ring moves southward it must rotate slower because it is moving to a region at greater distance from the earth's axis if it is to retain the same momentum or energy of mass in motion. The importance of these great torques in the earth's atmosphere can be seen from this general fact that while the weight of the earth's atmosphere taken as a whole is very great, and is, generally speaking, in vigorous motion, yet the currents as a whole are so interbalanced that the mass energy moving eastward is exactly equal to the mass energy moving westward when the whole atmosphere is summed up. This is proved by the fact that the rotation of the earth on its axis does not change by the smallest fraction of a second from century to century, or at least astronomers have been unable to detect any change in the period of the earth's rotation so long as observations have been continued. If this balance of eastward and westward momentum were not perfect, it would immediately be shown by a change in the period of the rotation of the earth upon its axis.

The picture which is presented by these ideal rings starting from latitude 33° in each hemisphere and moving respectively towards the poles and towards the equator is not very complete, because the rings do not continue to move as a whole with an increase or decrease of velocity. If we examine the actual velocity of the air in a given latitude, as over the city of Washington or again in the tropics, as over the Barbadoes, we shall find the following facts: At the ground in Washington the wind averages about six meters per second eastward; at an elevation of 2,000 meters the eastward velocity is about eighteen meters per second; at 4,000, it is about twenty-four meters per second; at 6,000, it is about twenty-eight meters per second; and at 10,000, it is about thirty-four meters per second.

Above this level the air moves eastward at a rate of about forty meters per second; that is, ninety miles per hour. That is to say the eastward velocity or the eastward drift increases upwards with the distance from the ground. Now these velocities are maintained throughout the year with certain seasonal variations, though, of course, they are at times disturbed by certain local circulations as when storms disturb the normal movements of the air. The gyrating rings then which we first considered may be more accurately described as sheets of air parallel with the earth's surface which flow over each other at different speeds, the upper sheets flowing faster than the lower sheets. This may be practically seen in the cirrus clouds which are higher than the cumulus clouds, and move eastward as a whole with twice as great velocity. It is evident that we have here another type of vortex motion. What we first considered in the course of our definition was a vortex in which the inner rings rotate faster than the outer rings, but in this case of the torque in the northern hemisphere, for example, we have the upper rings moving faster than the lower rings. This apparent inconsistency may be reconciled by assuming that the axis of the upper rings instead of being a line, as in the other case, is really a spherical surface high above the ground outside the earth's surface, to which the actual motion has to be referred. Mathematically considered such a spherical sheet is in certain aspects equivalent to a line so far as the reference of motion is concerned; that is, the motion may be a maximum along a spherical sheet in one case, or a maximum around an axial line in the other case.

Turning now to the tropics and examining the motion of the air in a vertical section just as we did in the north temperate zone, we find that the westward motion is distributed very differently. At the surface the westward motion is greatest, and it decreases gradually on going upwards from the ground till at 10,000 meters or so it has decreased to zero, and above that region an eastward motion sets in, gradually increasing with the height. The westward branch of the torque then, is strongest at the surface and decreases upwards. The eastward branch of the torque is a minimum at the surface and increases upwards. We have several times referred to the latitude of 33° north and south of the equator as separating the eastward branch from the westward branch of the torque, but it has now been indicated that at about 10,000 meters above the tropics the westward branch changes into an eastward branch of the torque. As a matter of fact the surface which separates the westward branch from the eastward branch spans the tropics in an arch resting on the ground at 33° of latitude and crossing the equator at 10,000 or 12,000 meters above it. Beneath this arch the western torque is included with its maximum motion at the bottom; above this arch with a broad base in each temperate zone rises the eastward torque in which the velocity increases upward and gradually overspreads the tropics in the higher elevations, the northern branch reaching southward, and the southern branch reaching northward in a comparatively thin shell till they touch somewhere above the equator. All this circulation therefore constitutes a complex vortex which can be referred to distinct mathematical laws. If the atmosphere were willing to circulate in this simple manner it would not be difficult to adapt our mathematical analysis to it, but unfortunately, instead of moving so that the branches of this torque remain intact and retain their theoretical individuality, there is a continual interchange or passage of currents from one branch to the other in a rather irregular way which it will be necessary more closely to examine.

The Circulation on the Rough Rotating Earth

The circulation which we have been describing might possibly be set up on a perfectly smooth globe having the size and shape of the earth, but the presence of continents and ocean areas, the mountain ranges stretching north and south on the American and east and west on the Euro-Asiatic continent, facilitate the breaking of these theoretical branches of the torque into great circulating masses which interplay among each other. It is evident that the Rocky Mountains of North America and the Cordilleras of South America tend to stop the westward currents in the tropics and the eastward currents in the temperate zones. On the other hand, the Himalaya range in Asia tends to hold the westward current in the tropical zone and the eastward current in the temperate zone. There are thus certain places, that is, certain longitudes, where the currents tend to curl from the tropics into the temperate zones. A conspicuous instance of this occurs in the United States, where there is a continual outpouring of warm air from the Gulf of Mexico over the Mississippi and central valleys of the United States. While the trade winds in the tropics tend to blow from the northeast, it is known that immense masses of air move from the tropics over the United States from the south, quite contrary to the general principle; and similarly, though not so conspicuously, a case is found in South America and south Africa. On the contrary, the warm air in the lower levels over the Indian Ocean, whose winds are called monsoons, simply beats upon the great mountain ranges to the northward of India without penetrating the temperate zone in Siberia. In this way certain great circulations called centers of action form in each hemisphere. There is one over the middle Atlantic Ocean; another over the middle Pacific Ocean of the northern hemisphere; and there are other corresponding centers of action in the southern hemisphere. These are especially well marked during the summer time when the ocean is cool and the land air is warm. In the winter time the tendency is to form centers of action over the land areas instead of over the ocean areas, but the process is much more irregular, and in the United States it is exhibited chiefly by a succession of cold waves which traverse the United States from west to east. Referring to the center of action over the middle Atlantic Ocean in summer, we know that the winds near the American side are from the south or southwest. On the Atlantic Ocean in latitude 35° to 40° north the winds are blowing eastward, and in latitudes 25° to 30° they are blowing westward; on the European side they are blowing from the northwest and north. The consequence is that the United States is bathed during the summer with warm, moist winds in the eastern half, and with warm, dry winds in the western half of the continent. In Europe, on the contrary, the northerly winds prevail, and it follows that the American continent is warm during the summer while Europe is cool, and this is the cause of the annual migration of tourists from America to Europe instead of from Europe to America. The control of the climate of Europe by the American Gulf Stream is a myth. As a matter of fact the European climate is controlled by the great currents of circulation referred to these centers of action.

More generally, warm masses of air find their way from the tropics into the temperate zones by very irregular paths, and cold masses find their way from the northern latitudes into the temperate zones by very irregular paths. A similar statement applies to the circulations of the southern hemisphere. The disturbances in the general circulation which are produced by the land and ocean areas make it well-nigh impossible to reduce meteorology to any simple scientific system. The irregularities produced by the interaction of these warm and cold masses are so great that the problem of forecasting seems to bid defiance to any clear classification. The eastward drift over the United States is, of course, the basis of any possible forecasts, and the irregularities caused by the interpenetration of the warm and cold masses, one after the other under the action of gravitation, produce what we call our storms, but technically are called cyclones and anticyclones. It would be beyond my province to attempt to analyze the technical side of the theories of cyclones and anticyclones, and yet the subject of circulation would be so incomplete without at least alluding to the prominent attempts which have been made to solve these great questions that I shall venture a few remarks along this line.

The circulation of the air is classified as general and local, "general" applying to the whole hemisphere, of which some description has been given, and "local" as applying to the individual storms and their accompaniments. The local storms are known as cyclones and anticyclones, hurricanes, tornadoes and water spouts. They are all features or phases of the circulation and can be referred back to a few simple mathematical laws. Two attempts were made to solve the question of the general circulation, but the year 1896–7, which represents a new era in meteorology, when the international cloud observations were established under the leadership of Dr. Hildebrandsson, marks an epoch in the theory of the subject. I refer to those of Ferrel and Oberbeck regarding the general circulation. They had one picture in mind, namely, that of the simple canal, heated at one end, to which allusion was made in the early paragraphs of this lecture. They conceived the air to flow from the tropics northward towards the poles in the upper levels, and from the poles towards the equator in the lower levels, the northward current being separated from the southward current by a neutral plane along which there was no motion. Ferrel discussed the equations of motion adapted to the general hemisphere, and threw considerable light upon the subject. He conceived the rings of parallel 33° to move towards the poles with increasing velocity, and he made serious efforts to account for the fact that the velocity in higher latitudes is comparatively moderate instead of excessively great, as his equations demanded. If Ferrel derived an excessive velocity near the poles, Oberbeck, as a result of his complex integration, derived an excessive velocity in the upper levels over the tropics. Neither of these authors accounted for the reversal of direction from west to east at a moderate elevation, as 10,000 meters over the tropics, nor did they attempt to take into account the great irregularities in the circulation in an east and west direction, which we have described in discussing the centers of action. The result of the work of the Weather Bureau in the international cloud observations in the year 1896–7, was to destroy this theory of a neutral plane separating the upper northward current from the lower southward current. In place of that it was explained that these interchanging currents, instead of passing over each other at different levels, really interpenetrate and pass by each other on the same level; that is to say, warm air moves from the tropics towards the poles in all levels, and cold air from the poles towards the tropics in all levels. The first theory can be illustrated by sliding the fingers of the smooth hands over each other in opposite directions, while the second theory can be illustrated by sliding the fingers between one another on the same level; the fingers of the one hand will represent the warm currents and the fingers of the other hand the cold currents. This new view is really revolutionary because it renders inapplicable the integrations which were attempted by previous authors. Unfortunately the problem has become in this way so very complicated, that no one of sufficient ability has yet been found to carry out the necessary mathematical analysis with anything like fullness or precision. At present meteorologists are engaged, by means of balloon and kite ascensions, in determining the nature of the currents from the south and from the north which prevail in different localities. Europe has already done a great deal of work in this direction, and the United States has recently made a beginning. A few soundings have also been made over the Atlantic Ocean. Generally speaking, however, this is a great field of research which it will require much money and time to adequately complete. The circulation of the atmosphere, therefore, is a great and fascinating problem for future development, and indeed it may require more than one generation of scientists to bring it into subjection.

We have described the cold and warm currents as interpenetrating on the same levels like the fingers of the two opposite hands. Gravitation takes these warm and cold masses and seeks to make them interpenetrate yet more intimately, so that the warm masses will become more cooled, and the cold masses more warmed, and the isobars and isotherms coincide with each other and the gravity levels. It is a curious fact that masses of warm and cold air having any size are exceedingly reluctant to mix with one another; that is to say, the interchange of heat is a molecular process which naturally goes on slowly, and in accomplishing it, in the atmosphere, a great deal of energy must be expended. The great masses are first torn into shreds along their edges, and are gradually fritted away in the local cyclonic circulation. The energy that is felt in storms of any kind is merely an illustration of this thermodynamic process of interchanging temperature.

The Local Circulations

Historically speaking, the year 1896–7 marks the beginning of a period of transition in the history of local as well as general theoretical meteorology. There have been two schools of meteorology: one American, whose head is Ferrel, and one German, of which Guldberg and Mohn, Sprung, Oberbeck, Margules and Pockels are leaders. These two schools agreed in one particular, namely, in that they assumed that the cyclonic and anticyclonic circulations are symmetrical about a center.

The first break in this theory was also made by Professor Bigelow in the cloud work of the international year, when it was shown that the distribution of warm and cold masses in the anticyclone was not symmetrical but asymmetrical. In the symmetrical theory the center of motion coincides with the center of heat or center of cold; in the asymmetrical theory the center of motion is located near the edge of the warm and cold masses. The actual cyclone is warm on the one side and cold on the other side of the center, and likewise the anticyclone is cold on one side of it and warm on the other side of it. The northerly cold current, therefore, has a cyclonic center on the east side of it and an anticyclonic center on the west side of it, while the southerly warm current has an anticyclonic center on the east side of it and a cyclonic center on the west side of it. These differences are also fundamental. Ferrel treated the equation of motion by one solution, quite similar to that which he applied to the general circulation of the hemisphere, and he found the vortical torque for the cyclone clockwise on the outer part, anticlockwise on the inner part, with complex lines of flow connecting them. The theoretical difficulties are quite obvious when we consider that such a vortex as Ferrel worked out is applicable only to a fixed mass of air; for example, put a mass of water in a cylindrical vessel and sprinkle sawdust in it so that the stream lines can be followed by the eye. If now heat is applied to the center it will boil along the stream lines indicated by Ferrel's vortex, and especially so if the glass vessel is rotating on its axis. This would make our cyclones storms in which the same mass of air is boiling over and over again along these fixed lines, whereas we have shown that the cyclonic circulation is simply built up by currents of air which are streaming through it in a very irregular way, and, anticipating the conclusion which we have reached in our research, it may be asserted that the cyclone, besides being asymmetrical, conforms only loosely to any known type of theoretical vortex. The German school of meteorologists also discussed the symmetrical vortex, but by another mathematical process. There are two other solutions of the second equation of motion, one of which was assumed to apply to the outer part and the other to the inner part of a cyclone. The solution for the outer part has no vertical current, while the circulation for the inner has a vertical current, quite like that in the vortical helix, such as may be illustrated by the ordinary tornado tube. Many attempts were made to join the outer part and inner part in a single set of equations, the results conforming very loosely to the observed facts in nature regarding the velocity and angular directions. It is not too much to say that neither of these systems of solution will find more than a very small application in practical meteorology. Ferrel discussed the three equations of motion, one by one, giving certain practical inferences which he found more or less illustrated in nature, but he never succeeded in uniting the three equations in one comprehensive system. The Germans approached more nearly a satisfactory solution, but as already stated, the assumption that cyclones and anticyclones are symmetrical, respectively, about warm and cold centers, is no longer tenable. We have already made the assertion that the asymmetrical cyclone, as it occurs in nature, does not conform satisfactorily to any homogeneous vortex. It will be possible to show how this is by giving a few details regarding waterspouts, tornadoes and hurricanes, which will lead up to this conclusion.

Local Vortices in the Earth's Atmosphere

A large waterspout was seen at Cottage City, Mass., in the Vineyard Sound, on August 19, 1896, about eight miles distant from Cottage City. Fortunately a series of good photographs was secured of the waterspout and its cloud, which together with the meteorological data, have enabled us to compute the dimensions and the velocities of motion in all parts of it by means of the vortex formulas. It happens that the same cloud developed two types of vortex, at short intervals of time between them. One is the funnel-shaped vortex and the other is the dumbbell-shaped vortex. Fig. 1 gives an illustration of a section

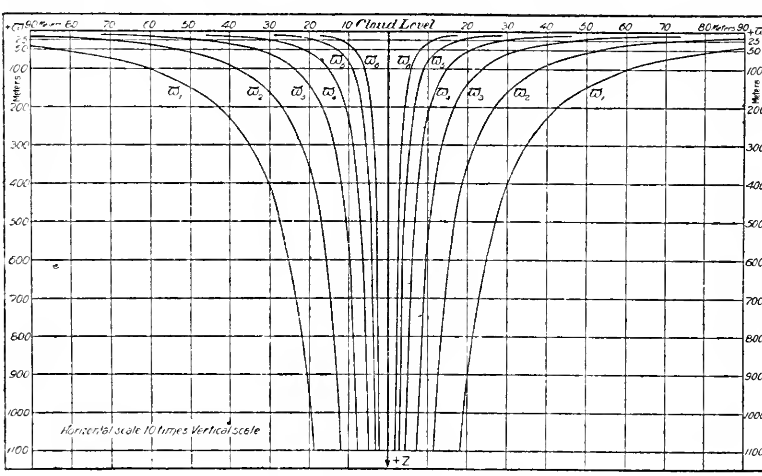

Fig. 1. Funnel-shaped Vortex.

through the funnel-shaped vortex, and shows the boundary of the several vortex tubes. The horizontal dimensions are multiplied by ten for the sake of showing the relative dimensions more plainly which exist from one tube to another. It will be noted that the distances between the successive tubes get smaller and smaller in a geometric ratio towards the axis. They concentrate at the lower part, and expand so that the lines become parallel to a horizontal plane in a region at the level corresponding to the base of the cloud. Fixing attention upon any one of these tubes, as the first or outer one, the theory indicates that a particle of air which is lying on that tube in the lowest level continues throughout its motion to follow the same tube. This particle rotates in a spiral about a central axis gradually rising from the ocean towards the cloud, and, rotating in larger and larger spirals, at last it flows out from the axis parallel to the surface of the cloud itself. On this outer tube the particle at the sea is moved with a velocity of 22 meters per second and gradually rises upwards and changes its velocity through 20, 18, 15, 12, 7, 5, 2 meters per second quite near the surface of the cloud, and finally the velocity falls to zero. At the sea level the velocity is in a circular direction around the axis; at the cloud level it is moving in a radial direction directly away from the axis. On the outer tube having a large radius the velocities as already given are small, but on the same levels on tube No. 5 quite near the axis the velocities on the same levels become, respectively, 182, 159, 136, 110, 80, 44, 31, 14 meters per second near the cloud level, and they finally run out to zero. With such enormous velocities as 182 meters per second at the sea level, the causes of the turmoil and destructive effects which are always found in the case of waterspouts and tornadoes passing over the land are readily appreciated. Illustrations of the destructive effects of tornadoes are commonly accessible. The purpose of such a vortex is to lift a mass of air, as in a suction pump, from the surface of the ocean to the cloud, and in this case it is computed that 2,468 cubic meters of air are lifted in each second through each section of this vortex tube. These natural lifting pumps are evidently of great efficiency.

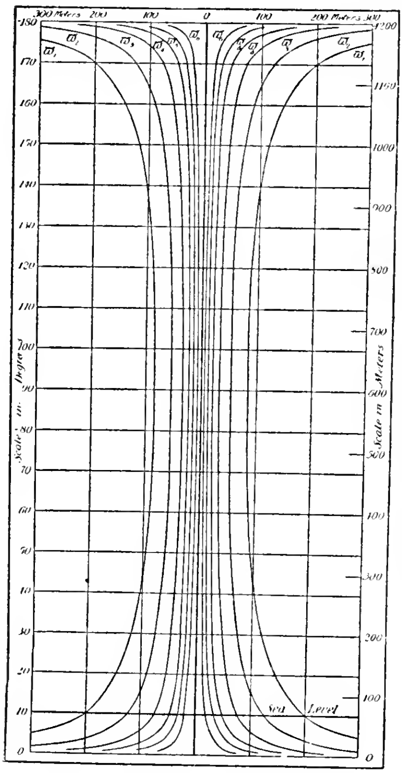

FIG. 2. DUMBBELL-SHAPED VORTEX.

The dumbbell-shaped vortex operates on substantially the same principles, though the details are different. In this vortex the air begins at the sea level to flow inwards towards the axis in a spiral which contracts up to about 500 or 600 meters above the surface of the sea, and then it begins to expand as in the funnel-shaped vortex. The dumbbell-shaped vortex is really composed of two funnel-shaped vortices, the lower one pointing upward and the upper one pointing downward, meeting half way between the two planes of reference. This vortex is really a more efficient lifting pump than the other one just described, and it is found that 16,452 cubic meters of air are moved upwards through each tube per second, so that the dumbbell-shaped vortex is carrying 6.7 times as much air upward as the funnel-shaped vortex. A careful examination of this dumbbell-shaped vortex at Cottage City shows that the lowest sections are not fully developed. The outward curvature of the tube is plainly shown on the picture, but at sea level it is cut off or truncated by the friction of the tube against the water of the ocean. The cutting off of these vortices at some section above their theoretical lowest plane seems to play an important part in practical meteorology.

On May 27, 1896, a violent tornado of large dimensions passed over the city of St. Louis, causing great destruction in Lafayette Park and thence to the bridge over the Mississippi River. The enormous power of the forces which accompanied this vortex is shown on many pictures which were secured at that time. Large trees were twisted off

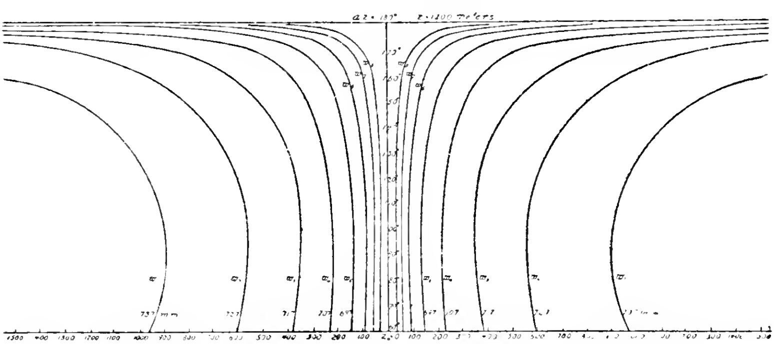

FIG. 3. TRUNCATED DUMBBELL-SHAPED VORTEX.

and stripped of their branches; buildings were overturned and destroyed in every conceivable way; heavy iron girders and stone work of the bridge were destroyed; and in short almost limitless powers seem to have been at the disposal of this great vortex. Fig. 3 shows a section of this vortex, the relative distance apart of the tubes, and the part which has been cut off or truncated at about one third of the distance from its lower plane of reference, several hundred meters below the surface of the ground. It has been shown that this St. Louis tornado was about 47 times as efficient as the large Cottage City waterspout in its lifting power, and that at the surface of the ground it developed somewhere between 150 and 250 meters per second; that is, 340 to 560 miles per hour. While it is not probable that these enormous theoretical velocities can develop near the center of a great tornado on account of the retarding effects of friction where the wind moves over a rough region like a city, yet it does show where the enormous power resides that is always observed in these conditions. It might develop, therefore, a pressure of 5,000 or 6,000 pounds per square foot. This is, of course, very much more than would be necessary to make all the destruction that has been noted.

Hurricanes such as are observed in the neighborhood of the West Indies, and the typhoon, which is the name of a hurricane in the neighborhood of the Philippine Islands and China Sea, are truncated dumbbell-shaped vortices built on exactly the same principles as the St. Louis tornado, only they are very much larger in their dimensions.

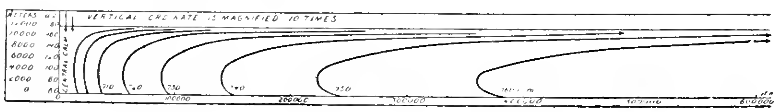

FIG. 4. HALF SECTION OF A HURRICANE VORTEX.

The tornado generally ends at a level something like 1,200 meters above the ground, and it is usually much less than half a mile in diameter. The hurricane, however, is probably 12,000 meters thick, and it extends several hundred miles in diameter. This makes the hurricane a very thin mass of air of broad extent, as compared with the word tornado, which is a relatively high mass of air and narrow in extent. We can construct the velocities in the hurricane from our meteorological data, and show that the winds blow at a certain angle, which conforms to the section that cuts off or truncates the vortex at a certain plane. These angles should be more fully explained. On the lowest plane the wind flows radially and directly towards the axis; on the uppermost plane it flows radially and directly away from the axis; at a middle section, half way between these two planes, it flows in circles tangentially around the axis. In passing from the lower plane to the upper plane the wind gradually makes a larger angle with the radius; first 10°, then 20°, then 30°, and so on up to 90° at the middle plane half way up the tube; then 100°, 110°, and so on up to 180°, which represents the wind flowing radially away from the axis. If now a vortex is truncated at a certain plane, all the winds on that plane will make a given angle with the radius. If a truncated plane is one third the distance up the axis then the wind will make an angle of 60° with the radius; that is, it will blow in at an angle of 30° from a circle. This is about the angle of the wind which observers have recorded in the case of hurricanes, and hence it is proper to infer that the truncated section should be drawn at about the distance indicated from the lower plane.

The *ocean cyclone* is a mass of air still larger than the hurricane, circulating on practically the same vortical laws, but unfortunately it shows indications of not being able to follow the law strictly, especially in the inner portions of it. The outer part of a strong ocean cyclone, where the barometer drops to 28 inches of pressure at the center, is very much like an enormous hurricane in its formation, but near the center the angles and the velocities begin to break away from the pure vortex law. This is probably due to the great extent of the wind areas, and consequently the congestion, and to the fact that the ocean cyclone is not deep enough, although it may be 3 or 4 miles high, to carry out fully the requirements of so large a vortex of a pure type. It is known that hurricanes are vortices which are 6 or 7 miles deep. The large ocean cyclone is probably not more than 4 miles deep, and the great land cyclone is rarely more than 2 or 3 miles deep.

The *land cyclones* in the United States conform to the pure vortex law less perfectly than does the ocean cyclone. The pressure in the land cyclone usually stops at about 29 inches near the center. Its depth is usually about 2 or 3 miles. It may cover a diameter of 2,000 miles. These dimensions are evidently unfavorable for the development of a pure vortex. Furthermore, the distribution of the temperature in the land cyclone is entirely different from that in the pure hurricane, and this too prevents the land cyclone from developing according to the perfect law. Furthermore, the cyclones of the temperate zone develop in the lower levels of the great eastward drift. In these lower levels the eastward velocity of the drift is not very high; something like ten meters per second. At the height of two or three miles the eastward drift is something like twenty to forty meters per second. It becomes evident, then, that a vortex which develops in the lower levels, from any set of causes, must lift its head into a rapidly flowing stream of air, and this necessarily will tend to break down the intruding head by stripping off portions of it and detaching the upper portions of the vortex from the lower portions. Now a vortex can not develop except as a complete individual. If it is intruded upon by cutting off the lower section, as in the hurricane over the ocean, or by the upper sections thrusting themselves into the stream of the rapidly flowing eastward drift, it is evident that this is a sufficient cause for the partial destruction of the vortex system. In the theoretical vortex, above the middle section, the wind has an outward component increasing with the height, as already explained. Below this section it has in every cyclone an inward component. Now as a result of the cloud observations which were undertaken by the U. S. Weather Bureau during the international cloud year 1896–7, in which between 6,000 and 7,000 observations were made by means of theodolites upon the direction of motion in the different cloud levels, it was found that there was an inward component over the cyclones in all levels from the ground up to four or five miles high. The strongest inward component was in the strata cumulus levels about two miles above the ground. Above this level and below it there was a radial inward velocity of a certain value corresponding to each level. There was no clear indication that the inward component in the lower levels reversed to an outward component in the upper levels, and it looked as if the intruding vortex of the lower levels did not succeed in reaching the middle plane where theoretically the outward component begins to develop. It looked as if this vortical system was so stripped of its natural features, by the action of its intrusion into the eastward drift, that only the lower half of the vortex really survived, and that there was an insistent struggle of the rotating cyclone with this eastward drift for the mastery. In a word, the upper sections of the vortex were stripped bare, and they gradually died out at the height of three or four miles within the eastward drift. What remains then is a set of stream lines in the lower levels which have certain features in harmony with the pure vortex system, though only roughly conforming to them, and which in the upper levels is broken down into a very imperfect kind of vortex. It should be said in passing that it is very difficult, on account of the prevailing clouds which occur in the cyclones of the United States, to get satisfactory measures of the cloud motions in the upper levels. Cumulus clouds develop strongly below the one-mile level, and above them it is possible to get the cloud motions in the higher levels only through the more or less occasional rifts in the lower cloud sheets. It is therefore very desirable that an extensive campaign of theodolite measurements of cloud motions in the upper levels of cyclones be instituted, in order to carry out much more fully the details of the discussion which have been suggested in this fundamental research.

Temperature Distribution

Having now described the general and local circulations in the temperate and tropical zones, it is important to make some further remarks regarding the distribution of temperature in those regions, also including the distribution of temperature in the sun itself. The circulations which take place are accompanied by certain changes of temperature in a vertical direction, called temperature gradients, which are characteristic of them. If a cubic centimeter of air at the sea level is lifted up to higher levels, so that it cools simply by the expansion of its own mass, and there is no mixture of warmer or colder air with it from the outside, then the temperature will fall 9.87° Centigrade for every 1,000 meters. Now it is found by balloon observations that the temperature gradients in different regions do not conform to this fundamental rule, which is called the law of adiabatic expansion. In the tropics in the lower levels this rate is very nearly approached, but there is a considerable deviation from it in the upper levels. In the temperate zones the normal vertical temperature gradient is only about 5.40° Centigrade, though it may be considerably more or considerably less according to the circumstances. It may be generally said that, except in restricted regions, the air does not cool as fast in going upwards as it should if it were caused by mere vertical expansion. The upper levels of the air are too warm; warmer than they should be if that law prevailed. In the temperate zones they are very much too warm, and that is why the vertical gradient is less than it should be according to that law. The fact is that the warm masses of air which flow from the tropics towards the poles retain their heat above what they should have for the given latitude, and in that way the upper levels of the atmosphere are maintained at a considerably higher heat than would be expected. When the air has once cooled to about 70° below zero, Centigrade, it seems disinclined to cool much further, and in the levels from 12,000 to 16,000 meters high there has been discovered a tendency for the air to be somewhat warmer than it is in the levels below, say from 8,000 to 12,000 meters high. It is generally thought that this phenomenon is due to radiation in some of its effects, but it is still a subject of discussion. If we should assume as the average vertical gradient for the entire atmosphere a rate of about 7° Centigrade per 1,000 meters then we should find that the temperatures in the tropics fall off too fast, and in the temperate zones too slow to conform to this average gradient. Now the mathematical law shows that if the lower levels of the atmosphere are relatively too warm for the upper levels there will be a westward drift as in the tropics, and if the upper levels are too warm relatively for the lower levels there will be an eastward drift as in the temperate zones. Speaking a little more broadly still, in order to avoid discontinuity, that is to say, changes by jumps in the atmosphere as regards the barometric pressure at the different levels, since the warm air has less density than the cold air, it follows that the warm air must move faster over the surface of the earth than does the cold air. Hence it is that in the tropics the air is too warm for its altitude, and it must move off faster than it otherwise would in the tropics. The westward drift in the lower levels compensates for this excessive temperature, and in the upper levels of the temperate zones the excess of motion compensates for the higher temperature. We find exactly the same principle working in the formation of hurricanes and tornadoes. Hurricanes develop in the northern hemisphere in the late summer and early autumn, and this is the season when the cool air of the northern latitudes begins to spread southward towards the equator as the sun begins its southward march into the southern hemisphere. At first the cool air flows over the warm air in the higher levels. This in a general way increases the vertical temperature gradient, and induces a more lively movement in the lower levels. In certain localities, in order to keep up the vertical continuity of barometric pressure, the warm air slides out radially in all directions, where conditions are right, and this movement first induces the vortical action in the upper sections of the hurricane which is gradually propagated, when it is highly developed, to the surface. Tornadoes are formed in somewhat a similar way, but in this case the cold and warm masses lie side by side on the same level, though there is a tendency for the cold air to overflow the warm air. The sliding action of the warm air against the cold sheet is the first incentive to the curling-up process which culminates in a tornado. In the ordinary cyclones the temperature distribution is such that the vertical gradient is about the same in the cold as in the warm mass, taken separately, though there are moderate variations in the different quadrants surrounding the high and the low areas of pressure. The warm air then overflows the cold air in two branches, and the cold air underflows the warm air in two branches. This tends to induce vortical action, but as already explained it is retarded, and the development is very imperfect on account of its intrusion into the eastward drift.

While our knowledge of the distribution of velocity and temperature in the atmosphere of the sun is much less perfect than it is of the atmosphere of the earth, we have yet definite knowledge regarding several important features. Apparently the sun's atmosphere does not operate in the same way that we have found to be the method of the circulation of the atmosphere of the earth. It is quite easy to see that these two atmospheres should work in a very different way. The atmosphere of the earth is really a thin shell of air heated in one zone by the solar radiation falling upon it, and then this thin shell simply slides around over the surface of the earth according to the laws which have been described. In the case of the atmosphere of the sun we have no definite knowledge as to its depth. It is proper to infer, from the law of pressure and mass, that the density near the center is such that the interior of the solar mass consists of a nucleus in a highly viscous or even solid state. Such a nucleus may be only one third of the diameter of the sun, but as the radius of the sun is 694,800 kilometers it would make a nucleus of about 400,000 or 500,000 kilometers in diameter. Above this the shell of the sun would be something like 400,000 kilometers thick, that is, about 250,000 miles. Our observations can not penetrate below the surface of the solar photosphere, and of course it is impossible to trace out the great currents which are undoubtedly operating within this enormously thick mass. On the surface we know from various sources that at the equator the solar mass drifts from east to west as we look at the sun's disc with a velocity such that the sun turns on its axis, as we see it, once in 26.68 days. This rotation of velocity falls off gradually towards the poles, until at the poles it takes something like 30 days to turn around. There is evidence to show that in the polar zones or near the poles there are certain variable velocities of rotation. These may belong to different sections in the sun's atmosphere. Our observations at the poles cut through the sun's atmosphere, as it were, parallel to the surface. At the equator our observations look down vertically through the sun's atmosphere. We can therefore near the poles get the same kind of observations at different solar levels. However this may be, the turbulence of motion seems to be much greater near the poles than near the equator. Within the sun's mass we can well imagine that many different periods of rotation, or of the daily angular velocity, actually exist. Looking at the solar surface as a unit, it consists of a huge wave whose crest advances around the equatorial regions at a considerably greater speed than in the polar regions. Now our mathematical analysis indicates that such a circulation can be maintained if the solar temperatures are greater in the polar regions than in the equatorial regions. That is a form of vortex, applicable to the solar mass, in which the velocities and temperatures are so connected together that the polar regions are warmer and have a slower angular velocity than the equatorial regions which are cooler with a greater angular velocity. This, therefore, is a condition of affairs practically the inverse of what we have been describing in the atmosphere of the earth. It is of course in some way associated with the great heat cauldron which is boiling inside the solar surface, where the heat accumulates and congests and finally works its way to the surface by means of this gigantic solar vortex. Within the great vortex there are innumerable minor vortices. These vortical tubes generally stretch from north to south perpendicular to the plane of the equator. These vortex tubes may be very irregular and broken up, but as a whole the sun may be described as a polarized mass throughout which the minor motions are nearly parallel to the plane of the equator.

Solar Phenomena

The different levels in the sun's atmosphere have received the following names: The lowest one which is visible is called the *photosphere,* and consists of mottled shapes like cumulus cloud forms, bright and dark areas being interspersed. Above this is the *chromosphere,* a layer of hydrogen and calcium and other gases 5,000 or 6,000 miles thick. The lower surface of the chromosphere is a reversing layer, so called, and is the level at which the dark lines of the solar spectrum are formed. Through these layers are projected jets of hydrogen and calcium flames which stretch out beyond the visible edge of the sun called *prominences,* and far beyond the region of the prominences extends the *solar corona* which reaches enormous distances into space. The corona is apparently composed of minute dust particles and ionized atoms and molecules held in certain positions by the action of electric and magnetic forces. The photosphere is penetrated in certain regions by *solar spots* which extend from the upper levels of the photosphere into the interior. It has been shown by recent photographs taken at the Mount Wilson Observatory that the sun spots are closely associated with motions so like those pertaining to the sections in a dumbbell-shaped vortex that the analogy appears to be very complete. If this is so, then terrestrial meteorology becomes intimately connected with solar meteorology in many of its features, in spite of the great differences of temperature. The average temperature of the earth's atmosphere may be taken as about 15° Centigrade below zero. The surface of the photosphere is apparently between 7,000° and 8,000° Centigrade, and the sun's temperature increases to more than 10,000° near the nucleus, though the gradient is not yet known. Taking the sun spot region as a whole, the sun spot belts form near latitude 30° north and south of the equator and they gradually drift towards the equator in the course of about eleven years, when new spot belts begin to form. The same is true of the faculæ which are closely associated with sun spots. The circulation within the sun spot belt is from the surface downwards, while the spots drift as a whole towards the equator. This indicates, therefore, descent into the sun from the surface in the neighborhood of the equatorial regions, and, of course, to compensate this, material must be projected from the interior outwards in the higher latitudes.

The *prominences* are hydrogen flames going through a periodic drift. They may be said to appear first in largest numbers in middle latitudes, and they seem to divide into two branches so far as the number of them is concerned. One branch drifts southward in the eleven-year period along with the spots and the faculæ. The other branch drifts poleward to the north and to the south, respectively. A study of the number of these prominences in different latitudes indicates that there is a periodic change in the apparent velocity of the rotation in the polar regions, fluctuating back and forth in about a mean value. Since the prominences have different elevations, and different levels in the sun have different velocities, it may well be that in the polar regions the prominences develop sometimes in the higher levels and sometimes in the lower levels, so that they actually drift eastward at different angular velocities according to their elevation. The spectroscope apparently indicates a certain angular velocity pertaining to special spectrum lines, which look like a fixed value for a given elevation, and at the same time it has been shown that hydrogen lines have different values from iron lines, and therefore the entire subject is open to an extensive investigation.

The atmosphere of the earth is filled with what is called *atmospheric electricity*. This consists of positive and negative charges of electricity distributed in a very complex way, depending upon temperature, vapor contents and barometric pressure. The distribution of electricity changes with the season of the year, and with the hour of the day, and differs from latitude to latitude, and from elevation to elevation above the same place. Similarly the sun's atmosphere is filled with electric charges. Every electric charge in motion produces magnetic field. If particles of electricity rotate about an axis, and parallel to a given plane, there will be a magnetic field perpendicular to that plane. These magnetic fields may occur at any temperature, provided the charge of electricity and the motion in a closed curve is at hand. If a ray of light in a strong magnetic field is looked at along the lines of force of the field, a single ray is split up into two lines slightly displaced and circularly polarized in opposite directions. If the line of light in the magnetic field is looked at perpendicular to the lines of the magnetic force, a single is split up into three or more lines. In the case of three lines the outside lines are displaced and polarized in one direction, while the middle line is not displaced but is polarized at right angles to the two side lines. These effects of the magnetic field upon a ray of light are called the *Zeeman effect*, and if these effects are seen it is strong evidence if not proof that the magnetic field has been acting upon the ray of light. The Mount Wilson Observatory has been able to show that the light which comes from the interior of the sun spot or vortex produces both types of the Zeeman effect, the two circularly polarized lines when one looks at the spot near the center of the solar disc; that is down the tube of the vortex; and the three plane polarized lines when one looks at the sun spot near the edge of the sun, that is, nearly at right angles to the sun spot vortex tube. At any rate enough has been shown to make it more than probable that magnetic field exists certainly in the solar spots, and probably throughout the mass of the sun where gyrations and internal vortices doubtless take place. If the sun spot produces a magnetic field strong enough to show the Zeeman effect at a distance of 93,000,000 miles, it is entirely reasonable to suppose that magnetic fields occur through the solar mass wherever there is actual circulation. It has already been intimated that the entire body of the sun consists of an enormous number of circulating tubes directed more or less perpendicular to the equator, and as a corollary the entire mass of the sun would be a magnetized sphere. The ends of these polarized circulations at the solar surface should develop an outside magnetic field to correspond with the interior. In my early researches of nearly twenty years ago it was shown that the lines in the solar corona are so distributed, especially at the time of minimum sun spot activity, as to indicate strongly that they were arranged around the *sun as a magnetized sphere.* It is not necessary here to review the many details which pointed to that conclusion. The great objection to that theory at the time in the minds of scientists consisted in the fact that the sun was too hot to be a magnetized sphere. It was pointed out by me that the earth is certainly a magnetized sphere, and that its interior has a very high temperature. Since those days the discovery of the ionization of matter, whereby dynamic forces of one kind or another disintegrate the atoms, of which molecules are composed, into their primal constituents, which are pure charges of electricity, and the demonstration that the free ions, positive or negative, as the case may be, wander about from place to place and produce magnetic field, have made this theory of the sun much more intelligible. The additional discovery of the Zeeman effect of magnetic field in the sun spots greatly strengthens my theory, and in fact it is not easy to see how solar phenomena can now be discussed on any other general basis.

The solar output shows itself in an irruption of prominences, in a very extended corona, and in an *invisible radiation* stretching out to almost unlimited distances in space. The polar magnetic field of the sun, of which the corona is an evidence, will expand to great distances from the center, and its strength may perhaps be detected as far as to the distance of the earth. Electromagnetic radiation stretches out over the solar sphere radially in every direction, a small pencil of the same falls upon the earth in its different positions along the orbit from day to day, and sets the circulation up in the earth's atmosphere which has been described. This solar radiation falling upon the earth's atmosphere is in part absorbed by it, so that the molecules and atoms yield up their ions, which by redistribution produce the observed phenomena of the earth's electric field, and also certain well-known variations in the strength of the earth's magnetic field. The entire subject is full of difficulties, but at the same time it possesses a fascination to the student such as pertains to very few branches of modern science. This same radiation of the sun falling upon the earth produces the temperatures which vary from place to place, from season to season, and from year to year, in a very complex series of changes which, taken as a whole, constitute what is called the earth's climate. There are many indications that this solar radiation, that is to say, the electromagnetic energy which the sun sends forth into space, is not exactly constant. The sun seems to be a variable star, the variation in its heat and light is the natural consequence of the incessant changes of temperature and pressure, in the circulation, the electricity and magnetism, which are going on within the solar mass. We have already been able to show from our studies of the barometric pressure, temperature and vapor pressure in different parts of the earth, especially of the United States, that there is a definite though complicated synchronism, which connects the variations of the solar action with the variation in the terrestrial climatic effects. This is a large subject which can not be properly undertaken in this lecture. It may be said in general that as the sun gets more energetic in some parts of its period, the temperatures in the earth's tropics are higher, and simultaneously in the temperate zones they are lower. At the same time the barometric pressures in the atmosphere of the earth centered around the Indian Ocean are higher, while in North and South America they are lower. In the Pacific states the temperatures increase with the solar energy, and in the central and eastern states they decrease. The solar impulse which produces these effects tends to precede the terrestrial exhibit which depends upon the solar impulse by some months, possibly by a year under certain conditions, and this anticipation of course promises an opportunity to develop what may become a rational ground for a seasonal forecast for terrestrial weather. The entire field of operations is very complicated, the circulation in both atmospheres tends to mask and make more complex the pure variation of the solar radiation, so that we must be very cautious in attempting to pronounce for or against certain tentative conclusions regarding this subject. It will probably require more than one generation of men to make practicable and popularize the result of this research. Mathematicians as well as laymen are cautioned to withhold negative evidence based upon half understood phenomena, because it is in fact very difficult to disentangle the net which nature has spread before us. The threads should not be torn and distorted by the bungling hands of those who have not the training required to unravel the several skeins which lead to the center of the great mesh. It is certainly not saying too much to assert that there is good ground for proceeding positively and firmly along this line of research, and the fact that it has attracted the attention of many commissions, international committees, scientific societies, observatories and institutions shows to what an extent the great problem has already commended itself to the favor of scientific men.

THE REORGANIZATION OF AMERICAN FARMING

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FROM the beginning, American agriculture has been characterized by its extensiveness rather than its intensiveness. Land has been more abundant than labor and, in the aggregate, more has been derived from a small yield on a large acreage than could have been realized from a large yield on a small acreage. The yields of American farm crops have been proverbially small, but the total production has been exceptionally large and, as a rule, the countries producing the largest amounts of farm crops have the smallest yields per acre. This fact is illustrated in the following table:

Table showing the Average Yield of Wheat per Acre by Ten-year Periods for the last Twenty Years and the Total Production for 1908

	Avr. Yield per Acre, 1888-97	Avr. Yield per Acre, 1898-1907	Total Production
United Kingdom	30.1 bu.	32.6 bu.	55,585,000 bu.
Germany	22.7	28.4	138,442,000
France	17.6	20.8	310,526,000
United States	12.8	13.9	664,602,000

The above table also reveals the fact that the production per acre when compared by ten-year periods has been increasing in all the countries. Much has been said and is being written about the decline in agricultural production, but statistics do not show that there has been any decline, but rather a marked increase when the productions of the leading countries are compared and using the production of wheat, which is the most universally grown farm crop, as the basis for comparison.

The intensity of culture always bears a direct relation to the density of population and while it is difficult to get a comparable basis of comparison between countries on account of the varying proportions of waste land in different countries and different methods of classifying statistics, the following table represents the most reliable figures available and, when compared with the preceding table, shows that the yield of wheat per acre varies directly as the density of population.

Number of Acres per Capita

United Kingdom	1.70 acres.
Germany	2.37 acres.
France	3.40 acres.
United States (exclusive of Alaska and Philippines)	24.02 acres.

In 1900 there were 838,000,000 acres in farms in the United States, and since then we have been adding to them about 15,000,000 acres each year from the public lands of the country. During this time, however, the population of the country has been increasing at the rate of about one and one half million each year. The public lands of the country that are suitable for agricultural purposes have practically all been taken up; the tide of immigration has been turned back from the Pacific coast, and the competition for land already under cultivation has become much more keen and, as a consequence, the values of farm real estates have advanced generally throughout the country, but to the greatest extent in the western states. Farm lands in some sections have doubled or even tripled in value in the course of a few years.

Together with the increased value of farm lands have gone other changes that have had an important bearing on the agriculture of the country.

The development of methods of transportation and the extension of railroads through the new agricultural lands have widened the markets of the country, for both buying and selling. The introduction of refrigerator car service has made possible the shipping of fruits, meats and other perishable products across the continent. This has resulted in bringing the products of cheap lands in competition with the products of high-priced land in the eastern states.

Another factor that has had an important bearing in this connection has been the development of labor-saving farm machinery. If the present wheat crop of the United States were harvested by the method employed at the time of the civil war, it would require every man of military age in the United States to work for at least two weeks in wheat harvest. The invention of labor-saving machinery has increased the producing power of the individual to such an extent that notwithstanding the increase in the agricultural exports of the country from $205,853,748 in 1858 to $1,017,396,404 in 1908, the percentage of the population engaged in agriculture has decreased by decades as follows:

1880	44.3 per cent.
1890	37.7 per cent.
1900	35.7 per cent.

But notwithstanding the constant decrease in the proportion of the population engaged in agriculture, the per capita production for the entire population of the most important classes of agricultural products has increased almost invariably.

The following table gives the average per capita production by decades, 1866–1908. These statistics are from the United States Department of Agriculture:

	Decade				Period
	1866–1875	1876–1885	1886–1895	1896–1905	1905–1908
Wheat, bushels	6.2	8.3	7.4	7.8	7.9
Corn, bushels	24.6	30.3	27.5	28.4	31.8
Oats, bushels	6.9	9.1	10.7	10.6	9.8
Barley, bushels	.7	.9	1.1	1.3	1.9
Rye, bushels	.5	.5	.4	.4	.4
Potatoes, bushels	3.0	3.0	3.0	3.1	3.4
Cotton, pounds	37.8	51.4	57.8	65.5	70.0
Hay, tons	.63	.76	.86	.76	.74
Horses, number	.20	.21	.23	.20	.23
Milch cows, number	.25	.24	.25	.22	.24
Other cattle, number	.37	.47	.55	.49	.55
Swine, number	.69	.75	.73	.58	.64
Sheep, number	·80	.84	.68	.63	.64

This almost inconceivable increase in agricultural production has been accompanied by changes in agricultural conditions that make a reorganization of American farming methods absolutely necessary.

Foremost among these changes has been the growth of cities from an urban population of 2,897,000, or 12.5 per cent. of the population total, in 1850, to a population of 24,992,000 or 33.1 per cent. of the total population in 1900. This concentration of the population has brought about new problems of food supply in furnishing the more perishable products such as milk, vegetables, fruits and such products as need to be consumed soon after production.

Another condition that has arisen is the tendency of the soil fertility of the farms of the older agricultural sections to become exhausted. To remedy this, the use of commercial fertilizers has become general in eastern United States and the statistics of 1900 show that $55,000,000 worth of goods were used by the farmers of the United States, which was an increase of 42 per cent. over the amount used in 1890, so that it is probable that not less than $75,000,000 per year is spent for this purpose.

The opening up of the middle west took from the farmer of the eastern states his market for wheat and other grain. He was thrown in competition on the open market with the farmer who had secured his land for practically nothing and land that was much more fertile and productive. The farmer of the middle west, in turn, has been thrown in competition in the live-stock markets with the live-stock products of the western and southwestern states and territories. Stock that was raised under range conditions and often on government land free of charge competed with stock raised on high-priced farms of the middle west.

While these conditions are not so emphatically true as they were a few years ago, yet the problem is far from being solved and the American farmer is now passing through a transitional stage and the most important problem before him at the present time is the question of reorganizing his farming methods so as to best fit the agricultural conditions as they now exist.

The unprecedented increase of values of farm products in recent years resulting in a greatly increased cost of living to every one has resulted in the most prosperous times the American farmer has ever experienced, except during the civil war by those who stayed at home and reaped the benefits of high prices.

The consumer, on the other hand, is alarmed at the continued rise in price of the necessities of life. He is interested in knowing what the end is going to be and how much longer prices are going to rise.

Writers who are ill-advised of the potential producing power of American farms are freely predicting that we are rapidly approaching the time when as a nation we shall not be able to produce sufficient food stuffs for our own population. They forget that our farms are not producing more than one half of what they are capable of doing. Our average wheat yield is 14 bushels per acre; our average yield of corn is 26 bushels, and of oats, 25 bushels; these yields can and will be redoubled in the future as the high price of the products will demand.

The profits of farming in the past gained from actual production has not been in proportion to the profits derived from other industries. The market price of farm products has tended toward the actual cost of production of the average crop at current wages rather than the cost of production of the part of the crop produced under the most unfavorable conditions. This is readily demonstrated by taking the actual amount of time required to grow and harvest an acre of any of the principal crops and calculating the time at current wages and the average yields at farm prices.

The results will show that the returns received for the time spent will not be more than enough to pay current wages and six per cent. interest on the investment in land and equipment. Farmers have received greater returns from the increased value of their lands than they have from the profits upon their productions.

The increased prices of farm products are beginning to bring to farmers a just return for labor expended and will do more than anything else to turn the city dweller "back to the soil" and to keep the country boy on the farm. There is no danger of a shortage of food supplies in this country, but higher prices must prevail in order to develop the potential agricultural resources of the country. Aside from the possibilities of doubling the present crop production on present area under production, there remains the undeveloped agricultural lands of the country. Aside from the limited amount of land suitable for agricultural purposes still remaining in the ownership of the government, the lands that may become valuable for agricultural purposes are of two kinds—the swamp lands that may be reclaimed by drainage and the arid lands that may be reclaimed by irrigation. The United States Geological Survey estimates that 75,000,000 acres can be made valuable for agriculture by draining swamps. This is the equivalent of one sixth of all the land now under cultivation in the United States. This land would be much more fertile and much more productive than the most of the land that is now being cultivated. The reclamation of arid lands is just in its infancy. The first federal act to provide for government assistance for this purpose was passed in 1902.

Projects are now under construction or have been completed that will reclaim one and a half million acres and others are under consideration that will reclaim three and one half million. To what extent this work of reclamation will be carried in the future can scarcely be estimated, but doubtless many millions of acres can be and will be added to our cultivable lands in the future.

The period of low prices for farm products and extensive methods of farming is rapidly passing. The large grain and live-stock farms of the eastern states are giving way to the smaller dairy, fruit, vegetable or poultry farm. The large wheat farms of the northwest are being divided into moderate-sized farms for mixed farming. The ranges of the west and southwest are being broken up into stock farms and the movement everywhere is toward more intensive methods of farming.

The problem that now confronts the American farmer is to reorganize his method of farming so as to adapt it to the present conditions. The increased prices for farm products will increase their production and insure a supply sufficient for all needs for the future.

INSECTS AND ENTOMOLOGISTS, THEIR RELATION TO THE COMMUNITY AT LARGE. II

By Professor J. B. SMITH

RUTGERS COLLEGE, NEW BRUNSWICK, N. J.

AND now, having given a very hasty and superficial statement to show how important a place the insect really occupies in the social economy, it behooves me to say something of some of the men whose labors made some of these facts and conclusions known.

Many of the matters of which I have spoken are of recent development and the men who have done the work are still with us and still working. Some are in attendance at this very meeting and as we expect still better work from them, nothing will be said of what they have done thus far. And while it is intended to confine the mention to American entomologists, it is necessary to include under that head some whose claim to be called American rests altogether upon the work done with or on American insects. Let me say too that the order in which the names come is not meant to represent anything more than convenience in arrangement of topics, and finally, it is not to be understood that omissions show lack of regard, but only that within my time limit no photographs were obtainable.

Thomas Say has been termed the father of American entomology, and certainly no one is better deserving of that term than he. He builded well and broadly and his knowledge of the American insect fauna was surprising. His work was in all orders and the amount of material that passed through his hands was very large. Unfortunately most of his types have been destroyed, so that we are not now able to see the specimens that he had to work with. This has made less trouble than with some other authors, because Say had that wonderful faculty of seizing upon and describing the specific peculiarity of the individual before him. I well remember the hours that I spent over his descriptions, trying to identify captures made thirty-five years ago, and while I was often disappointed, I succeeded in correctly identifying what I now consider a really large percentage of the forms taken. Say's experience meant hard work under difficulties: no money—very little literature. His bed, for a time, the floor of the Exhibition Hall of the Academy of Natural Sciences in Philadelphia, his food costing six cents per day. Encouragements there were few—discouragements many and none greater than the lack of literature. None of the younger men can appreciate that hunger for books with which the older men were compelled to fight and the enjoyment of getting into an alcove with

GEORGE H. HORN

SILAS S. HALDEMAN

JOHN L. LE CONTE

BARON R. VON OSTEN-SACKEN

THOMAS SAY

THADDEUS W. HARRIS

WILLIAM H. ASHMEAD

HERMANN LOEW

H. A. HAGEN

volumes that you knew were in existence but had never before seen. And yet Say was well off in these matters because he had the library of the academy to draw upon, and there were then—possibly there are now—more works on entomological subjects in Philadelphia than elsewhere in the United States.

Melsheimer and Haldeman were also of the Philadelphia clan, coleopterists and systematists, and to the former we owe the first catalogue of American coleoptera—an excellent piece of work for its time and of very great use to students until it was superseded by the Crotch check list, which remained the standard for many years until it in turn was superseded by the Henshaw list. These latter check lists are both the work of the Boston circle, Crotch having done most of his work at Cambridge, where Henshaw is still doing excellent service.

Dr. John L. LeConte, of Philadelphia, has without doubt done more for American coleopterology than any one other man. It was my privilege to know him personally and to profit to some extent by his encouragement and advice. Dr. LeConte, though confining his work to the coleoptera, was by no means narrow in his knowledge, and the comprehensive view that he was able to take of his subject is witnessed in the "Classification of American Coleoptera," which forms to the present day the basis of our knowledge in this order, and which will maintain its value though the order of families may be changed and their relationships better established. Dr. LeConte's collection is now at Cambridge, accessible to all serious students.

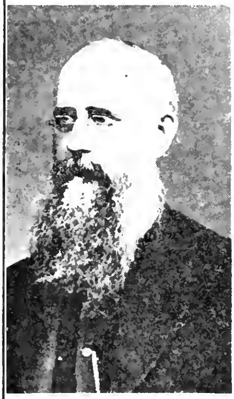
Dr. George H. Horn, first a pupil, later a collaborateur with Dr. LeConte, did as much or even more systematic work in coleoptera. But the work is different: Dr. Horn was a genius in the separation of species and in their arrangement within generic or family limits; but he lacked the broad views of Dr. LeConte and was more precise in working out details. With Dr. Horn I was well acquainted, and many an hour did I spend in his room among his boxes, while he was on his rounds; for the doctor had a large practise and entomology was his recreation. I regret that I can not give a picture of that room. There was a cot in one corner which was often the only available place to sit: there was a huge table or desk occupying most of the floor and, during the many years that I knew that room, this table was cleared only once. Occasionally the cigarette stumps would be gathered together and thrown out; but the dust and dirt were never otherwise disturbed. Cabinets and book-shelves were about the walls and books were everywhere—on the floor, the chairs and often even on the bed. It was strictly a workroom and the doctor was an indefatigable worker. His collection is now in the rooms of the American Entomological Society in Philadelphia.

John Abbot, associated with J. E. Smith in the work on the rarer

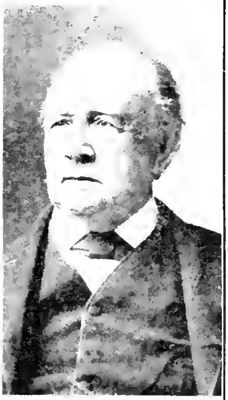

Wm. H. Edwards

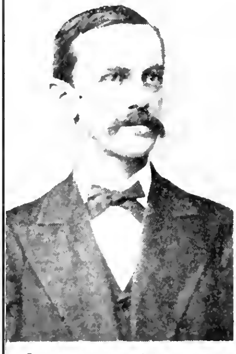

Henry Edwards


Brackenridge Clemens


Herman Strecker


Samuel Scudder


J. G. Morris


George D. Hulst


Augustus R. Grote


John Abbott

lepidopterous insects of Georgia, is an example of the combination of artist and entomologist, and his *published* drawings give no idea of the amount of the work he actually did, nor any real idea of its beauty and accuracy. There are bundles of unpublished drawings in the British Museum, a few of them in the Boston Society of Natural History, and others scattered about. Some of the insects figured have never been found since; some, described from the figures by Guenée, Boisduval and others have never been satisfactorily identified, and I well remember my hunt through Paris, over twenty years ago, under the guidance of M. Aug. Sallé after the original of one of Boisduval's descriptions, which was finally located in the possession of a former housekeeper, who fell heir to some of the effects of her master.

A hale, hearty old man was Dr. J. G. Morris, of Baltimore, when I first met him thirty years or more ago, and never was I more pleased to meet any one because, somehow, I had received the impression that he was dead. Dr. Morris made the first attempt to gather together the descriptions of American lepidoptera, and his volume in the Smithsonian series proved a very useful one to the collectors of that day. Unfortunately the scheme was never completed, and a very small section only of the Heterocera is represented in the volume. Dr. Morris did not, I believe, ever describe either genus or species, and never pretended to any extensive collection.

A. R. Grote, of Buffalo, and later, New York, was a most earnest worker in the heterocerous lepidoptera and chiefly in the Noctuidæ. To him we owe the first satisfactory arrangement of our species, and the identification of the species described earlier by Guenée and Walker. It was no light task, and how remarkably well done it was I did not realize until years thereafter, when I undertook similar work. Mr. Grote's collection is now in the British Museum, where I have had the opportunity of comparing its types with those of Walker and Guenée which are also in that rich treasure house.

Mr. W. H. Edwards, of Coalburg, W. Va., I never met, although his death is comparatively recent. But his magnificent work in the butterflies lives on, and will continue to live. Mr. Edwards was much more than a describer of genera and species. He was a real student of the life of the insects, and he did more to make known their early stages than any one other worker: and besides, he set up a standard of thoroughness and accuracy, that our younger students must live up to if they expect their work to be regarded. His collection is now in the Carnegie Museum, at Pittsburgh.

Mr. Henry Edwards, of New York City, was one of the centers of entomological interest in that city—hearty, whole-souled, enthusiastic. He made friends wherever he went and his travels carried him not only throughout our own country, but into Australian and Asiatic countries as well. He was an excellent collector and his cabinet was unusually rich in Californian and Pacific coast forms. This collection remains in New York, and forms the nucleus for the lepidoptera in the collection of the American Museum of Natural History.

Dr. George D. Hulst was one of the Brooklyn entomologists and devoted his energies to work in the lepidopterous families Geometridæ and Pyralididæ. While his systematic work in these groups is most useful, it is not equal to his personal influence upon those that were fortunate enough to come into contact with him. I grew to love that man and felt his death as a personal loss. His collection is now in my charge at Rutgers College, to which institution it was given by him before his death.

Dr. Herman Strecker, of Reading, Pa., was known to many of our older members, and never were there more diverse judgments than those passed upon him. But he was earnest if erratic, and succeeded in accumulating an enormous collection of lepidoptera during his long life. He would pay any price for a specimen that he wanted, and halt at no expedient to secure what he could not buy. He was a genius with pen, pencil and chisel; a sculptor of mortuary emblems by profession, and a painter of butterflies by choice. His publication on this subject was unique: all the drawings and engravings were made by him, and all the plates were hand colored. His industry was continuous and he was tireless in his work. His writings were spicy and he never hesitated in printing what he wanted to say: he was his own publisher and had none to say him nay. His collection is now in the Field Museum in Chicago.

In the tineid families of the Microlepidoptera there was an immense untilled field which only one of the older American students had the courage to undertake. To Brackenridge Clemens belongs the honor of breaking ground in this series, and upon his work the subsequent students in the group, whom fortunately we yet number among our associates, have built their own. Clemens also did some work in the macros, notably the Sphingidæ, and many of his types are yet to be found in the collections of the American Entomological Society.

Among the unique figures in American entomology none looms larger than Dr. H. A. Hagen, of Cambridge. Big, ponderous, thoroughly German to the end of his life, intensely loyal to his chief and his work, he was easily the most learned entomologist of his day. His monumental work in the literature of entomology has proved a gold mine for later students, and would alone have been considered a creditable life work. But Dr. Hagen was also a special student in the Neuroptera, and his volume in the Smithsonian series is essential to every student in the order to the present day. I knew Dr. Hagen well and was his guest at times. I won his heart by the meekness with which I accepted a severe reproof concerning a sending of diptera for determination. He had kindly replied to a letter of mine asking for aid and, in return, I had packed a cigar box as full as it would hold of undetermined specimens, big and little. I got it back next mail, and with it a letter. The letter was instructive, very—and if the medicine was bitter, it was at least salutory for I never did the like again, and have never dealt quite so hardly as I might with those who have in later times imposed upon me, as I did upon Dr. Hagen. His library and his collections are at Cambridge, and no one who has not seen both can appreciate the amount and character of the work that the good doctor did during his lifetime.

Baron von Osten-Sacken was an unusual combination of diplomatist and entomologist. Of his standing in the former capacity I know nothing: as a dipterist none stands better. To him we owe the early systematic work done in this country and the series of volumes published by the Smithsonian Institution, for even the work of Loew was made available through translation by Osten-Sacken. And so these two pioneers of American dipterology must almost necessarily be considered together, although the influence of Loew could not be so great because of his dependence on a translator in reaching the American public. Shortly before his death Osten-Sacken published his memoirs, which certainly make interesting literature. A large part of his collection is in the museum at Cambridge.

Among the hymenopterists I can mention only William H. Ashmead, whose death is so recent that most of us remember him personally, and whose gentle manner and unfailing courtesy endeared him to all who came into contact with him. His work was monumental and his systematic sense so developed that he seized almost at a glance upon the really essential structures of the species studied by him. So constant and persistent a worker was he that, to those of us who knew him personally, the surprise was not that he died so young, but that he lived so long.

Dr. A. S. Packard, of Brown University, was more than an entomologist: he was a biologist and a teacher. His work as a systematist was great; but as a teacher he was greater. And his teaching was not confined to the classroom: his "Entomology for Beginners," his "Guide to the Study of Insects" and his "Text-book of Entomology" continue his work, though his voice in the classroom is hushed. His interests were broad enough to include even the economic side of the subject and he appeared as a member of the U. S. Entomological Commission, though his part of the work was that which was more technical in the publications.

I can scarcely avoid referring at least to Dr. S. H. Scudder, although he is yet with us, not only because his work, unfortunately,

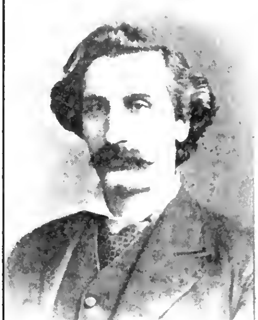
WM. LE BARON

J. A. LINTNER

TOWNEND GLOVER

A.S. PACKARD

JAMES FLETCHER



C.V. RILEY

ASA FITCH

B.D. WALSH

is done; but because it was carried into fields not theretofore frequented by American entomologists. His labors on the fossil insects of America are unique, and his collection of material for further work is immense. Of his systematic papers on orthoptera and his accomplishments in other directions I will not speak at present.

All these men paved the way—they made the studies necessary to familiarize us with the insects round about us, and theirs is the labor that is not spectacular and whose apparent results are not of public interest: yet such work we must have as a foundation for what we consider the more practical side of the subject.

First among the economic entomologists of this country we must reckon DR. THADDEUS WILLIAM HARRIS, whose work on the "Insects Injurious to Vegetation" is a classic and, like most of the classics, was a labor of love rather than a money-making proposition. The state of Massachusetts paid him $200 for that work. Since that time it has learnt to pay rather more highly for entomologists, and nowhere have insects done more injury nor have they anywhere demanded the expenditure of greater sums. Harris's work is not only intensely practical, but it is interesting and informing—as useful to the beginning collector and entomologist as to the agriculturist, and always accurate.

Quite a different sort of man was TOWNEND GLOVER, for a series of years entomologist to the U. S. Department of Agriculture, who wrote comparatively little, but used his pencil industriously; producing a perfectly enormous number of drawings of insects in all stages, and engraving them on plates from which only a very few impressions were taken. Unfortunately, Glover had almost no systematic knowledge of insects, and while he made excellent pictures of the specimens as they appeared to him, he had not the slightest idea as to the identity of the insects figured, nor did he preserve the originals.

DR. ASA FITCH, of New York, was a man of different type. A hard worker and hard student, industrious, of course, he studied not only those species that his field work demonstrated to him as injurious, but their allies and neighbors, and with a sure glance he fixed upon certain of the hemipterous families as entitled to the special consideration of the economic worker. Dr. Fitch's reports as state entomologist initiated a work in that state which has not been abandoned since, and which has put it among the leaders in organizations for entomological work.

Meanwhile, in the middle west the ravages of insects had developed new needs and new workers, and Walsh, Riley and LeBaron, began to make themselves felt, and really to develop a science of economic entomology.

BENJAMIN DANN WALSH, of Illinois, had a career much too short, and it terminated before he had more than shown his vigor and originality. In company with Riley, then a young man, he had planned much in the way of entomological work; but one report and a few vigorous papers in journals form the total of what remains to us.

Dr. William LeBaron, his successor in office, was a much less positive character, but an equally conscientious worker, and, in his fourth report, began what was intended to be a popular treatise on the insects, the systematic portion forming a sort of supplement to the specially economic portion. Illinois is another of the states which has never allowed its service to deteriorate, and there is no better work now done in the United States, nor is there a more effective organization than that within its limits.

Dr. Charles V. Riley was a prime factor in the development of economic entomology in the United States. His series of reports on the injurious and other insects of Missouri is a model which has never been exceeded in interest and value. Not the least important feature of these reports is the list of illustrations—wood-cuts most of them—that have never been surpassed in their fidelity to nature, and their artistic merit. Most of the insects figured in Riley's reports *look* natural, and that is the highest praise that can be given to any figure of this type. So well done are they that they have become common stock and are used again and again in bulletins and reports throughout the country. With his transfer to Washington his field of activity was enlarged, and he became a force in the development of the practical side of entomological work. The real development of our present battery of spraying outfits, arsenical poisons and kerosene emulsions began under Riley, and the fight to secure their adoption was a more difficult one than is understood. Congress thought itself very liberal when it reached the $20,000 mark for the division of entomology, and when we consider the force of men that Riley gathered and trained for that sum, men who form the nucleus of the division to the present day, we begin to appreciate the ability of the man.

I will not attempt to give a list of the men who were associated with Dr. Riley in the development of his office at Washington; I knew them all and worked with some of them for a time. And not the least of Dr. Riley's ability was in getting all that there was out of his assistants, in commanding their devotion and loyalty, although he constantly quarrelled with every one of them. He was the best loved, best hated, most admired and most detested man I ever knew; but he was always a better friend than he was an enemy, and never lost an opportunity to do a man a good turn even when he personally lost by it. Economic entomology owes much to Dr. Riley and his influence is still with us. I need hardly say that his successor has fully maintained the standard set for him, and that there is nowhere in the world at the present time a more efficient body of workers in economic entomology than that connected with the U. S. Department of Agriculture at Washington.

DR. J. A. LINTNER, who was for many years state entomologist of New York, was a model of gentle, persevering labor. Quiet and deliberate in manner, very painstaking in his work and observations, he maintained the high standard set for his office by Fitch, and his reports are models of completeness in the treatment of the subjects contained in them. He was a familiar figure at the meetings of the American Association for the Advancement of Science, and was always listened to with respect.

Last of all in this list of those who have been influential in the development of the fight against insect pests, because his loss is one of the more recent, is DR. JAMES FLETCHER, of Ottawa, Ontario. Who of the entomologists attending the annual meetings of the American Association does not remember his hearty and cheering presence. Who does not remember his cordial greeting, his constant good nature and the directness and convincing qualities of his contributions to our discussions and debates. As for the work that he did in Canada —none could have done it as he did. He was widely informed, not a narrow specialist, he was a student of men as much as of insects, and he commanded the confidence of his constituency. It will take two men or more to carry on the work that this one did alone.

To summarize—insects are a factor of very great importance in the community: (1) because of their injuries direct and indirect; (2) because of their benefits, also direct and indirect, and millions of dollars annually are involved on both sides of the ledger.

The entomologist who studies these insects, determines which are harmful and which are beneficial, who works out their life histories and habits and who determines methods of controlling those that are harmful and improving those that are beneficial, is a worker of high importance to the community and deserving of every possible aid and assistance.

ANCIENT CLIMATES OF THE WEST COAST

By Professor JAMES PERRIN SMITH
STANFORD UNIVERSITY

WE naturally look at things from the standpoint of the present, and regard the existing distribution of climates as the normal one. But even in our own times there are slight fluctuations of climatic conditions, for we hear wonderful stories from our elders of cold winters and hot summers, and tremendous storms of former years. The advances and retreats of existing glaciers give us surer testimony of recent fluctuations in temperature and moisture, as does also the shifting of the zones where wine grapes can be grown successfully in Europe.

If we go still further back into older history we find still stronger evidence of change, for in northern Africa and in central Asia there are remnants of ancient cities, evidently the flourishing capitals of prosperous peoples, where now is nothing but desert, and where even the most advanced modern skill in irrigation could not support the population of the old days.

And yet all the changes alluded to above may be only the secular variations in climate that we know are going on all the time. The climatic changes of the west coast which will be described in this paper are older than those fluctuations recorded in history, and much greater.

The old geological theory was that the earth cooled down slowly from the poles toward the equator, and that life first appeared at the poles. It was further thought that in the more remote geologic ages the interior heat of the earth was so great that there was little difference in temperature between the equator and the poles, and that, until Tertiary time, there was no differentiation into climatic zones. The Glacial epoch was supposed to be the culmination of this secular cooling off of the earth.

Then came the discovery of the old Tertiary fossil floras of Siberia, Alaska and Greenland, with abundant forests of trees that evidently lived in a temperate climate where it is now arctic. This was so remarkable that geologists had to invent some extraordinary explanation for the phenomenon. They rose to the occasion and invented the theory of the obliquity of the poles in early Tertiary time, to account for the warm temperature under the arctic circle. This, however, did not agree with the known distribution of life at that time over the rest of the earth, and also the physicists declared this obliquity, or any obliquity, to be a mathematical impossibility.

Later it was discovered that there was a great glacial epoch in the late Paleozoic era, about the line between Carboniferous and Permian, and that too in the regions around the Indian Ocean, where it is now tropical or subtropical in temperature.

Before we had entirely recovered from the shock of that discovery, it was found out that in China and Australia there was another glacial epoch, or epochs, near the beginning of Cambrian time. Now the geologist's spirit is so broken, that when the supposed discovery of glacial epochs in Silurian and Devonian time is announced, he hardly raises a dissenting voice, and appears to be resigned to the occurrence of glacial epochs at almost any time in the history of the earth. The theory of ancient climatic uniformity is definitely abandoned, and we must accept fluctuations of climate from the earliest geologic record all through the history of our planet. The old idea was delightfully simple, but too good to be true.

Criteria of Ancient Climates

Physical Criteria.—Physical evidence as to ancient climatic conditions is limited to two classes—glacial deposits and ice-work, and sediments indicating desiccation, that is, saline and gypsiferous beds. These are both necessarily limited to continental areas, and tell us nothing of marine conditions. And as we go back in time they become more and more indefinite, so that there is much difference of opinion as to their value. The evidence of the recent Glacial epoch is positive enough to satisfy the most critical, but geologists are not yet united as to the glacial epochs in older periods of geologic history, because of the difficulty of determining whether the ice-masses were true sheets or whether they were mere local highland glaciers.

Also the sedimentary deposits indicating desiccation may have been merely local, and although they are positive as to prevalence of evaporation at that particular place, they can not tell positively of wide-spread dry climate, and certainly they do not indicate temperature.

Organic Evidence.—Fossil remains of animals or plants known to have lived in either warm or cold climates are more definite, and tell us equally well of land and water conditions, but they are authentic only when the fossils are animals or plants that have either lived on into our own time, or when the groups to which they belong have always had the same habits. This becomes more and more conjectural as we go back in geologic history, and have to deal not only with extinct species, but even with extinct genera, families and orders.

Extensive fossil beds of deciduous trees point to moist climates, and usually to temperate conditions. But deciduous trees extend back only to the middle of the Cretaceous, and beyond that time we have no positive criteria for temperate climate.

Cycads and palms are the best evidence as to tropical climates on the land. At present, cycads are almost exclusively tropical, ranging outside only a short distance in eastern Asia. Palms are not quite so delicate, ranging outside the tropics to 34° N. lat. on the west coast of America and to 36° N. on the east coast. But in any case, abundant remains of either point to tropical or subtropical conditions.

Reef-building corals are even more definite in their testimony concerning tropical temperature of the water. They are now found only in the tropics, where the winter temperature does not fall below 68° F. (20° C.), and in general between 26° N. and 26° S. But since this temperature zone may be extended by marine currents, coral reefs may sometimes reach beyond 26° N. lat., as in the Bermudas, but more often they fail to reach this geographic limit, as on the west coast of America.

The principal reef-builders, the Madreporidæ and the Astræidæ, are confined to the hottest part of the tropical belt,[1] within 18° of the equator, and where the temperature does not fall below 74° F. (23° 20′ C.). Between this line and the isotherm of 68° F. coral reefs occur on both sides of the equator, but they are composed largely of Poritidæ and Milleporidæ.

On the west coast of America the minimum isotherm of 68° F. runs north of the equator, and the Galapagos Islands have no reefs, for the temperature there often falls below 68° F. Reef-building corals occur in patches from Panama to Magdalena Bay on the coast of Lower California, but they do not form any reefs, and are composed almost entirely of Poritidæ.

Fossil deposits of Astræidæ, in any age and anywhere, indicate with a reasonable degree of certainty that the sea had a temperature of not less than 74° F., and corals of any of the modern reef-building groups show that the temperature was not less than 68° F.

But the reef-building Hexacoralla are not known below the Triassic, and for the Paleozoic era we must use other criteria. From the Cambrian to the upper part of the Carboniferous coral reefs are known, but they are formed by Favositidæ and Tetracoralla, both wholly extinct, so that we can only infer their habits. It is, however, nearly certain that these ancient reef-forming corals lived under the same conditions as the modern groups, and that the temperature of the sea where they lived was tropical.

Absence of coral reefs from any formation does not prove that the temperature of that time was not tropical, for even now coral reefs are lacking in many parts of the tropics, on account of unfavorable conditions other than low temperature. Also the corals of the ancient reefs have often been obliterated by metamorphism, and only massive limestone left.

[1] J. D. Dana, "Corals and Coral Islands," 3d ed. (1890), pp. 108–114.

Now while one swallow does not make a summer, one reef-building coral, or one palm, or one cycad does, since neither one of these organisms now lives outside of a warm climate.

Paleozoic Climate of the West Coast

All the Paleozoic sediments on the west coast are marine, and while the record is fragmentary, the evidence points uniformly to warm temperature of the sea, and, thus by inference, of the land. The Lower Cambrian, or Pre-Cambrian, glaciation of China and Australia has not been recognized in this part of the world, but this is merely negative, since land formations of that period are unknown here.

The Lower Cambrian limestones of Inyo County, California, and the adjacent region of Nevada, have extensive coral reefs of Archæocyathidæ: similar reefs are known in Europe and Australia, but not in the Arctic region.

In the Silurian of Plumas County, and the Devonian of Shasta County, California, there are coral reefs composed of Favositidæ and Tetracoralla, and in both these ages similar reefs are known in Siberia and Alaska, which may show that the temperature of the sea had grown warmer in the middle Paleozoic, with a northward extension of the isotherms.

The Carboniferous of Shasta and Plumas counties, California, has great limestone masses full of reef-building Tetracoralla, and similar reefs are known up to 82° N. lat., and down to the equator. Whatever the temperature was, it was remarkably uniform. The flora of the Coal Measures[2] in the northern hemisphere indicates a warm and equable climate for the land, extending up into the Arctic region, and without evidence of any trace of climatic zones.

The Permian, or Upper Carboniferous, glaciation, which was so widespread in India, Australia, South Africa and South America, has not been recognized in North America. But this event is now recognized as the greatest catastrophe in geologic history, and its effects probably extended far beyond the limits of glaciation. With the accompanying lowering of oceanic temperature, near the end of the Paleozoic era, the ancient types of reef-building corals, the Favositidæ and Tetracoralla, disappeared. Hardly anything but solitary corals, that may have been deep-water forms, are left in the Permian, and in the Lower Triassic no corals of any sort are known.

The Hexacoralla, the modern reef-builders, had already originated in the Paleozoic, but were then little developed, unspecialized types. They escaped the general catastrophe either by being distributed in regions where the destruction did not take place, or by being then deep-

[2] David White, *Jour. Geol.*, Vol. XVII., No. 4 (1909), p. 338.

sea forms, habituated to lower temperatures. When the amelioration of the earth's climate took place, near the beginning of the Mesozoic era, they found a free field on the coasts, and at once took possession. In the epoch of the Middle Triassic they had already become widely distributed, but as yet had formed no known reefs.

The distribution of the cephalopods in time shows a strong contrast to that of the corals. There is an unbroken genetic series of ammonoids and nautiloids from the Coal Measures, through the Permian, and extending into the Lower Triassic, several genera ranging through the interval. This does not necessarily mean that the cephalopods were hardier, for they probably were not. But they were very widely distributed, and must have lived on in some region, or regions, where great catastrophe had little or no effect, and by their superior facility in locomotion got back into the regions affected by glaciation, when the temperature of the seas had risen again.

Mesozoic Climates of the West Coast

Since corals are wholly unknown in the Lower Triassic, and since the flora of that epoch is as yet little known, it is not possible to determine the temperature of either the land or the water. It is, however, certain that the oceanic temperature in India, in western America and in northern Siberia, was the same, for there is a remarkable similarity of the cephalopod faunas in all three regions.

It is also known that in the Permian and the Lower Triassic a dry climate prevailed over large areas, for products of desiccation, such as gypsum and saline deposits are common in many parts of the world, and even in regions that are now rainy, as in western Europe.

In the Upper Triassic there are great limestone masses and coral reefs in the Alps, the Himalayas and in California, with many species common to the three regions. Certainly the epoch of the *Tropites subbullatus* fauna was tropical up as far as Shasta County, California, for there reefs of Astræidæ are extensive. We may even be justified in assuming that the isotherm of 74° F. extended that far north. Also in the Blue Mountains of northeastern Oregon there are coral reefs in the Upper Triassic, but no Astræidæ were found in them, only extinct genera. This outlying occurrence may correspond to the isotherm of 68° F., in which now corals may form reefs, but Astræidæ can not flourish.

After the formation of the coral reefs in northern California and Oregon the facies changed suddenly from limestones to clay shales, and with this came an abrupt change in the marine fauna. The Indian types of cephalopods disappeared entirely, and in their stead came in a fauna of which the home seems to have been the boreal region. *Pseudomonotis ochotica* was the commonest species in this fauna, and was widely distributed around the North Pacific. It has also been found as far south as Peru, on one side, and down to the equatorial part of the Indian Ocean on the other. This wide dispersion does not necessarily mean a lowering of the oceanic temperature during this epoch, for this species may have lived in deep water, and therefore could easily find uniform temperature from the equator to the Arctic region. But the sudden change of facies and impoverishment of the fauna over such an enormous area are suggestive. A slight drop in temperature, below 68° F. would account for it.

The last epoch of the Triassic, the Rhætic, has no marine faunas anywhere in America, but the flora, with its abundant cycads, is widely distributed in both the northern and the southern hemisphere. Coal deposits are common in this epoch, and this points to a very uniform and mild climate far beyond the present temperate zones.

At the opening of the Jurassic period we find a Mediterranean marine fauna established in western America; this same fauna also extended from the equatorial regions to Alaska, so that we are without evidence as to climatic zones, and can only infer that the temperature was uniform.

In the Middle Jurassic reef-building corals lived in the waters of the Great Basin Sea, and their remains are quite common in Plumas County, California, but in that province they formed no reefs, for the waters were not clear, and much disturbed by the deposition of volcanic ash. Abundant cycads lived on the land in California at this time, adding their testimony to the warmth of the climate. This same Middle Jurassic marine fauna extended up to Queen Charlotte Islands, and to southern Alaska, in the latter place with cycads interbedded with the salt-water fossils. Here, as was often the case, the cycads extended some distance north of the corals, a coral reef with Astræidæ being known in this epoch on Queen Charlotte Islands, in 53° N. lat., while cycads occur as far north as 57° N. lat. In this same epoch the northern limit for coral reefs in the Atlantic region was 53° N., in southern England, while the other invertebrates and cycads ranged up to 80° N. lat. A mild climate must have extended up nearly to the pole.

The Upper Jurassic of California shows a sharp contrast to the preceding epoch; its marine fauna is scanty, and what little there is belongs to the boreal type, the *Aucella* fauna, which is characteristic of Russia, northern Siberia and Alaska. For a short time this fauna ranged down into the edge of the tropics in Mexico. This does not mean that the climate was cold, but merely that the temperature was lower than that at which reef-building corals and the other sensitive invertebrates could flourish. In the Lower Cretaceous we find the same boreal type still persisting as far south as middle California. But here, as in the Upper Jurassic, the evidence is conflicting, for cycads are known in both formations.

In the Lower Cretaceous epoch there was a sharp contrast between conditions on the Pacific and those on the Atlantic side of America. In the Atlantic waters coral reefs extended as far north as Texas, while no corals at all are known in the Pacific waters of America in California. In the Upper Cretaceous, on the other hand, coral reefs extended to Ensenada, Lower California, lat. 31° 30′ N., while in the Atlantic waters they did not reach so far north. In other words, the Pacific waters on the western side of America became warmer in Upper Cretaceous time than they were in the preceding epoch, while in the Atlantic the conditions were reversed, as was the case also in southern Europe, where coral reefs extended much further north in the Lower Cretaceous than they did in the Upper Cretaceous.

The change in faunal geography in western America about the middle of the Cretaceous period is very remarkable. The Knoxville epoch had a boreal fauna, while with the opening of the Horsetown epoch the facies changed rather abruptly, and an Indian fauna came in. Swarms of ammonites of Indian type occupied the shallow marginal sea, showing at least a great change in geographic connections, if not in climate. It has been suggested by the writer that the opening of the Bering Sea passage during the Mariposa epoch of the Upper Jurassic and the Knoxville epoch of the Lower Cretaceous would account satisfactorily for the change of facies and the lowering of the temperature at that time. The closing of this passage near the end of the Knoxville epoch explains the change of facies from the boreal to the Indian type of fauna, and also the accompanying rise of oceanic temperature on the coasts of western America.

The favorable conditions, inaugurated in the middle of the Cretaceous, continued throughout the Chico epoch, during which coral reefs extended up to Ensenada, Lower California, N. lat. 31° 30′, and a warm climate prevailed even in Alaska. Reef-building corals extended up to the middle of California, but they formed no reefs, since there were no stretches of clear sheltered waters in which they could flourish.

Neozoic Climates of the West Coast

The Eocene climate of the west coast was nearly the same as that of the Upper Cretaceous. The marine deposits have numerous molluscan genera that are now confined to the tropics, and on the land palms abounded in California, Washington and Alaska. No reef-building corals of this age are yet known anywhere on the west coast, and it is probable that the marine temperature was slightly below that necessary for their existence in this region. The climate of the coast, from California to Alaska, was probably very much like that of the states bordering the Gulf of Mexico. There to-day many tropical molluscan genera are found in the waters, and on the marginal coastal plain there is a mixture of palms, deciduous trees and conifers. This is just what we find in the fossil Eocene flora of California and Puget Sound; laurels, figs, sycamores, chestnuts, elms, liquidambar, oaks, palms and sequoias lived together. From this association we should infer that the climate of the west coast was no longer tropical, but subtropical, and very rainy.

The middle Tertiary faunas are very like the present in the association of genera, and the flora on the land agrees with this. The palms have disappeared, but laurels still occur. It is probable that the climate of the upper Miocene had about the same temperature as that of the present in California, but it had, apparently, a much greater rainfall, or one much more evenly distributed.

The Tertiary flora of the west coast was immensely richer than the present. No elm, liquidambar, nor true laurel lives wild on the west coast now, and many other types that flourished here are gone. The impoverishment of the present tree flora of California, as compared with that of the Tertiary, has been ascribed to volcanic activity, but this is absurd. In the first place the great extinction of the old types took place in the lowering of temperature near the end of Eocene time, while the era of great lava outbursts on the west coast was after the middle of the Miocene. The climate continued to cool off in the Pliocene, as is shown by the northern types of mollusca that then ranged as far south as Los Angeles, and by the freshwater lake deposits of middle California, which contain a fauna at present confined to the Klamath region of northern California and southern Oregon. The flora of the Pliocene in California is very scanty, composed largely of willows, alders and conifers, very much like that of the Olympic Peninsula in Washington.

The constantly decreasing temperature throughout the Tertiary is sufficient to account for the reduction of the flora. The tropical and finally the warm-temperate types were killed off locally, and such as were confined to this region were wholly extinguished. Some of the forms that lived in more favored regions to the south returned after the Glacial epoch. But most of the region to the south of California is not favorable to the extensive growth of forests, and many of the types have never returned to California, except when brought in by man.

In the early Quaternary there were extensive ice-sheets in the Sierra Nevada, and probably the climate of the sea-coast was cool. The glaciers came down the slopes to a line that is now about 3,500 feet above sea-level; it is thought, however, that California stood considerably higher than now, and that conditions here were more like those of the present on the Olympic Peninsula.

After the Glacial epoch was past the climate became warmer, and many mollusca crept slowly up the coast, from the warm waters of Lower California. This southern type reached as far north as Santa Barbara in the upper San Pedro epoch of the Quaternary, during which time the sea probably had a temperature as warm as it now is on the shores of Lower California.

This warming up of the west coast was no mere local phenomenon, for the same thing occurred at the same time on the eastern coast of America, when a warm-water fauna ranged up to the Champlain district. And also in Europe the climate after the Glacial epoch was, for a little while, warmer than it is at present. After the San Pedro epoch on the west coast, and the Champlain in the east the climatic conditions became approximately what they now are, although it may well be that the Terrace epoch had a larger rainfall than that of the present.

Summary

In the foregoing pages it will be noted that during all the known Paleozoic the west coast enjoyed a warm and probably tropical climate, with some suggestion of a northward march of the isotherms, reaching a culmination in the Upper Carboniferous. There is then some indication of a southward recession of the isotherms in the Permian, and a renewed northward advance in the Lower Triassic. This continued until the middle of the Jurassic, but the farthest north was never again reached in the Pacific waters.

In the Upper Jurassic and the Lower Cretaceous another considerable southward recession of the isotherms is indicated, followed by a renewed northward advance in the middle of the Cretaceous. But this advance did not reach so far north as that of the Middle Jurassic. The Eocene epoch shows the temperature of the west coast nearly holding its own, but with a probable slight reduction. The Miocene climate had grown considerably cooler than that of the Eocene, and by the Pliocene it was already rather cold as far south as California. The early Quaternary climate was probably even colder than the Pliocene, for there we have the local ice-sheets in the high mountains of California. The post-Glacial amelioration of climate is as distinct here as it was in eastern America, and in Europe, and probably as short-lived. Middle and late Quaternary time was probably much longer than we have been accustomed to consider it, and there have doubtless been considerable fluctuations in our climate in that period, but we have as yet been unable to decipher these in the geologic record of the west coast.

SOME TESTS OF ACADEMIC EFFICIENCY[1]

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I HAVE come here from Boston for the simple purpose of manifesting the good will of an eastern institution to this vigorous university in the middle west. I need not remind you of the historical connection between Massachusetts and Kansas, but I should like to express the hope that frequent interchange of academic courtesies may at any rate keep alive the memories of that interesting connection. My mission here, however, is extremely simple and my duty entirely congenial. It is merely to congratulate you on this new exhibition of western energy and to join with you most heartily in the dedication of your splendid laboratories to the great purpose for which they were designed, the pursuit of science and its application to the problems of to-day.

I need not assure you that I have come here in no spirit of eastern superiority. In fact, if there is anything of east and west in my mind at all it is the old suggestion that the wise men of the east displayed their wisdom in going to the west for inspiration. I believe that this might well be done more frequently to-day.

But what impresses me most in a visit such as this is not so much the difference between the east and west, not so much the distinction as the points of similarity. The old distinctions seem to be rapidly disappearing and all are recognizing that the prosperity of one part of the country is intimately bound up with the prosperity of every other part. And there is no field of our national activity in which this is more clearly recognized than in the field of education. There have been differences, there have been jealousies, there have been rivalries between different colleges and technical schools. There are some of these differences and rivalries still left, but never before was there a time when the essential solidarity of the whole educational world was more clearly recognized, and when men saw so well as they do to-day that in all of our colleges, universities and technical schools we are fighting, if we are fighting at all, on the same side. Rivalries in some sense there must needs be, but no longer do we desire weak rivals. We want our rivals to be strong and we want them strong so that in the process of emulation and of competition we may be all forced to higher levels and there may be a general trend upwards rather than downwards.

[1] An address delivered at the dedication of the engineering laboratories of the University of Kansas, February 25, 1910.

Now it seems to me that in the process of striving to raise our standards we are a little apt to slavishly copy what other people are doing without clearly recognizing why we are copying them and what we are striving to attain. One college opens a new department in some sphere of activity; another thinks it is bound to do the same thing, although the local conditions may be totally different. If one school of engineering establishes a new course another is sure to follow with a similar course. We need a measuring rod to determine whether our level is above or below our competitors. How are we to reach a real standard of efficiency? How are we to know whether our institution is better or worse than some other institution? Of course various standards have been suggested. The great objection to most of them is that they are too mechanical. The best part of any educational institution is a spiritual thing and a spiritual thing must be spiritually discerned.

Now one of the institutions in this country which is doing its best to carry out a leveling process and trying to raise the institutions of the country is the Carnegie Foundation for the Advancement of Teaching. Its course is so brief that none here can have missed the opportunity of following it. Founded only a few years ago by Mr. Carnegie for the avowed purpose of pensioning professors who had long served their country as teachers and investigators, it is being put by those who have managed it to a quite different purpose and that purpose is to standardize our institutions.

I am not going to discuss what the foundation has done or is doing, but I should like to refer to a report, the advance sheets of which the Carnegie Foundation has just issued, under the title "A Comparison of Academic and Business Efficiency." The fundamental idea that suggested the drawing up of the report is one that must attract us all. It was to obtain a report on the efficiency of different educational institutions looked at from the view-point of a business man. To this end the foundation employed the services of an accomplished engineer, Mr. Cooke, and asked him to report on a number of educational institutions in this country. He was instructed to employ the same methods in his investigation that he would if he were reporting on the efficiency of a cotton mill or an automobile factory. To simplify the problem he was to confine his attention to eight institutions; to further simplify it he was to deal with a single department in each of these instituions; that department happened to be the department of physics. The report is a lengthy one—those of you who are interested will doubtless read it for yourselves—but I may just sketch with extreme brevity the fundamental guiding principle.

Mr. Cooke begins with the truism that if you are to test the efficiency of a factory from a business point of view you want to know the cost of the working of the machinery. He therefore proceeds to discuss how much it costs to train men in physics in these different institutions and sets up a standard of measurement of what he calls the "student hour," the cost of teaching a student the subject of physics for a single hour. After an elaborate system of figures and a great deal of computation he discovers what is supposed to be the cost of teaching a student in physics for one hour in Harvard and Boston Tech, and these different institutions. Now whether his figures really represent the cost or not is questionable, but there can be no doubt that they do not gauge the efficiency of the institutions under consideration.

The efficiency of an automobile is not gauged by its cost, and certainly the efficiency of Harvard or Boston Tech is not gauged by their cost. You must of course look to the product. Now a man of Mr. Cooke's acumen could not overlook so obvious a fact, although he passes it over with almost unpardonable brevity in a report that professes to deal with the question of *efficiency*. He does not always seem quite true to himself. He tells us in one place that "the cost per student-hour has absolutely no value in distinguishing relative educational values." Elsewhere he says "certainly some idea of quality will be gained by simply knowing the cost." However, he does recognize that the *quality* of the product must be tested before we have any real gauge of efficiency, but when it comes to suggestions for a test of quality he formulates a plan that a serious educator could regard only with laughter or with tears. Here it is—let us establish a central bureau to which may be submitted the examination papers and the answers from the five highest and five lowest students, and let the central authority assign marks for the difficulty of the questions and the rigor with which they were answered. I shall not presume upon your patience by pointing out to what abuses such a plan would be exposed, nor how paltry a contribution it is towards the solution of an extremely important national problem. I should like, however, to call your attention to various matters to be kept in view when we set out on the task of testing the efficiency of any educational institution.

I would remark at the outset that the matter is extremely complex and that no wise man would even dream of giving a *numerical* measure of the efficiency of Harvard or the University of Kansas. He would no more do that than he would say that the efficiency of his friend Jones is 62, and of Smith is 55. On the face of it, such apparent accuracy is ridiculous. But we do want to know in a general way how we are to gauge efficiency, and I need only sketch the process which is a fairly obvious one. The natural way of attacking the problem would be to attack it directly. We are interested not in the machinery but in the product. The obvious procedure would be to examine the product in the different institutions and see how they stand relatively to one another. We would have, of course, to set out with some fundamental conception of what all of these educational institutions are striving for. Unless we agreed about that we could not possibly agree as to their efficiency. Fortunately, there is general agreement to-day that the aim of all educational institutions is a social one. The University of Kansas, and Boston Tech and Columbia University and all the rest are striving to this great end—to train men to serve the state intelligently, honestly and effectively. We are all attempting that. To what extent do we succeed relatively to one another?

Now, the natural process, I say, would be to examine the product of these different institutions and see whether men coming from these different institutions have "made good." This, however, is no easy matter where there are thousands of men to be considered and the gauging of the social efficiency of a single man is so difficult and delicate an operation. And then, you have to remember that the "making good" by an individual may have really little to do with the educational institution in which he has been trained. I had the honor of being brought up in the English university of Cambridge, which has been spoken of by a poet as a "nest of singing birds," for the reason that that university has produced, if I may use the term, an extraordinarily large number of great poets. But no one seriously suggests that the poetic power of Tennyson or Wordsworth had much to do with his training in the University of Cambridge. And so it is with the actual making good of a great many of our leading men; in most cases it is only indirectly due to the training they received in the university. Then you must bear in mind that an extremely important factor in the making of good flour is to have good grain, and that one institution might be as efficient as another, but yet for the lack of good grain not turn out so fine a product. Thus you would have to gauge not only the graduate, but the men at entrance, and this would greatly complicate the problem. Practically, then, I think, you would have to proceed indirectly by carefully examining the means that were employed in the institution to produce the results. If you bore in mind the idea of social service as a thing toward which we are all striving, you would have to begin, I suppose, with some estimate of the relative social value of a college education and the education in a professional school, taking each at its best. The aim of a college is to train a man broadly and so develop every side of his charcter that he can devote himself to the duties of citizenship in whatever special sphere of activity he can be most effective. The professional school does not neglect breadth of outlook or the duties of citizenship, but it bends its powers to the education of men for the service of society through the medium of definite professions. To gauge the relative value of these two schools you would need to decide whether it was more important to have an alert broad-minded man with no professional skill, or a man who could set your leg if you broke it, or bridge the Mississippi if you wanted to cross it. It would be an extremely difficult question to decide, but you would have to do it somehow if you wanted to solve this problem numerically. Then if you confined your attention to professional schools you would need to estimate the relative value to the community of a doctor, lawyer, clergyman or engineer, and so on. In doing this you would necessarily take into account local needs and local peculiarities. You would have to consider, as a single sample of what I mean, whether there was a real demand in the community for an increased number of doctors, and so with the other professions.

Here to-day we are celebrating the foundation of buildings which are to be devoted to science and its applications, and so it would seem natural to consider that kind of educational effort somewhat more minutely. You would have to begin with deciding on the usefulness to the community of an education such as is being given in this institution, and in particular in this school of engineering where men are trained in the sciences for the service of the state. Now, it is such a commonplace to-day that science has revolutionized the world that I shall not weary you with attempting to demonstrate that fact. At the same time I should like to say in passing that, like many another commonplace, it is too often neglected in actual practise. It seems that individuals and states in making provisions for education constantly fail to recognize how enormously important to the welfare of the state it is that men should be trained in science, and in its application to every branch of practical life. We live in an age preeminently scientific, and if we are not able to cope with a problem scientifically we can not cope with it at all. But not only is a scientific training essential anywhere to any country to-day, it is, I think, peculiarly important in this country at this particular time. It seems to me that one of the great dangers of our democracy is the prevalence of the idea that one man is as good as another. It is an idea founded on an erroneous theory of democracy and one that appears utterly false from a scientific point of view. It too often gives support to the doctrine that any man will do for any position that he is clever enough to get. Nothing has surprised me more in moving about this country than to see countless instances of men who have had no adequate scientific training employed in the service of cities and of states, to do work that really needs a very considerable scientific equipment. They are amateurs doing the work of professionals. We have suffered too much at the hands of these amateurs, and we must remove them—root and branch. We must educate our communities in such a way that it will shock their moral sense to see a man, let us say, administering a department of public health who knows little or nothing of biology and bacteriology or any of the other fundamental sciences that enter into the very heart of his work. Then we have to bear in mind that this nation is peculiarly given to extravagance. This is due largely to the optimism of the American people, a quality on which so much of America's success depends. But it has its drawbacks, like other good things, and the spirit of extravagance may yet drive us upon the rocks. We must not forget that conditions are rapidly changing and that what might suffice for a past generation will not do to-day. A generation ago we could speak of our natural resources as practically unlimited, now we begin to see their end—at least in some directions. And apart from this we must recognize that under any circumstances *waste* is a sin and that the record of progress is largely the record of the elimination of waste. We shall have to make up for the diminution of our natural resources by new applications of science which will make ten blades of grass grow where one grew before, and by new inventions which will save fifty per cent. or more of the waste in most of our industrial processes. However, even without any new inventions we could easily make enormous savings by the proper use of existing knowledge. Let me give you a single example. A few years ago a graduate of the Massachusetts Institute of Technology, trained in the department of biology, was appointed to an administrative post in one of the great cities. He invented nothing new, but merely joined common sense and executive ability to the scientific knowledge that his training at "Tech" had given him. Before long he had given the city a much better service than it had ever had before, and at the same time had *saved it more than a million dollars each year.* Suppose you multiply the million dollars thus saved by even a very small fraction of the thousands of men trained each year in the scientific institutions of this country and you may form some estimate of the saving grace of such institutions and of their value to the community.

I think, then, that there can be no question that you would have to put in a very large factor of usefulness, if you were estimating the value of such an educational institution as we are considering to-day—at least if you realize in any adequate degree the importance of scientific knowledge in public and private life. And, of course, a not unimportant element in such scientific knowledge would be a knowledge of physics, and under ideal circumstances this knowlege might be at least partially tested by Mr. Cooke's method, to which reference has already been made. It would, however, at best be only a partial test of knowledge, and it would neglect a great many factors of the first importance. May I remind you that *knowledge* is very far from being everything and that much of our educational work to-day and in the future must be to deliberately *smash up the idol of knowledge.* We are peculiarly prone to this form of idolatry in a scientific school, for science rightly lays a great stress on facts and their accurate apprehension. We are very apt to overestimate the value of such knowledge, and it is because we have done this so much in the past that there has been so much disappointment in many quarters over the results of scientific teaching. It is a fact that water is composed of oxygen and hydrogen, and it is the knowledge of such facts that is tested by such examinations as Mr. Cooke proposes. But, except to a very few, such knowledge profits little or nothing—what is infinitely more valuable is an understanding of the method by which the facts are reached and an appreciation of the spirit that compels their investigation. Here, as elsewhere, it is the spirit that giveth life, and any test of efficiency that ignores the spirit and deals only with the bare fact is a mockery.

It would be a monstrous oversight to ignore the method and the spirit of the teaching. Are the pupils trained by a mere grind over knowledge, a mere hammering in of facts—enough perhaps to ensure that they reach the requisite 50 or 60 per cent. in Mr. Cooke's examination? We must all know schools that would appear to be highly efficient from such a test, and which are really extremely inefficient; and on the other hand some of our best institutions might not make a very good show when subjected to Mr. Cooke's scrutiny. At the Boston Tech a method has been in vogue for long that is there deemed highly satisfactory—it is known as the "do-it-yourself method." The students are put as much as possible upon their own resources and learning is not made easy where it seems better for a man to experience the apparent hardship of overcoming a difficulty for himself.

Then, when considering method, we should want to know whether the students are taught to master fundamental principles, or to spend most of their time over details or particular examples. Is it made manifest to them that the details of practise are constantly changing, that what is good in that respect to-day may be antiquated to-morrow, whereas fundamental principles, like the brook, go on forever?

As to the spirit of the teaching—is it possible to overlook the character of the teachers? Are they men who understand the depth and breadth of their calling? Do they take a large view of the life of to-day, and have some prevision of to-morrow? Are their circumstances such as to make this larger outlook possible or probable? Are they narrow specialists or broad-minded, far-seeing men? Are they paid so that a reasonably full life is a possibility, or are they so ground down by poverty that they must give most of their thought to the vexed question of the cost of living?

Finally, is a successful effort made by the teachers to convey their largeness of view and breadth of outlook to their pupils? Do the students learn to understand that science does not affect mankind merely on the material side? Do they see that all the changes that science has brought about necessarily involve a profound mental and spiritual change—a change, so great, indeed, that it is well-nigh impossible for us thoroughly to sympathize with our grandfathers? Do they realize that science has thrust us into a new world and that our new surroundings have made us new men? Unless they appreciate this they can not be in real communion with the life of this age. They must live more or less apart, and move away from the great current that is sweeping the world along. Like Bernard Shaw, they must find that they were born in the seventeenth century and that they have not yet outlived it.

I might express this last test of efficiency otherwise by saying that you must look to the *cultural* element in the teaching of science—but I am afraid of the word "culture." It has been so terribly abused. Some speak as if the test of culture were the knowledge of Latin, or of Greek, or of French literature, or of Italian painting, or of what not. As a matter of fact it is none of these things, for I take it that the root of culture in any worthy sense of that word is *the possession of an ideal that is broad enough to form the basis of a sane criticism of life.* I hope that I need not turn aside to demonstrate the competency of science to present such an ideal. I willingly admit that some such ideal may be reached by various paths, through the study of literature, or of art, or of science. I should be the last to suggest that these are rival or mutually exclusive pursuits or that any one can justly claim a monopoly of culture. To know the best that has been said in literature and to use this as a touchstone in the criticism of the life of to-day, or to reach through art the ideal of perfection in form and color and make this broad enough to embrace life as a whole—each opens a promising avenue to culture. But how can a criticism of life be broadly enough based to-day unless the main results of scientific investigation lie at its roots and the method and the spirit of science be in the atmosphere that surrounds it? It can not, I think, be broad enough, unless we greatly exaggerate the part that science has played and is playing in the modern world. And I do not think that we exaggerate it, for practically all must recognize that there are few important problems of life to-day that science does not touch and touch most closely. This being the case, can a school be declared efficient that fails to give its students a vision and a grasp of the scientific ideal—an ideal that will guide them in the solution of all the complex problems that face individuals and face the state?

THE PROPHECY OF FRANCIS BACON (1560–1910)

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I. *Bacon and the Spirit of Discovery.*—There are several ways in which the importance of a philosopher may be estimated. He may be regarded as an exponent of his times; that is, as a representation in which the manifold tendencies of an age are focalized and idealized. Or he may be regarded as the author of a panorama of existence, of a world-view or system, which, while it may be superseded, will always retain enough of logical and imaginative coherence to make it typical and classic. Or the philosopher, like other servants of mankind, may be judged according to the degree in which he has been confirmed by posterity. Judged by this last standard, the great philosopher will be the philosopher who, while he may, like Bacon, have been born three hundred and fifty years ago, is nevertheless modern, in the sense that he is identified with important ideas which are now generally held to be true. This brief summary aims to present the Bacon that is living to-day in our common opinion, in our expert knowledge, and in our dominant ideals.

Any one who considers Bacon in relation to European civilization of the modern period must be impressed with the degree to which he represents its progressive ideas. Those characteristics of the sixteenth and seventeenth centuries which are most marked in Bacon are the characteristics in which they anticipate later centuries. It is possible for our immediate purposes to reduce these characteristics to one: the disposition, namely, to look for a betterment of human life from the advancement of knowledge. "Advancement of knowledge" does not here mean the education of the individual, but the winning of new truths by the race and for the good of the race. We may call this the spirit of discovery, where "discovery" is used both in the theoretical and in the practical sense. Bacon himself was not a discoverer of new scientific truths, but the discoverer of the art of discovery. As he expressed it, he "rang the bell that called the other wits together." While it is doubtless inaccurate to attribute so general an idea to any individual authorship, Bacon was its greatest prophet. His brilliant literary gifts, his imagination, his sanguine temperament, his breadth of view and his native regard for utility, the very qualities that helped to unfit him for exact research, made him the most important medium through which the idea of discovery, or of intellectual conquest, has gradually become the hope of mankind.

II. *The Baconian Reform.*—This idea was defined by Bacon largely in opposition to what he believed to be the blindness and errors of his own and earlier times. Philosophical literature nowhere else contains so acute and so comprehensive an examination of man's intellectual bad habits. Bacon's criticisms may conveniently be brought together under four heads.

First, he defined the persistent error of *anthropomorphism*. It is customary for man to fashion things after himself. He is deceived by what Bacon calls the "idols of the tribe" or the prejudices characteristic of human nature in general, and by the "idols of the den" or the prejudices peculiar to the individual. But if he is to view nature as it is, he must efface himself.

Second, he found the thought of his own time to suffer peculiarly from *conventionality*. It was customary for men to accept what was current and supported by general opinion. There are two important means through which arbitrary or ungrounded ideas are foisted upon belief: language, which gives rise to what Bacon calls the "idols of the market-place," and established systems, or theories which have the stage, and which give rise to what Bacon calls the "idols of the theatre." In the interests of truth it is necessary to guard against the suggestive power of words, which are often obscure or even meaningless, and against the inertia of doctrines that have acquired repute and prestige.

Third, it was customary in Bacon's time, to a degree that is scarcely intelligible to-day, to assent to theories of nature on grounds of *authority*, ecclesiastical or political. Bacon is among the first to formulate the principle of tolerance, according to which there is hope of knowledge, provided only that the mind be free from external constraint. The truth-seeking mind can acknowledge no obligations except to evidence.

Fourth, Bacon attacked the tendency, common at the time of the Renaissance, to rely on *antiquity*. The essentially modern character of Bacon's mind is nowhere more apparent than in his repudiation of the idea that dominated the revival of letters. He detected the dangerous fallacy which had arisen with the new study of the ancient languages and literatures. Historical retrospect inverts the intellectual values of the race. The wisdom of the ancients is but the folly of youth—*Antiquitas sæculi juventus mundi.* The hope of knowledge lies not in a return to childhood, but in a maturity yet to come.

III. *The Baconian Survey.*—As a pioneer in a new intellectual enterprise, it fell to Bacon to draw a rude map of the settled domain and border wilderness of knowledge. It is impossible here to enter into the merits and demerits of his classification of the sciences. Most interesting to us of the present is his explicit provision for what is now known as "applied science." But there can be no doubt of the service which Bacon rendered in making such a classification at all. To Bacon modern science is largely indebted for the sense of solidarity that obtains among all special investigators. He was, in a measure at least, responsible for the organization of the Royal Society in London, and of similar societies on the continent. He inspired the collective scientific movement of the Encyclopædists; and, directly or indirectly, the systematization of science made by Comte, Spencer and others. The present idea, then, that the several sciences are the members of one body, and that those who serve them are serving in one army to achieve the conquest of the unknown, is an idea to which Bacon testified clearly and effectually.

IV. *The Baconian Method.*—But Bacon did not merely point out the promised land and exhort men to discovery; he organized a plan of campaign. There is an opinion to the effect that while Bacon was enlightened in his general ideas, he was benighted in his particular ideas. This opinion is entirely unjust. Bacon does make many of the mistakes current in his time; and he deliberately makes many loose statements in the hope that they may prove suggestive and stimulating. Furthermore, he necessarily uses terms, such as "form," which, because they were borrowed from Greek and medieval thought, suggest to our minds something pre-scientific and obsolete. But this very term, as actually employed by Bacon, is the closest approximation in his time to the modern conception of cause, as employed in such sciences as molecular physics and chemistry. Furthermore, and be it said to his great and enduring credit, he was the great systematizer and popularizer of experimental method. The incompleteness of the Baconian method is the incompleteness of the experimental method. Although he did not by any means ignore it, it is true that Bacon did not adequately realize the importance of the quantitative or mathematical formulation of scientific laws. But this fact in no wise affects the correctness of his statement of the experimental method. The Baconian plan of research, avoiding technicalities, may be said to contain four important ideas, all of which have been approved and employed in subsequent scientific procedure.

His first and fundamental idea is that of *observation.* Bacon never wearies of reminding us that the mind must be brought into direct contact with things. In the study of nature, we may see, he believes, by the "ray direct." To avoid verbalism, dogmatism or ambiguity, it is necessary that the mind should be open to the facts, and that it should follow their leading. "We can only conquer nature by first obeying her." But Bacon understood the fruitlessness of desultory observation. For purposes of explanation all facts are not equally significant.

Hence, secondly, he was led to define certain methods or *canons of induction.* It was Bacon who first called attention to the importance of "glaring" or "striking" instances, in which the phenomenon under investigation is thrown into relief; "parallel" instances, which permit of the argument from analogy; and "crucial" instances, which serve as tests of contrary hypotheses. From Bacon, Mill derived the methods to which he gave such prominence in his *Logic,* the methods, namely, of "agreement," "difference" and "concomitant variation." By means of these methods it is possible to single out from among the circumstances attending or preceding the phenomenon to be explained, that which is its probable cause. That which is present when the phenomenon is present, which is absent when the phenomenon is absent, and which shows like quantitative changes, may be assumed to be connected with the phenomenon, and to point the way to its explanation.

But, thirdly, it is necessary to supplement observation of the natural course of events with artificial *experiments.* Nature, like men, will reveal her secrets only when put to the torture. Bacon was a consistent advocate of the first-hand manipulation of natural bodies. He saw this to be the only method of study which afforded any prospect of laying bare the more "subtle" physical phenomena, such as heat, light and the transmutation of substances. The later development of physics and chemistry not only confirmed this judgment, but in several signal cases fulfilled definite predictions which Bacon based on it.

Fourthly, Bacon recommended the *comparative* and *historical* method. He was one of the first to appreciate the importance of studying all phenomena that develop, in different stages of their development. In the particular case of anatomy, he called attention to the importance of studying the structure of organs in their simpler forms, and using the results as a key to the complex forms.

V. *The Baconian Pragmatism.*—Bacon's extraordinary modernism appears not only in his definition of sound and fruitful methods of scientific study, but also in his conception of the relation of science to civilization. And in nothing is he so modern as in this. He asserted that the hope of man lay in his advancing knowledge and control of nature. This idea is undoubtedly a present commonplace, but there are few philosophers that anticipate the commonplaces of mankind by three centuries and a half! But the idea is too fundamental properly to be called a commonplace. It is the most fruitful idea in modern life, the main presupposition of progress. Bacon sought to promote learning for the sake of power. That this is essentially a modern idea will be apparent to any one who will study the motives underlying earlier periods of European civilization. The ancient world had its critical and its dogmatic idea of progress. The former was that of national or racial aggrandizement, the conquest of territory and political control. The latter, contributed by the genius of Greece, was the humanistic idea of the intensive cultivation and refinement of human nature. These ancient ideas were superseded by Christian supernaturalism, which referred man's hope of salvation to another world which might be won by the repudiation of this. As christian Europe became secularized there developed the theocratic idea of a fixed system in which all human activities should be limited and controlled by religious authority. Finally, as a reaction against the established order, there appeared the idea of the Renaissance, an enthusiasm for antiquity, and desire to reverse the course of history. The modern idea, though it borrows something from all of these ideas, is fundamentally different. It bespeaks a solidarity of mankind in the enterprise of life, and in this manifests its christianity; and it derives from paganism a respect for human capacities, and a confidence in man's power to win the good for himself. But these motives are so united in the modern spirit as to produce something genuinely new. The good is to be won by the race and for the race; it lies in the future, and can result only from prolonged and collective endeavor; and the power to achieve it lies in the progressive knowledge and control of nature. This is the Baconian idea. The incentive to knowledge lies in its application to life. "For fruits and inventions are, as it were, sponsors and sureties for the truth of philosophies." Therefore, Bacon would have men of learning begin and end their study with the facts of their present environment. "For our road does not lie on a level, but ascends and descends, first ascending to axioms, then descending to works." In the last part of the *New Atlantis* there is a remarkable description of the riches of Solomon's House, the great museum and laboratory, the treasure house and workshop, which was "the lantern of this kingdom." The words with which the father of Solomon's House receives his visitors are a terse and eloquent summary of that which Francis Bacon prophesied, and which posterity has steadily achieved. "The end of our foundation is the knowledge of causes, and secret motions of things; and the enlarging of the bounds of human empire, to the effecting of all things possible."

JOHN DALTON AND HIS ACHIEVEMENT: A GLIMPSE ACROSS A CENTURY[1]

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IT is a melancholy reflection that the treasure laid up by great men in our memories should be corrupted often by the moth and rust of error. But, after all, this mischance roots in the nature of the case. Necessarily, our views of the past are synoptic, because the daily details, even of big events, escape us, much more the complex, ceaseless pulsations of the persons who have served their time and place rarely. Be we appreciative or critical, we lie under sore temptation to forget the inevitable limitations of human lot, and thus to lose perspective. Accordingly, my scientific colleagues,[2] with whom you have done me the honor to associate me in our effort to pay worthy homage to the genius of John Dalton (1766–1844), whose "A New System of Chemical Philosophy," although not completed in the second part of 1810,[3] had reached all its epochmaking significance, have requested me to introduce the subject with some account of the difficulties, amazing to us in our conditions, under which this strenuous pioneer labored. To this end, we must try to pierce the cultural inwardness of English life at the close of the eighteenth century, keeping in mind the peculiar qualities that characterize English science even yet.

I

As usual, the bare facts of Dalton's story need interpretation, the invisible atmosphere, their setting, imports much. Born 1766, in a little village of Cumberland, a county still remarkable for its sparse population, of a Quaker family, who eked out a precarious livelihood upon the home industry of woolen-weaving, Dalton's social relations isolated him from the chief cultural organs of the national life. Till the tender age of twelve he received such instruction as the local Friends' school afforded, and he appears to have made excellent use of his opportunities: then he went to work as a teacher there, and as a

[1] Read before the Research Club of the University of Michigan at its annual memorial meeting, devoted in 1810 to a celebration of the centennial of Dalton's atomic theory.

[2] Professor S. Lawrence Bigelow, of the department of chemistry, and Professor Karl E. Guthe, of the department of physics.

[3] It was never completed; the second part of the second volume did not appear.

hand in the paternal fields, for three years. At fifteen he migrated—literally walked!—to Kendal, forty-five miles away, where he taught in a mixed school, the venture of a cousin; and, remember, a mixed, local school in the England of that generation portends not a little respecting absence of amenity, appliances and opportunity. Here he spent twelve years, fruitful in many respects. For, the day's darg done, he contrived to improve himself by private study of Latin, Greek, French, mathematics, and "natural philosophy," with most important help and encouragement from John Gough[4] (1757–1825), the blind naturalist, celebrated by Wordsworth in "The Excursion."

> Methinks I see him how his eyeballs roll'd
> Beneath his ample brow, in darkness pained
> But each instinct with spirit, and the frame
> Of the whole countenance alive with thought,
> Fancy, and understanding; whilst the voice
> Discoursed of natural or moral truth,
> With eloquence and such authentic power,
> That in his presence humbler knowledge stood
> Abashed, and tender pity overawed.

In 1793 he removed to Manchester where, on Gough's recommendation, he had been appointed science tutor in New College, a Presbyterian institution, and, therefore, once more without the pale of national higher education; he held this position for six years, at a salary of $400. On the transference of the college to York, he resigned, and gave himself to private tuition, an exiguous vocation, sufficient for daily bread. But the Manchester experience proved a turning point, for it offered an environment wherein he could make pure science his avocation. From 1786 Dalton had been engaged in meteorological observations, and published his maiden work in the autumn of 1793—"Meteorological Observations and Essays." Printed for the author, it failed of due publicity. Thanks to his connection with the Manchester Literary and Philosophical Society, he read his famous paper, "Extraordinary Facts Relating to the Vision of Colours," in October, 1794, a month after his election. In 1801 he presented his first classical research, "On the Constitution of Mixed Gases," which was followed by three memorable papers, "On the Force of Steam or Vapor from Water and other Liquids in Different Temperatures, both in a Toricellian Vacuum and in Air," "On Evaporation" and "On the Expansion of Gases by Heat." In the last he enunciated the law of expansion of gases formulated by Gay-Lussac a few months later.

It was in 1802, after six years of research in chemistry, that he referred to the possibility of multiple proportionate combinations of the elements, in a paper entitled "On the Proportion of the Several Gases or Elastic Fluids Constituting the Atmosphere." The atomic symbols

[4] See "Dictionary of National Biography," sub voce.

devised by him are first found in his note-book under the date September 6, 1803; and, under the same date there is a table of atomic weights, showing that, by this time, he had grappled with the fundamental problem—that of fixed "relative weights of the ultimate particles of bodies." For unknown reasons Dalton appended it, in a somewhat different form, to a paper "On the Absorption of Gases by Water," read before the Manchester Society in October, 1803, but not published till November, 1805. The table was added during the interval between presentation and publication. The summer of 1804, as Dalton himself tells us, was the crucial period of the investigation. The first part of the first volume of the "New System of Chemical Philosophy," published in 1808, gives the mature theory, while the second part of 1810 describes the chemical elements in detail. Dalton was now forty-four. And it is significant that, although he had lectured twice at the London Royal Institution, and in Glasgow and Edinburgh as well, the French Academy of Science recognized his merits six years[5] before any native body. In 1822, Dalton being fifty-six, the Royal Society honored itself by his election. Another decade elapsed ere Oxford conferred her D.C.L., on the occasion of the second meeting of the British Association, and he was sixty-eight when Edinburgh enrolled him among her honorary doctors. In 1833, the government took note of his services, and he received a civil list pension, increased afterwards in 1836, when the announcement was publicly made under dramatic circumstances by Sedgwick, at the Cambridge meeting of the British Association. "The imagination may picture, if it can," writes Roscoe, "the feelings of the son of the poor Eaglesfield handloom weaver as he sat in the Senate House of the University of Cambridge listening to this eulogium—the observed of all observers."[6] As Sedgwick remarked in his striking speech, "without any powerful apparatus for making philosophical experiments—with an apparatus, indeed, many of them might think almost contemptible—and with very limited external means for employing his great natural powers, he had gone straight forward in his distinguished course, and obtained for himself, in those branches of knowledge which he had cultivated, a name not perhaps equaled by that of any other living philosopher of the world."[7] Evidently, then, Dalton wrought under grave disadvantages. What were they?

We would all agree, I take it, that certain results of human activity must remain intimately personal, and that, as a consequence, they must vary from age to age, or diverge even among different peoples in the same epoch. Art and poetry, religion and, possibly, some portions of philosophy, can not well escape these very subtle contrasts. But, with

[5] Cf. "John Dalton and the Rise of Modern Chemistry," Sir Henry E. Roscoe, p. 175.

[6] *Ibid.*, pp. 204, 205.

[7] *Ibid.*, p. 203.

Wissenschaft, particularly in that development of it known to us as positive science, the case stands far otherwise. Yet, even here, the unification of knowledge, each nation contributing its quota to the common fund, happens to be perhaps *the* achievement of the nineteenth century. Organization by countries, especially in the case of France, there was between the Renascence and the French Revolution; but a world-wide pact, embracing all effort, no matter where, did not eventuate then. Now, it is of prime moment for the present subject that the instruments of this recent unification have been the German university system, and the academies and institutes of France. By contrast, the English-speaking world possessed no such developed organs, if we except the Scottish universities where, naturally enough, Dalton met immediate recognition. Thus English science till but yesterday—*teste* even Darwin—has betrayed individualistic tendencies. These were never more evident than in Dalton's career, and during his life, moreover.

At the beginning of the nineteenth century, when Cuvier, in his "Rapport" of 1808, is extolling—and justly—the preeminence of France in the exact sciences, an extraordinary contrast manifests itself across the Channel. In the same year, John Playfair bewails the "incontrovertible proofs of the inferiority of the English mathematicians," and refers to "the public institutions of England" as its cause.[8] Eight years later, in a damnatory notice of Dealtry's "Principles of Fluxions," another writer notes it for a paradox that, Newton dead, his country "should, for the last seventy or eighty years, have been inferior to so many of its neighbours."[9] Once more, in the same review for 1822, a third critic deplores the state of affairs at Cambridge, where "for want of facilities" men "are apt to lose the spirit of investigation." Brewster's article in the *Quarterly Review*[10] which, as is well known, led to the foundation of the British Association, is no less sarcastic and outspoken. These attacks were directed against the English universities:[11] that of Babbage, the peg on which Brewster hung his exordium, had the Royal Society for its mark.[12] Now the extraordi-

[8] Cf. *Edinburgh Review,* No. XXII., January, 1808, pp. 249 f. A review of La Place's "Traité de Mécanique Céleste."

[9] *Ibid.,* No. LIII., September, 1816, pp. 87 f. (Dealtry was a fellow of Trinity College, Cambridge, and a fellow of the Royal Society.) Dalton himself made the same complaint in his lectures at the London Royal Institution (1810); cf. "A New View of the Origin of Dalton's Atomic Theory," Roscoe and Harden, p. 105.

[10] Vol. XLIII. (1830), pp. 305 f.

[11] Analogous circumstances produce analogous protests even now—*e. g.,* "Oxford at the Cross Roads," Professor Percy Gardner (1905).

[12] "Reflections on the Decline of Science in England, and on some of its Causes," by Charles Babbage, Lucasian professor of mathematics in the University of Cambridge (1830).

nary thing is that, prior to and during these years, or, to be quite exact, between 1774 and 1828, Britain had contributed at least a dozen discoveries of the first magnitude, and as many more of scarcely less importance. As you all know for what each stands, I need only mention Priestley, Black, Landen, Davy, Benjamin Thompson, Cavendish, Herschel, Nicholson and Carlisle, Dalton, Young, Wollaston, Ivory, Robert Brown, Charles Bell, Brewster, William Smith, Prout, Faraday, George Green and Rowan Hamilton. Still more wonderful, continental leaders were well aware of these contributions, and wont to emphasize them. In 1821, Cuvier gave most generous testimony: and Moll, of Utrecht, repelled Babbage's criticisms with no uncertain sound, remarking, "all must allow that it is an extraordinary circumstance for English character to be attacked by natives and defended by foreigners."

Although I can not comment upon the ramifications to-night, the puzzle has some obvious causes. The English universities were not scientific organs, but groups of residential colleges. The advancement of science was no *primary* part of their purpose, precisely as the laborious elevation of incompetents to a bare level of possible passability was no *primary* part of the purpose of the German universities or the French institutes. The colleges cherished their individuality fondly, because they aimed to produce a certain type of man for life—to anneal him by forming his *ethos*, and to fit him for the exercise of civic influence by giving him a respectable general acquaintance with the "things of the mind." In a word, the English universities did not exist to promote science or learning, any more than the continental organizations existed to provide an educational top-dressing for the sons and daughters of "the people." So, too, of pure thought. The apostolic succession of English philosophers—Bacon, Hobbes, Locke, Berkeley, Hume, the Mills, Spencer, even our contemporaries, Hodgson, Balfour, Shand, Haldane and Bertrand Russell—do not adorn the universities. Again, the peculiar position of the metropolis, its new university in the melting-pot at this moment, must be taken into account. Lacking the academic center, its scientific societies could not be organized for the advancement of discovery after the style of French and German associations.[13] These causes, together with the distinctive arrangement of English society a century ago, tended to render the great scientific pioneers lonely figures, sitting loose to the main expressions and modes of national culture. The wails over the condition of English science are traceable as much to this severance, with its absence of constant intercourse and cooperation, as to aught else. How Priestley and Dalton and Joule, Young and Davy and Faraday were hampered by these

[13] For example, in the preface to "A New System," Dalton makes the (to us) astounding statement, that he did not know whether the abstracts of his lectures, left by him for this express purpose, had been published in the *Journals* of the Royal Institution. Some five years had elapsed since their delivery!

circumstances is notorious. Others, like George Green, received no recognition whatsoever. In addition, the English passion for independence played its part. The demand for complete freedom, if it fostered the eccentricity of which the docile, drilled Germans complained, although it led to pig-headedness, as in Dalton's case, also proved greatly favorable to original genius. For, it is well to recall that more original notions, basal to modern science, have come from England than from any other land, even if, as with Newton and Darwin, France was to systematize *Newtonianisme*, Germany *Darwinismus*. England possessed no trained regiments to accomplish these things. Accordingly, if we remember all this, some apparent mysteries that cloak Dalton's career and mental characteristics begin to dissipate. In short, the Dalton we commemorate would have been nigh inconceivable had he been "born to the intellectual purple of the ancient universities"; but the Dalton we regret, who remained obdurate to Gay-Lussac despite Berzelius's intercession, might never have been. The qualities of the man, like his defects, pertained to his strong, wayward and undisciplined, if narrow and often uncouth, provincialism. *Qui a nuce nucleum esse vult, frangat nucem.*

II

Dalton maintained silence from 1793 till 1799, hindered, perhaps, by college duties. On reappearance, he soon dropped the rôle of meteorologist for that of chemist and physicist. The new line was taken in the paper entitled "Experiments and Observations on the Power of Fluids to Conduct Heat, with Reference to Count Rumford's Seventh Essay on the same Subject," read before the Manchester Society on April 12, 1799. The simple nature of his apparatus may be illustrated aptly from this communication.

> Took an ale glass of a conical figure, 2½ inches in diameter, and 3 inches deep; filled it with water that had been standing in the room, and consequently of the temperature of the air nearly. Put the bulb of a thermometer in the bottom of the glass, the scale being out of the water; then having marked the temperature, I put the red-hot tip of a poker half an inch deep in the water, holding it there steadily for half a minute; and as soon as it was withdrawn, I dipped the bulb of a sensitive thermometer about ¼ inch, when it rose in a few seconds to 180°.[14]

Then follow the tabulated temperature results. Another experiment, described in the same paper, suffices to show that Dalton had pondered the discontinuity of matter thus early. Having mixed hot and cold water for half a minute, he proceeded to determine whether the upper layer became warmer than the lower. Observing that it did not, he remarked: "If the particles of water during the agitation had not

[14] *Memoirs of the Literary and Philosophical Society of Manchester*, Vol. V., p. 381.

actually communicated their heat, the hot ones ought to have risen to the top, and the cold ones subsided, so as to have made a material difference in the temperature."[15] Furthermore, these and many other experiments afford us indications of his mental habit as a scientific investigator. Conceptual processes find him at his best; his theoretical expectations and deductions are good. In experiment he is not so happy, and what we understand by "fine" or refined work occurs seldom. Thus, in the case just cited, Dalton infers "that the expansion of water is the same both above and below the point of maximum density." But, when he comes to determine this crucial point precisely, he goes wide of the mark, setting it at 36°.

These references may enable us to grasp his manner of approach to a problem, and to realize his general plan of attack upon the atomic constitution of matter as it stood when he entered the field.

I wish that space permitted me to present some consecutive account of the doctrine of "matter" as it developed down the ages—but this is impossible. The subject deserves attention, because so bemused in the minds of the laity. And not only this. Scientific men themselves misconceive it at times, not deliberately indeed, but because, absorbed in researches of immediate moment, they have not troubled to follow the marvelous story with patience. The long, tortuous endeavors that culminated in Dalton's atomic theory, with its kernel, the law of multiple ratios, are the tale of man's attempt to reduce his notion of "matter" to *conceptual* simplicity; this to the end that it might be rendered an obedient instrument. Freed from contingent accessories, the central problem was this: Given such a vast multiplicity and variety of phenomena as the "substantial" world presents, how can all be grasped under a single, synthetic idea? Plainly, whenever man began to reflect upon nature, he encountered this sphinx. The elusive, yet persistent, relationship between the one and the many forms part of ancient history in science no less than in metaphysics.

Now, stating the situation very synoptically, and omitting the metaphysical reference in favor of the natural-scientific, it may be affirmed that the problem itself is also a many in a one. For, if we are to reach clear concepts about natural phenomena, we must reckon with three investigations at least. In the first place, a particular phenomenon must be selected, and treated as the starting point. This done, it is requisite to obtain an all-round view of *what* it is. In the second place, one must proceed to elucidate its relations to other phenomena, preferably to those which evince evident, or apparent, kinship. In the third place, order must be induced in the relations that have thus come under observation by reducing them, as far as possible, to numerical expression. The primary methods of weighing, measuring and enumeration

[15] *Ibid.*, p. 385.

must be invoked. This achieved, we may assert that we have arrived at that species of conceptual simplicity which we call a "law of nature." On a broad view, it is fair to say that, prior to Dalton, investigation and fancy pursued the one (*i. e.,* the conception of "matter") through the many (*i. e.,* these three aspects of the problem). For, on the whole, till we come to J. J. Becher (1635–82) and G. E. Stahl (1660–1734), the element theory held the field. And this is only to affirm that men were trying to master the properties of particular bodies, while reserving the remoter question of the ultimate constitution of "matter." Roger Bacon's view, probably the least fantastic we possess, is exceedingly significant of this.

There are four Elements—fire, water, air, earth; that is, the properties of their condition are four—heat, coldness, dryness and wetness; and hyle is the thing in which there is nor heat, nor coldness, nor dryness, nor wetness, and a body is not. And the Elements are made of hyle; and each of the elements is transmuted into the nature of the other element and everything into everything else. For barley is a horse by virtual possibility, that is, occult nature; and wheat is a man by virtual possibility, and a man is wheat by virtual possibility.

The age of phlogiston, with its theories of combustion, marks a move to the second question. Men are now engaged in an effort to relate phenomena. Or, as Stahl puts it, in his conspectus: Combustible substance *minus* phlogiston is burnt substance—*e. g.,* metals, sulphur, phosphorus, etc., *minus* phlogiston, are metal calxes, sulphuric and phosphoric acids, etc. On the other hand, burnt substance *plus* phlogiston is combustible substance—*e. g.,* metal calxes, sulphuric and phosphoric acids, *plus* phlogiston supplied by carbon, are metals, sulphur, phosphorus, etc. In a word, the most different phenomena, such as the burning of carbon and the calcination of a metal, are shown to belong to the same class, and to be explicable by a simple conceptual hypothesis. Finally, when Lavoisier sent phlogiston by the board, the third question came to the fore, and men began to ask, How can we weigh, measure and enumerate the exact degree of relationship between the properties of substances? Dalton ranks among the great epoch-makers, because he first brought this inquiry within the range of practicable *uniformity.*

Discussions about prior discovery, over which much time and no little temper have been expended, prove profitless affairs, as a rule. You see, error and loyalty are human. For instance, I am well aware that scientific chemistry is dated usually from 1776, when Lavoisier made the balance *the* chemical instrument: but you will bear with Sadler[16] and me if we travel a little farther back and, as loyal sons of alma mater, find the initial point in the classical investigation of latent heat, conducted by Black between 1759 and 1763, at Glasgow. Nevertheless, as Dalton's priority has been impugned, we are bound to consider the facts.

[16] Herbert C. Sadler, professor of naval architecture.

Of course, every one knows that the conception of the discontinuity of "matter" appears in ancient history. And, when we descend to modern times, Boyle (1627–91) speaks of corpuscles, Boerhaave (1668–1738), Albrecht von Haller's master, of *massulæ*. Moreover, Dalton was a youth of only seventeen when the most important developments occurred. First, and with special reference to the framework of possible method, we have Lavoisier's (1743–94) celebrated memoir, "Reflections concerning Phlogiston," where he dismisses the dominant theory in sarcastic terms,[17] and establishes the *quantitative* method on a firm basis. In the same year (1783) Bergman (1735–84), the last of the great phlogistic chemists, published his notable work on what he called "elective attraction" (*i. e.*, affinity), a phenomenon attributed by him to the attraction between the most minute particles. Naturally, Bergman's table of "single elective attractions in the moist way, and in the dry way," with its curious alchemical signs, was a description of *qualitative* relations. It marked the beginning of investigation of mass action, and provoked the striking researches of Berthollet (1748–1822), who, in 1799, presented his paper, "Recherches sur les lois de l'affinité," out of which grew his major work, "Essai de statique chimique" (1803). The main result of his assault upon Bergman was to show that chemical change depends, not merely upon the affinities of the substances involved, but upon their *quantities*. In other words, a new method asserted itself. For, as Berthollet says:

> To find the affinity of two substances towards a third, in accordance with the conception we have now gained of affinity, can mean nothing other than to determine the *ratio* in which this third substance divides itself between the two first.

Therefore, chemical change hinges upon the nature of the relative *masses* of the substances involved, but, "to determine the ratio of the affinities of two substances towards a third . . . is attended by unsurmountable obstacles." Here was the blank wall, so to speak, that shadowed Berthollet's services till the time of Guldberg and Waage (1864). As Berthollet stood to Bergman, so did Proust (1755–1826) to Berthollet. Baffled in every attempt to determine the distribution of salts in solution, Berthollet had good reason to doubt the doctrine of constant composition. Here was Proust's opportunity. Having distinguished between "combinations of elements" and "associations of combinations," the latter variable under analysis, Proust was able to enunciate the law of fixed proportions—in his own words, "Election and proportion [*i. e.*, affinity and fixity of composition] are the two poles about which revolves immutably the whole system of true compounds, whether produced by Nature or by Man"; or, as Lothar Meyer phrases it, "Definite chemical compounds always contain their con-

[17] Cf. "Œuvres," Vol. II., pp. 623 f.

stituents in *fixed* and *invariable* proportions." Notice, in the words I have italicized, the unanimous trend towards *quantitative* measurements and accuracy, the ruling notion being that of *numerical ratio.*

We come to closer quarters with our central theme in the work of Richter (1762–1807), an investigator, it is important to note, obsessed by mathematical methods. Despite his obvious idiosyncrasy, Richter arrived at the law of equivalent ratios—"The qualities of acids and bases equivalent in one neutralization are equivalent in all." In 1802 Fischer made Richter's conclusions known to Berthollet, and chemical ratios became an integral part of the science. As Wollaston says, in 1814:

> It is to Richter we are originally indebted for the possibility of representing the proportions in which the different substances unite with each other in such terms that the *same substance* shall always be represented by the *same number.* He discovered the law of permanent proportions.[18]

The experimental proof was clinched by Berzelius in 1811–12, and the law of "permanent" or "definite" ratios, as it is called now, put the problem of composition on a practicable footing.[19] It should be noted also that, in stating the numerical values of the elements, Dalton employed some determinations of other chemists, at all events as checks.

We are now in a position to see that series of complicated researches, all looking to *quantitative* results, furnished Dalton with material which enabled him to render the atomic theory perspicuous and applicable from the very outset. Notwithstanding, to him must be given sole credit for the final simplification, which had been exercising his mind for some eighteen years—since 1790, in fact. A quotation from Berthollet's "Essai" (1803) may suffice to emphasize the long step due to Dalton's insight.

> Some chemists, influenced by having found determinate proportions in several combinations, have frequently considered it as a general law that combinations should be formed in invariable proportions; so that, according to them, when a neutral salt acquires an excess of acid or alkali, the homogeneous substance resulting from it is a solution of the neutral salt in a portion of the free acid or alkali. This is a hypothesis which has no foundation, but a distinction between solution and combination.[20]

Undoubtedly, events tended towards the new climate of opinion, nay, this had become so far prevalent that the Irishman, William Higgins (17?–1825) came nigh playing Wallace to Dalton's Darwin. Indeed, in 1814, he raised a claim to priority, which was disproved at once by Thomson, the Glasgow chemist who had made Dalton known. This Higgins is to be distinguished from his uncle, Bryan Higgins

[18] The italics are mine.

[19] Reference should be made to the classical experiments in further confirmation by Stas (1865).

[20] Cf. Lambert's English translation, p. 39.

(1737–1820), who, in 1775, in a prospectus of lectures, proposed to discourse of "his notions and experiments concerning the primary elements and properties of matter," and of "experiments, observations and arguments, persuading that each primary element consists of atoms homogeneal: that these atoms are impenetrable, immutable in figure, inconvertible, and that, in the ordinary course of nature, they are not annihilated, nor newly created." He also conceived of atoms, of simple particles, and even of gases, as uniting *sometimes,* in approximately, if not completely, fixed proportions. Yet, he never arrived at true causes, because his experiments failed to dove-tail with his advanced theoretical suggestions. Accordingly, the explicit variety of the former destroyed the implicit unity of the latter, and the *status quo ante* was maintained.[21] William Higgins, the claimant of 1814, published his book[22] in 1789. It contains forecasts of the atomic theory, such as the following:

> I am likewise of opinion that every primary particle of phlogisticated air is united to two of dephlogisticated air, and that these molecules are surrounded with one common atmosphere of fire.[23]

But, after all, less than a dozen pages of the 300 deal with the subject; and, although he assigned causes for definite proportion and saturation in a few cases, he never suspected a simple, universal and necessary law. His real acuteness led him to see that combining particles had the same weight (multiple proportions), but he missed his chance to generalize in a maze of suspicions directed against the phlogistic theory, which had already lost its primacy; his indolence also hindered him, like his eccentricity.

III

Finally, coming to Dalton's characteristics as a thinker, we may find the clue in his forcible independence. In the preface to Part II. of "A New System of Chemical Philosophy" (1810), he declares:

> Having been in my progress so often misled, by taking for granted the results of others, I have determined to write as little as possible but what I can attest by my own experience. On this account, the following work will be found to contain more original facts and experiments, than any other of its size, on the elementary principles of chemistry.

Here the strong man places himself on record, and the question of priority takes to flight. Accordingly, I state it as my clear impression that the merits and defects of his achievement are alike traceable to the fact that our laureate lay under direct obligation to but one of his

[21] His chief work is, "Experiments and Observations relating to Acetous Acid, Fixable Air, Dense Inflammable Air, Oils and Fuel, etc." (1786).

[22] "A Comparative View of the Phlogistic and Antiphlogistic Theories, with Inductions, etc."

[23] P. 132 (2d ed., 1791).

predecessors—Newton. Dalton encountered certain phenomena, such as multiple and definite proportion, aqueous vapor as a distinct constituent of air, and, seeking for the simplest common representation, found it in Newton's well-known doctrine. For example, he says:

According to this view of the subject [heat], every atom has an atmosphere of heat around it, in the same manner as the earth or any other planet has its atmosphere of air surrounding it, which can not certainly be said to be held by chemical affinity, but by a species of attraction of a very different kind.[24]

And he quotes from Newton:

All bodies seem to be composed of hard particles. . . . Even the rays of light seem to be *hard* bodies, and how such very hard particles which are only laid together and touch only in a few points, can stick together, and that so firmly as they do, without the assistance of something which causes them to be attracted or pressed towards one another, is very difficult to conceive.[25]

This was the secret of the opposition of Hope and, later, of Faraday's complaint. In a letter, dated January 2, 1811, Hope wrote to Dalton as follows:

I need not conceal from you that I am by no means a convert to your doctrine, and do not approve of putting the result of speculative reasoning as experiment.

While Faraday, similarly suspicious, as late as 1844, said:

The word atom, which can never be used without involving much that is purely hypothetical, is often *intended* to be used to express a simple fact. . . . There can be no doubt that the words definite proportions, equivalents, primes, etc., . . . did not express the hypothesis as well as the fact.[26]

The truth is that Dalton was a first-rate theorist, who arrived at his conclusions, not primarily on the basis of induction from experiment, but by reflection. Analogically, he imports the view of "matter" peculiar to celestial mechanics, through molecular physics, into the realm of chemistry. Proceeding thus deductively, he evinces little awareness of the very complex problems involved, which the later developments of the atomic theory were to reveal. Cut off from the world, he did not possess intimate acquaintance in detail with the labors of his immediate predecessors and contemporaries—a happy accident, no doubt. For, this freedom from puzzle and disturbance enabled him to proceed boldly with a generalization when men of the caliber of Wollaston and Davy hung back. Dalton had natural capacity for logical thought, and complete confidence in the validity of those mathematical syntheses of *physical* facts which he had pondered.

But, as happens frequently, his limitations are traceable to the same source. Like Kant before him, Dalton became so entangled in the theoretical ways of his own thought that, after he had promulgated his

[24] *Manchester Memoirs*, Vol. II. (2d series), pp. 287 f.

[25] Royal Institution Lecture Notes.

[26] "Experimental Researches," Vol. II., pp. 285 f.

theory, he stopped short in middle life, and could not appreciate the work of others who followed and supported him. This is the blot on his 'scutcheon. Still, even so, we must hold the balance true. The kinetic doctrine of "matter," integral to the Cartesian philosophy, had paled before Newtonian atomism. And Dalton had grasped Newton's view so logically that he could not admit the law of equal volumes, because, as he held, "no two elastic bodies agree in the size of their particles." The very success of his hypothesis blinded him to Gay-Lussac's experimental evidence—it would not conform to the conceptual scheme. As he wrote to Berzelius, in September, 1812:

> The French doctrine of *equal measures* of gases combining, etc., is what I do not admit, *understanding it in a mathematical sense.* At the same time I acknowledge there is something wonderful in the frequency of the approximation.[27]

Of course, the fact was that, as Wurz points out,

> The relation which exists between the densities of gases and their atomic weights is not so simple as we should at first sight be led to expect, and as for a long time it was thought to be.[28]

Nay, "understanding it in a mathematical sense," Dalton had his reasons. By a kind of paradox, the very simplicity of his notion befogged him here, just as the problems bred of the atomic theory diverted chemists for many a long day from the study of affinity.

We may conclude, then, that the logical character of Dalton's mind enabled him to formulate the timely conceptual representation on which chemical logic has pivoted ever since; that his numerical conception has stood the test of further discovery better than most hypotheses; and that, little as he knew it, or could admit it at the moment, he laid the foundation for that intimate alliance between physics and chemistry which forms one of the most pregnant among contemporary movements. For, the active criticism of the atomic theory—that it dogmatizes about the physical constants marking the differences between the elements, that it reveals little or nothing of the *processes* incident to chemical composition and destruction, that it neglects synthesis—testifies also, if negatively, to the revolution wrought by its author. Pity is akin to praise here. And to-night, as we celebrate Dalton's "thoughts that breathe," we are bound to let praise have its free way, especially when we contemplate the indomitable devotion of a character who, amid sore difficulties, but furnished with the splendid spur of consecration to the ideal, achieved so much for man's conquest of the secrets of nature.

[27] The italics "understanding," etc., are mine.

[28] "The Atomic Theory," p. 35 (English translation).

Alexander Agassiz.

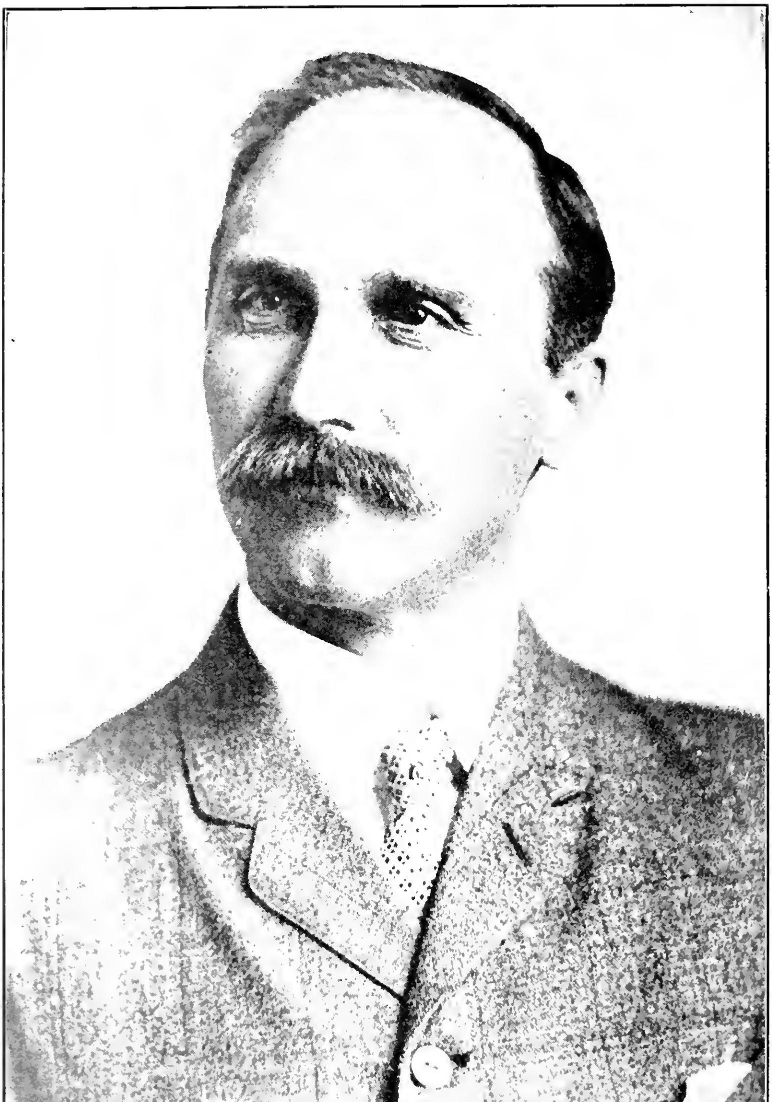
THE PROGRESS OF SCIENCE

THE DEATH OF ALEXANDER AGASSIZ

In the death of Alexander Agassiz, America loses its foremost naturalist, as a few months ago in the death of Simon Newcomb it lost its most eminent representative of the exact sciences. Both were born in the year 1835, and in a century preeminent for science both gave distinction to this country when it was relatively backward in scientific productivity. Each maintained his intellectual leadership and continued his researches and publications to the very end of a long life. America is no longer behind the nations of Europe in the number of its scientific workers, but among them all are none to take the places left vacant by Agassiz and Newcomb.

Alexander Agassiz was endowed at birth with the heritage of his great father, Louis Agassiz, whose work at Harvard he carried forward. Born in Switzerland, he came to the United States in 1849 at the age of fourteen and graduated from Harvard College in 1855, continuing graduate studies in mining and chemistry in the Lawrence Scientific School. In 1859 he went to California as an assistant on the coast survey and in the following year became assistant in the museum founded by Louis Agassiz, during whose absence in Brazil he was in charge. From 1866 to 1869 he was engaged in mining in the Lake Superior region and became superintendent of the Calumet and Hecla copper mines of which he was president at the time of his death. He thus acquired abundant wealth, and was able to give more than half a million dollars to the Harvard Museum of Comparative Zoology and to conduct as he wished his oceanographical expeditions.

In 1869 Mr. Agassiz visited European museums and on his return in 1870 renewed his duties at the Harvard Museum, of which he became curator and director on the death of Louis Agassiz in 1873. He was for a series of years one of the seven fellows who form the corporation of Harvard College, and was on two occasions elected an overseer. In 1875 he visited the western coast of South America and subsequently went to England to assist with the reports of the *Challenger* expedition, writing the monograph on the Echini. Previously and subsequently to the end of his life, he made a great number of valuable scientific contributions to marine zoology, the embryology of fishes and coral reefs. In awarding to him its Victoria research medal, the report of the Royal Geographical Society said "he has done more for oceanographical research than any other single individual" and summed up his work by noting that for thirty years he had carried out personally oceanographical expeditions over most of the oceans of the world. In 1877–80 he explored the Florida Straits and Gulf of Mexico, the Atlantic Coast and the Caribbean Sea. In 1880 he studied the surface fauna of the Gulf Stream; in 1892–4 he investigated the Sandwich Islands, studying recent and extinct reefs. In 1891 he conducted three cruises off the West Coast of Central America, and in 1895–6 he studied the Great Barrier Reef of Australia and in 1897–8 the Fiji Islands. In 1899–1900 he carried out a cruise from San Francisco via the Coral Island groups to Japan. In 1904–5 he investigated the eastern tropical Pacific. In the Indian Ocean in 1901–2 he devoted himself to the Maldive Islands. In 1874–5 he investi-



Charles Reid Barnes.

gated Lake Titicaca. Mr. Agassiz has done this entirely at his own expense. The results have been published by him through the Museum of Comparative Zoology at Harvard College, in thirty volumes of memoirs and fifty-three volumes of bulletins, mostly containing the results of his own various expeditions and of the work of the specialists who examined his collections. Besides the numerous publications through the Harvard Museum, in 1888 Mr. Agassiz published in two volumes the narrative of his three cruises in the Gulf of Mexico, the Caribbean Sea, and along the Atlantic Coast of the United States, with charts and illustrations.

Mr. Agassiz had been president of the National Academy of Sciences, and was a foreign member of the leading academies of the world. He was not only the author of important contributions to science, but was also a great man, possessed of complete courage and frankness and a dominant will, which gave him leadership throughout the broad and rich experiences of his long life. As he was happy in his birth and in his life, it may be said that he was not ill-starred in his death, for he died with faculties undimmed, suddenly, on the sea, which he loved so well and had explored so persistently.

CHARLES REID BARNES

The death of Dr. Charles Reid Barnes, professor of plant physiology at the University of Chicago, as the result of a fall, is a serious loss to botany. He was born at Madison, Ind., in 1858 and was educated at Hanover College and Harvard University. After occupying successively the chairs of natural history and of botany and geology at Purdue University, he was called to the chair of botany at the University of Wisconsin in 1887, where he remained until he took up his final work at Chicago in 1898. During all of these years he was associated with Professor Coulter in the editorship of the *Botanical Gazette*. Professor Barnes had served as vice-president of the botanical section of the American Association and as president of the Botanical Society of America. Professor Barnes's best known earlier publications dealt with the taxonomy of mosses. Just before his death he completed the final proof-reading of the physiological part of a general text-book of botany that is expected soon to appear from the Hull Botanical Laboratory. Within the past few years Professor Barnes had become greatly interested in morphological problems among the bryophytes, two papers having been already published in conjunction with Dr. Land and several others being partly ready.

THE TROUBLES AT PRINCETON

The secret history of almost any American university is not less complicated than recent events at Princeton, but it is certainly unusual for such family quarrels to be so completely exploited before a public which can scarcely be expected to understand them. It is, however, probably not a bad thing for a university to conduct its affairs in the open and for large numbers to become interested in them, even though the principles involved may not be so vital as they appear to those immediately concerned. Probably the circumstance of greatest general interest at Princeton is the control exercised by the alumni. This is a factor likely to become increasingly important in the history of our universities, and it is not without its dangers, for the alumni bear gifts and are more likely to be concerned with athletics and fraternities than with scholarship.

The outlines of the Princeton story are now common property. Dean West has long urged with enthusiasm a graduate college on the lines of the Oxford colleges and President Wilson approved the plan. Then came President Wilson's move against the clubs—fraternities are forbidden at Princeton—and in favor of more democratic "quads," which divided the faculty and trustees and awakened the opposition

Lieutenant Ernest Shackleton,
the eminent arctic explorer, who is at present lecturing in the United States.

of the rich alumni. The Swan bequest of $300,000 for a graduate college then became available, and there was difference of opinion as to its site. Mr. W. C. Proctor at this stage offered to give $500,000 for the graduate college as planned by Dean West and on condition that an equal sum should be subscribed by others. There was again difference of opinion as to the site and the control of the college, and while the president and a committee of the trustees were trying to come to an agreement with Mr. Proctor, he withdrew his gift.

The question of site is somewhat trivial except in so far as it has become identified with policies. Whether the residence hall should be in the midst of the Princeton campus or on its outskirts can not be a matter of serious consequence. The fact is that the president of the university and some of the trustees were unwilling to place the dean of the graduate school in as complete control of its development as the acceptance of Mr. Proctor's gift might have implied. The real trouble is one of men rather than of measures.

It is a curious circumstance that President Wilson and Dean West are in pretty close agreement in favor of a financial democracy and of an intellectual aristocracy or snobbishness, as one may please to call it. When Dean West favors a residential college with oak-panelled dining hall in which the students shall dine in evening dress, he does so because he wishes to give the young men without money a chance to live in the environment which he regards as proper to the scholar and the gentleman. The ideal of such a college was well put in an address made some years ago. We read of

> a place removed—calm Science seated there, recluse, ascetic, like a nun, not knowing that the world passes, not caring, if the truth but come in answer to her prayer; and Literature, walking within her open doors, in quiet chambers, with men of olden time, storied walls about her, and calm voices infinitely sweet; here "magic casements, opening on the foam of perilous seas, in fairy lands forlorn," to which you may withdraw and use your youth for pleasure.

Those who have followed the recent Princeton controversy may be surprised to learn that this not a quotation from Dean West, but from the concluding part of Dr. Wilson's address on the occasion of the Princeton sesquicentennial celebration. It might be that President Wilson had learned new things in the meanwhile, but at the meeting of the Association of American Universities a couple of months ago, he presented a paper urging the old ideas of amateurism and dilletantism in college studies. He writes:

> All specialism—and tnis includes professional training—is clearly individualistic in its object; that is, the object of professional training is the private object of the person who is seeking that training. . . . The minute professionalism enters learning, it ceases to wear the broad and genial face of learning. It has become a commodity; it has become something that a man wishes to exchange for means of support. It has become something that a man wishes to use in order to get the better of his fellowmen; to enhance his fortunes; to do all the things that center in and upon himself; and it is professionalism that spoils the game, the game of life, the game of humanity, the game of cooperation in social undertaking, the whole handsome game that we are seeking to throw light upon by the processes of education.

It is a remarkable and interesting fact that Princeton is becoming a great university and a great scientific center almost in spite of those in control. The large gifts made to the university have found their way to build fine laboratories and to secure scientific men of the first rank. The preceptors intended for less modern purposes brought to Princeton a large group of younger men from various institutions who have given it new life. The efforts for a graduate residential college, which in Dean West's words should "show that God is the end of all our knowing and

Christ is the Master of the Schools," or, in President Wilson's phrase, should be "quick to look toward heaven for the confirmation of its hope," will lead to a true graduate school for the training of professional scholars and the advancement of knowledge.

SCIENTIFIC ITEMS

We regret to record the deaths of Professor Robert Parr Whitfield, curator of geology of the American Museum of Natural History; Dr. Borden Parker Bowne, professor of philosophy at Boston University, and of Dr. Eduard Pflüger, the eminent German physiologist.

Dr. T. Muir, F.R.S., has been elected president of the South African Association for the Advancement of Science for the meeting in Cape Town, the date of which is not yet set.—Dr. George W. Hill, of Nyack, N. Y., and Professor E. B. Wilson, of Columbia University, have been elected foreign members of the Brussels Academy of Sciences.—A testimonial dinner to Dr. Charles Frederick Chandler was given at the Waldorf-Astoria on April 2, to permit his former students and associates to express, before his retirement, their appreciation of his forty-six years of service to Columbia University, and his lifetime of devotion to the cause of education and science. It was announced that a lectureship in honor of Dr. Chandler would be endowed by his former students and that the chemical museum of the university would be named in his honor.

The Oceanographical Museum at Monaco, established by the Prince of Monaco, was opened on March 29. The different European governments and the principal scientific societies were represented at the ceremony.—A Brooklyn Botanic Garden is now being established by the City of Greater New York in cooperation with the Brooklyn Institute of Arts and Sciences. Between twenty-five and thirty acres of land, south of the museum building of the institute in Brooklyn, have been set apart for the purposes of the garden. A laboratory building for purposes of investigation and instruction, together with a range of experimental and public greenhouses, will be constructed during the coming summer and autumn. For this purpose the City of New York has appropriated $100,000 and friends of the garden in Brooklyn have subscribed $50,000 as an endowment. Dr. C. Stuart Gager, professor of botany in the University of Missouri, has been appointed director.

THE POPULAR SCIENCE MONTHLY.

JUNE, 1910

SCIENTIFIC WORK OF THE DEPARTMENT OF AGRICULTURE

BY W J McGEE, LL.D.

NATIONAL CONSERVATION COMMISSIONER (SECRETARY SECTION OF WATERS)

THE ancients saw in the four elements of earth, air, water and fire the basis of being; moderns recognize earth, air, water and sun as the prime requisites for individual and national existence.

The earth is of three parts: the life and growth on the surface; the surface, which sustains life and growth; and the part beneath, which sustains the surface with its life and growth.

The air is of four aspects: it is an extension of the earth; it yields a part of the substance for life and growth on the surface; it is a vehicle for movement of other things; and in its own movement it affects the surface and influences life and growth.

The water is of three forms, liquid, solid and gaseous, and performs five functions: it is a part of the earth; it is jointly with the air an extension of the earth; it yields the chief part of the substance for life and growth; it forms a vehicle for bodies and powers; and in its proper movement it is an effective agency of process, including life and growth.

The sun possesses several powers: it holds the earth in its place; it fixes the succession of days and seasons; it controls the forms of water and the movements of both water and air; it effectuates process, including life and growth; it yields heat, light and actinity; and it stores power on and beneath the surface in fuel to be released through fire.

The power and prosperity of men and nations are measured by knowledge of and control over these natural elements—*i. e.*, human life is, as it were, balanced against and paired with the elementary materials and forces. In modern times the knowledge is organized in science, and both knowledge and control are gained and promoted by institutions. In leading nations these institutions are partly voluntary associations of individuals, and partly governmental agencies. During recent decades the knowledge is not merely imparted, but measurably gained by educational institutions.

In the United States the earth beneath the surface is investigated by geological surveys, state and federal; the surface is surveyed chiefly by the Geological Survey and Land Office of the Interior Department, the Soil Bureau of the Agricultural Department and the Coast and Geodetic Survey of the Department of Commerce and Labor, with corresponding instrumentalities in some states; and the life and growth on the surface are investigated chiefly by the Forest Service, the Biological Survey and the Bureau of Entomology, so far as natural conditions are concerned, and by the Bureau of Plant Industry, the Bureau of Animal Industry and the Office of Experiment Stations, so far as artificial conditions are concerned, with related instrumentalities in several states. The air in its general aspects and the water in its forms and certain functions are investigated in the Weather Bureau; as vehicles for movement of other things they are investigated in the Geological Survey and some state institutions; in their primary relation to life and growth they are investigated chiefly in the Bureau of Soils, the Office of Experiment Stations and other branches of the Department of Agriculture, and in the Reclamation Service of the Interior Department; and in their immediate relation to life and growth they are investigated chiefly in the Forest Service, the Bureau of Plant Industry, the Bureau of Animal Industry and the Bureau of Fisheries, while the running and standing water in certain applications are considered in the Hydrographic branch of the Geological Survey, the Corps of Engineers of the War Department, the Hydrographic Office of the Navy Department and the Bureau of Corporations in the Department of Commerce and Labor. The general relations of the sun are investigated in the Naval Observatory of the Navy Department, the Coast and Geodetic Survey, the Weather Bureau and the Smithsonian Institution; the relations to the surface and its life and growth are considered in the Bureau of Soils; and the more direct relations to life and growth are considered in the Forest Service, the Bureau of Plant Industry, the Bureau of Animal Industry and other branches of the Department of Agriculture.

So far as the federal government is concerned, the four natural elements of power and prosperity are investigated or considered in themselves or in their applications chiefly in a score of bureaus in five departments, as follows:

Departments	Bureaus
I. War	1. Corps of Engineers
II. Navy	2. Hydrographic Office
	3. Naval Observatory
III. Interior	4. General Land Office
	5. Geological Survey
	6. Reclamation Service
IV. Agriculture	7. Weather Bureau
	8. Bureau of Animal Industry
	9. Bureau of Plant Industry
	10. Forest Service
	11. Bureau of Chemistry
	12. Bureau of Soils
	13. Bureau of Entomology
	14. Biological Survey
	15. Bureau of Statistics
	16. Office of Experiment Stations
	17. Office of Public Roads
V. Commerce and Labor	18. Bureau of Corporations
	19. Census Bureau
	20. Coast and Geodetic Survey
	21. Bureau of Fisheries
	22. Bureau of Standards

23. Smithsonian Institution

Half of the official bureaus (much more in effective strength) belong to the Department of Agriculture. This department was designed and is maintained expressly to increase and diffuse knowledge concerning the natural sources of power and prosperity; and it is significant that more than three quarters of the investigative work of the federal government has either grown up in or gone over to the youngest two departments of the federal organization, of which the last-formed is essentially commercial.

The federal bureaus are supplemented by corresponding instrumentalities in most of the states, with which there is large and rapidly growing cooperation. The spirit of the work arises chiefly in, and is largely guided by, some score of voluntary associations, with an aggregate membership of several thousand, including most of the investigators for the state and federal agencies. On the whole, the state agencies are of the greater magnitude and the more largely devoted to applications, the federal agencies the more largely devoted to investigation; the latter seem to be growing the more rapidly to meet a strong demand for effective cooperation with states and associations. The most rapid growth is that of the voluntary associations, of which an increasing proportion are devoted to the application rather than to the increase of knowledge; while the growth of the investigative branches of the educational institutions is proceeding at a geometric rate.

In the strictly scientific aspect, the governmental work pertaining to knowledge and control of the natural elements enters or occupies the fields of astronomy, meteorology (including climatology), geology (including mineralogy and paleontology), biology (including phytology or botany, zoology, entomology, ornithology, ichthyology, etc.), ecology, chemistry and physics—*i. e.,* a large part of the concrete or objective sciences; and it involves applications of all the abstract or subjective sciences, and touches on that series of human sciences with which the others are in a sense paired. In the strictly practical aspect, the work is directed specifically to the earth as affected by air and water and sun in relation to life and growth, including that of men and nations, along lines laid down in the organization of the bureaus and departments; and there is little tendency to follow the lines or occupy the fields of the conventional sciences.

The developments of the last three decades indicate an unforeseen trend: While the subjective sciences are continuing their steady advance as bases of definite knowledge, they are of lessening prominence; the objective sciences are advancing much more rapidly both as applications of the primary sciences and as branches of definite knowledge in themselves; yet the most rapid advance of all is in applications of the objective sciences (with their subjective foundation) to special lines or fields in strict accordance with the established methods and principles. So the sum of definite knowledge is subdivided into ever-multiplying specialties, while the applications become essentially scientific in themselves; observation matures in experimentation, and both purposes and the objects themselves are progressively modified in ways which gradually become utilitarian, *i. e.,* directly tributary to the power and prosperity of men and nations. Meantime the specialties rise to a new plane; in philosophic view (following the suggestions of Sir William Hamilton and Lester F. Ward) they become *conative* or —more abstractly—telic, and reflect that ever-springing desire for betterment expressed by invention; in practical view by the light of current progress they become *directive,* in that the specialist not merely investigates but gradually brings under control and redirects the natural development of the phenomena with which he deals. Now this modern trend is too definite and too consistent to escape thoughtful observers, and has indeed been widely recognized; it may justly be regarded as an expression of inherent tendency and a mark of natural if not inevitable movement. It by no means necessarily indicates a scientific decline, as some apprehend, but rather a normal readjustment of the human mind to the external factors of human existence and welfare; in fact, it but renders progressive and purposive that prevision which is properly extolled as the highest form of science. It seems to define a third stage in the advance of consciously organized knowledge: the first was the subjective stage, marked chiefly by deduction from ill-generalized and often subconscious experiences; the second was the objective or Baconian stage, marked by induction from clearly realized experiences; and the third is the directive (or panurgic) stage, marked by the combined investigation and control of phenomena. The three orders of thought are emotion, cognition, conation; the phases of faculty pass into invention, and are maturing in creation. Knowledge in the first stage was largely accidental; in the second chiefly incidental; in the third it is a means to ends. The progress was and is normal; just as objective science arose largely as applications of subjective principles, so directive science has arisen largely as applications of both subjective and objective knowledge whereby nature is rendered subservient to the power and prosperity of men and nations. The trend does not mean that science is enfeebled or degraded, but only that definite knowledge has been made common knowledge.

In the light of this trend, the rôle of the federal department is clear: Jointly with the strictly scientific associations, it is the custodian of established principles, not merely as the sum of knowledge concerning the natural elements, but as a means of control over these elements. So viewed, the entire department is in proper sense a scientific institution, and both in size and advanced position the foremost in existence. Viewed in the same light, indeed, America is par excellence a nation of science, and this all the more truly because of the general application of definite knowledge to every-day affairs. It may not be denied that the very abundance of knowledge conduces to an ease of life opposing that always rigorous and often unprofitable research required as a basis for continued progress; herein lies the chief need for a national institution of science too firmly founded on established principles to be swayed by passing opinion or popular pressure, yet too near the actualities of national welfare to drift into the realm of unreality; and here has lain the function of the department during a dozen years of wise administration.

In the department the division of the work is both logical and practical, and the methods combine investigation and direction of phenomena: they deal with the substantial basis of individual and national existence—the earth as vitalized and fecundated by the powers of air and water and sun. The primary line of work in logical order pertains to the productive surface as affected by climate and by its own life and growth; the correlative branch of the department is the Bureau of Soils. The second in order pertains to climate; its correlative is the Weather Bureau. The third pertains to the flora, native and cultivated; the correlative branches are the Forest Service and the Bureau of Plant Industry. The fourth pertains to the fauna, both wild and domesticated, correlative respectively with the Biological Survey and the Bureau of Animal Industry, together with the ancillary insect life, correlative with the Bureau of Entomology. Adjunct lines of work pertain to certain molecular relations, treated in the Bureau of Chemistry and the Office of Public Roads; to quantitative or economic relations, treated in the Bureau of Statistics; and to ecologic relations, treated largely in the Office of Experiment Stations. In each line the primary purpose is to discover facts and relations connected with development or growth; the secondary purpose is to redirect and control the course of natural development, and the ultimate purpose is to progressively artificialize the earth with its life and growth for the benefit of men and nations. In every line the constant effort is to increase the efficiency of the better and to either improve or eliminate the worse, and this in the light of all knowledge and the exercise of all natural and human power.

The immediate basis of life and growth on the earth is the soil; it yields substance for the flora, which in turn sustains the fauna. At the same time it is itself derived from cruder earth-matter largely by the action of plants and animals, and its chief elements of fertility (such as nitrates and potassates and phosphates) are organic derivatives. Thus the primary law of the soil is cumulative enrichment through interaction with floras and faunas; to this law it has normally conformed throughout the geologic ages; and the primary duty of the soil specialist is to accelerate and intensify the natural progress, and thereby to increase soil efficiency. Now the efficiency of soils depends wholly on the associated water and air (unless indeed these be considered integral parts of the soil), of which the former especially maintains a sort of circulation, dissolving earth-salts, conveying plant-food into and through the circulatory systems of the living and growing plants, and carrying the acids of growth and decay back to the earth-matter to hasten its solution—so that the active agency or principle of soil efficiency is the soil water. The normal processes are sometimes interrupted or impeded by abnormalities: Certain organic derivatives are excretory, and poisonous to the plants yielding them and sometimes to others; climatal and other natural conditions in connection with cultural changes sometimes disturb the circulation of soil water, or permit surface erosion and leaching to impoverish or even completely remove the soil; and unsuitable plants sometimes gain such foothold as to exclude organisms better adapted to normal enrichment of the soil. Accordingly, the soil work comprises (1) examination and classification of soils with respect to materials and potentialities; (2) determination of the soil water and its movements and interactions; (3) discovery of normal tendencies toward enrichment, physical, chemical and bacterial; (4) detection and elimination of abnormal tendencies; and (5) prescription of treatment required for regulating and intensifying the natural processes and thereby increasing efficiency. The researches render it clear that the soil is the product of uncounted eons of interaction between the organic and inorganic; that the slow production of a soil is a process no less definite than the quicker production of a crop or a flora; that the process may be brought wholly under human control; and that in view of increasing population, the welfare of men and nations henceforth must depend on the care and intelligence devoted to the maintenance and improvement of this gift of the ages.

The controlling condition of life and growth on the soil is climate, especially that ever-varying temperature and moisture and air movement forming weather. The first need concerning weather is foreknowledge (or prevision) definite enough to permit prediction; and while the earlier investigations were directed to this end, they necessarily included examination and classification of the atmosphere with its aqueous vapor, and determinations of temperature, rainfall, vapor-tension and other factors. Herein the usual course of progress was reversed; commonly discovery of principles precedes both appreciation and utilization of phenomena; but in weather work the need inspired search for the principles—*i. e.,* the ends led the means. With like contrariety, the effort for control was directed not so much to the natural factors of weather as to the movements of men and other organisms in adjustment thereto—indeed even yet the wind bloweth as it listeth, while men merely prepare to meet or escape its force. Still, as the work progressed, both the constants and the caprices of the air with its associated water were measured in such manner as not only to permit prevision within reasonable limits, and thereby afford practically useful weather prediction, but to yield definite knowledge of a use extending far beyond the primary need. Thus, it has become clear that in so far as life and growth are concerned the rôle of the aqueous vapor is paramount; plants absorb and transpire water to an amount usually exceeding many times their own volume during each season; and their action affects not only the circulation of soil water air below the surface, but the humidity of the air and the circulation of both air and water about and above them. Again it appears that the average rainfall of the United States is less than half that required for full productivity in native and cultivated organisms; yet that some 90 per cent. of the rain-water gathering into streams is wasted in floods which annually wreak damage to an amount exceeding the estimated cost of flood prevention, and this despite a large saving of life and property by reason of flood warnings issued by the Weather

Bureau. So the measurements are preparing the way for such control of the rain that this gift of the heavens will be made an unmixed benefit instead of a partial evil. Of the entire rainfall, only about a third flows through rivers into the sea (chiefly in floods), while it is estimated that fully half is evaporated, thereby returning to the air to affect the weather and temper the climate; and measurements of evaporation have begun, and will doubtless open means of exercising some control over the water in the air, no less than that on the surface and within the soil. Meantime it is estimated that less than a sixth of the mean annual rainfall is actually utilized in life and growth and other useful processes connected with the soil and its productions; and it is becoming clear that larger and better uses of the elemental water are possible through progressive redirection of the natural processes and powers. In the beginning, men bowed to the storm and fled the flood; later they predicted in order to seek shelter before the storm arrived; now they seek control at least of the storm waters in order that their volume and strength may be directed to welfare.

The four elements interact through organisms, of which the substance is mainly from the soil and water and their products; their circulatory medium and chief constituent is water, their force is from the sun, and their functions are maintained by air. During the ages the native flora adjusted itself to soil and earth-shaping agencies so closely that each type produced a surface to fit its needs—forests developing deep and friable soils and steeper slopes, grasses developing thinner soils and flatter slopes, and mosses producing spongy soils lining basins, each according to its kind and its capacity as conditioned by climate. A quarter of the area of the United States was too arid to sustain a full floral mantle, a third was wooded and more than a third was grassed when settlement began; for wherever the water supply suffices, vitality overspreads the surface and dominates the inorganic earth. Without water, vitality fails; there is neither assimilation nor germination, nor yet metabolism, in the absence of liquid, while transpiration and respiration depend largely on the passage of water from liquid to vapor. With water, the primarily organic circulation extends from the plant to the soil below and the air above and passes into still more complicated interrelations in animal bodies; and the locus of most effective energizing on the planet is the infinitely complex surface—the soil with its extensions in stem, leaf, flower, fruit and other organic bodies—at which water is continually passing from one form to another, absorbing or yielding latent heat, and mechanically interacting with the sun in seizing and storing and transferring molecular action. This is the complex in which vitality attains dominance over lower nature; and through it investigators are attaining control over the vital powers for the welfare of men and nations.

Thus, the normal circulation is notably complete in woodlands, and is notably deranged by deforestation; when the trees are felled and not replaced by other cover transpiration ceases, the air dries so that seeds and seedlings may wither, and the soil-water level lowers; the duff is desiccated and wind-blown, leaving the previously porous soil to harden and bake; and as storms arise the raindrops are no longer dashed into spray by twigs and foliage and conveyed gently through litter and natural mulch into a friable soil of enormous capacity for feeding springs and brooks, but beat still harder the indurated ground—and then gather in surface rivulets and rills running swiftly down the slopes, eroding and gullying the soil on the way, clogging valleys with the débris, and rushing as turbid torrents into the sea with little benefit and large injury on their way. The Forest Service was created largely to counteract reckless deforestation and maintain the timber supply in certain sections of the country; yet it has grown into administration of 170,000,000 acres of woodland, while its highest duty has come to be that of acquiring and diffusing definite knowledge and directing specific effort toward control over the powers of nature in such manner as to protect the water supply and regulate that balance of industries connected with woods and waters required for the common prosperity. The investigations extend into vegetal physiology and the vital mechanism of the individual seed or slip or tree no less than into the collective action and relations of the forest considered as a unit, and pass over into both natural and artificial production. The aim is increased efficiency of both individual trees and forests; the end is higher national efficiency; the means, progressive control over natural powers through definite knowledge and purposive application.

Over millions of acres of grass-lands and former woodlands, the native flora is wholly or partly replaced by crop plants, and it is the manifest destiny of all available lands to be consecrated wholly to production or inhabitation or other human uses. In prehistoric times men began to subsist on the products of the soil, and through unwitting selection improved wheat and rye and barley and rice in the old world and corn and beans in the new; and during the historical period the improvement of the useful types and the replacement of useless or noxious types were continued under the guidance of increasing knowledge. Since the Department of Agriculture was created—and largely through its agency—the sum of human knowledge relating to crop plants and their efficiency in this country has more than doubled; and now the utility of plants is traced directly to individual vitality—to the specific factors of cell function and reaction to stimuli and hereditary tendency combining with capacity for transpiration to determine rate and limit of growth—which is itself measurably susceptible of modification. In this way the Bureau of Plant Industry is steadily gaining control over the powers of nature through redirection of the vital energy of the plants along more useful lines directed toward ends of human welfare. The control is collective no less than individual: Native plants vary, and the fitter survive; Darwin noted the increasing variation of plants under domestication, and thereby detected a natural law of increasing plasticity of types; and now under the law variability is accelerated and the fitter forms are selected and multiplied, so that the efficiency of crops is increased. Under natural conditions, plants spread slowly and with the tediousness of unlimited time adjusted themselves to particular soils and climates; with settlement, pioneers introduced new plants which were often found fitter than those of native growth; now the plains and mountains of the world are scoured to find types adapted to less productive districts, and thereby the efficiency of entire floras is increasing. And the end is not yet. Agriculture began with the accidental dropping of seeds in accidentally fertilized spots; in time the middens were expanded into gardens and these into fields; and now plain common sense and reasonable foresight look to the extension of planting and cultivating and cropping over all the humid country and so far into the arid lands as complete utilization of the scant waters will permit. Our 3,000,000 square miles or 2,000,000,000 acres, now sustain about 90,000,000 inhabitants, or 30 per square mile, and our exports of food-stuffs are falling off; within 65 years the population will doubtless double, and by the end of the century it will treble—yet the 250,000,000 mouths must not only be fully fed, but a margin of food-stuffs for export must be left over if prosperity is to persist. To attain this end, plant efficiency must be increased; not only must two heads of wheat be made to grow where a blade of grass grew before, but each square rod must be made to yield a bushel instead of a peck of grain, and more nutritious grains must be invented and created and kept employed in converting the crude ore of lower nature into the coin of individual and national welfare. It is no longer enough to know the plants and vital processes of nature; it is becoming necessary so to redirect nature as to produce more efficient plants by improving the vital processes—and this is a current duty of the Bureau of Plant Industry.

Even more plastic than plants are the faunal forms, both wild and domesticated; and before history began, kine and swine and sheep and fowls were so far artificialized by selection and breeding that the ancestral forms were obscured. It is the business of the Biological Survey and Bureau of Entomology to investigate the native fauna and classify the forms, technically into orders and genera and species and practically into useful and injurious—and then to perpetuate the good and reform or extirpate the evil, operating largely through the vital forces of the organisms themselves; and the world is scoured for information as to species and stocks of mammals and birds and fishes, for insect mates to symbiotic plants and insect enemies to noxious organisms, and even for germs and cultures affecting the course of organic progress. Meantime the Bureau of Animal Industry is not only acquiring and diffusing definite knowledge concerning stocks and breeding and feeding, but is importing and acclimating and crossing the animals with the view of supplying each section with forms adapted to its particular conditions and requirements. Thereby the domesticated animals are modified and adjusted to a complex industrial mechanism, each yielding flesh or milk or leather or textile or eggs or feathers or labor after its kind in connection with the human purpose; and if the natural powers are feeble or aimless, they are so redirected and intensified as to increase the efficiency of the organisms in promoting the welfare of men and nations.

Broadly, the functions of the other Federal Departments pertain chiefly to relations among men, those of the Department of Agriculture chiefly to the relations between men and nature. Its primary purpose, both logical and legal, is to increase and diffuse knowledge concerning those fundamentals of human power and prosperity residing in the soil and its products. In carrying out this purpose, it necessarily assimilates and promotes that consciously organized and definite knowledge pertaining to nature which constitutes both the subject-matter and the object-matter of science; and with its growth it has been called on to make all manner of applications, from the extirpation of insect pests to the protection of the purity of foods and medicines for men and the making of roads for moving the produce of the soil. Its final function, which has arisen and taken form with its growth, is the redirection of natural processes and powers along lines which are not only prevised, but clearly preconceived in relation to ends—and hence are practical. In performing this function, it deals constantly with the four primal elements in their relation to man; beginning with the earth, it progressively increases the efficiency of soils and plants and animals; and through this element it utilizes and so gains partial control over the air, the water and the power of the sun—and the measure of the efficiency is human power and prosperity.

Thus far the relations chiefly considered in the Department of Agriculture have been those of nature, and of men to nature, adapted to increasing the efficiency of nature for human ends; there has been little effort to apply the natural powers to men or to increase their efficiency except by arming them with better knowledge. The time for directly increasing human efficiency by intensifying human power has hardly come; yet it may easily be descried as the next stage in the development of relations between men and nature.

INSTINCT AND INTELLIGENCE IN BIRDS.—I

By Professor FRANCIS H. HERRICK
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I

THERE is no doubt, as Jevons has remarked, that if ants had better brains than men, they would either destroy the human race or reduce it to a state of slavery, but these busy little workers offer no black or yellow peril to mankind, for they are all headed in the wrong direction. In the social hymenoptera nature seems to have done her best with a nervous system built upon the simple arthropod plan, in which segmentation, begun at a still lower level in the animal scale, is the dominant character of its structure, and instinct the ruling method of its response.

The vertebrate, on the other hand, has a nervous system of not only a higher but of a very different order, in which response has left the beaten track of instinct, and become more and more molded upon experience. Classification of these higher types on the ground of anatomy agrees plainly with classification on the score of behavior, and this agreement is based upon the structure of the nervous system, the chief function of which is to order and control response.

It is to the evolution of the cerebrum that the vertebrate owes its powers of rational response, and the higher we rise in the scale of vertebrate ascent from the bony fishes, the greater the development of the cerebral cortex, and the keener the mind of the animal, or the greater its power to subdue its hereditary tendencies, to make its acts accord with the results of experience, or the needs of the moment, and to anticipate the future.

The instincts used to be regarded as immutable, and are now often spoken of as "stereotyped," but in the use of the latter term there is need of frequent qualification, and habits even by repetition become automatic. The mechanical operation of habits, which is universally recognized, has given rise to the idea that acquired automatism may appear in the descendants as inherited or congenital automatism, that instincts are inherited habits and merely illustrate "lapsed intelligence," or habits from which the intellectual processes through which they were originally acquired have "lapsed" or disappeared. The confusion and absurdity with which this view can invest a difficult question is well illustrated by Eimer's[1] attempt to explain the parasitic instinct of the European cuckoo, which regularly lays its eggs in other birds' nests.

[1] Eimer, Theodor G. H., "Organic Evolution," p. 256, London, 1890.

Eimer is convinced that the little foundling of a cuckoo has so good a memory of its foster-parents and of the nest in which it was reared, that it is able to make a proper choice of both when it comes to lay its eggs in after life, and further that the experiences of its early youth have "at last become instinctive by inheritance." It can not build a nest because it has never learned how, and if it never builds it can not of course transmit the instinct of nidification. When its original progenitors adopted their piratical methods, they did so with their eyes open, for they acted from "reflection and with design." The male cuckoos are dissolute vagabonds and the females as bad or worse, for they wander about not so much to find nests to steal, as to appease "their insatiable sexual desires."

That some instincts, in both arthropods and vertebrates, have not perceptibly changed from age to age is not to be doubted. As Sidney Smith observed, the wonderful instincts of animals seem to have been given them for the preservation of their species, and that without them they would have long ago perished. He says:

> The bee that understands one particular kind of architecture so well, once out of his own special line of business, that of making honey, is as stupid as a pebble stone, and with all his talents only exists that we may eat his labours, while poets sing of them; or he constructs his boasted edifice for an egg of which he knows neither the meaning nor the object, to produce a grub of which he can form no possible conception; whereas man knows the beauty of every brick he lays, or tower that he builds. The bee now builds just as he built in the days of Homer; the bear is just as ignorant of good manners as he was two thousand years ago, or ages ago; the baboon still as unable to read and write as persons of honour or quality were in the days of Queen Elizabeth; but there is no progress among the three B's, whereas now among all classes of men those who can read and write are to be counted by the millions.

We might add that the European cuckoo seems to have been no less adept in stealing nests in the time of Aristotle than it is at this day, and that even among the most rational, adaptable, and most plastic of living beings, in his humblest estate, progress has been but little greater.

II

In some of the fishes, in reptiles, and more particularly in the birds, we can discern the early if often halting steps of that intelligence which in the highest of the primates was destined to turn the world upside down. We can not attempt to specify with any detail the structure of the avian brain, nor would it be of any use to do so, unless we could award the proper functions to its several parts. While this can not now be done, psychology has already learned some valuable lessons from anatomy, at the hands of such a master as Edinger, and is destined to learn many more. Without doubt, in the future, knowledge of the brain of the fish, of the reptile and of the bird will serve as primers for the understanding of the cerebral cortex.

Edinger[2] has shown that to the primitive division of the brain of the vertebrate (or the paleencephalon), which is the bearer of the reflexes and the instincts, there has been gradually added with peculiar adjustments a newer division (the neencephalon), which corresponds to the cerebrum, in which alone is centered the power of association, and of forming memory images. In proportion as the cerebral cortex increases, the primitive brain recedes, while in a corresponding ratio intelligence rises, and purblind instinct wanes.

A very interesting fact for us, as Edinger has further shown, is that while the cerebral cortex of the bird is more highly developed than in reptiles, the far greater bulk of the brain is mainly due to an enlargement of the primitive division, the parts of which reach a size and proportion nowhere else seen, while at the same time they are very generally connected with the cerebrum. From these facts alone we are warranted to infer that while birds are intelligent and able to form associations of some sort freely, they must be animals in which the instincts are developed to an extraordinary degree of perfection, comparable in large measure with those of the social insects. All this is amply proved by their behavior, and in describing the activities of birds it seems best to discriminate as sharply as possible their instinctive activities from the operations of intelligence, assuming, until the contrary is proved, that their reflexes and instincts pertain exclusively to the primitive division of the brain, as already stated, while the power of association is lodged in the cerebrum alone.

Not only does the bird's brain possess great basal ganglia of which the huge optic lobes are most prominent, but a large cerebellum, and very diminutive, possibly rudimentary olfactory lobes. These facts find their clear counterpart in behavior. Large optic nerves, optic tracts and lobes, are to be expected in animals like the birds, which possess the keenest eyes of any vertebrates known, and which depend so largely upon vision for finding their food and for detecting their enemies and their friends.

The wonderful powers of flight, possessed by birds as a class, may not only be long sustained, as in the golden plover which is supposed to make the journey from Nova Scotia to the West Indies, a distance of 1,700 miles, in a single flight, but is often so rapid that fatal results would follow were the control of direction less precise. Their movements clearly demand an organ for the most perfect coordination of their skeletal muscles, and such is undoubtedly found in their large cerebellum, the action of which is purely reflex. Thus swallows are often seen to enter a barn, where they have their nests, at a perilously rapid rate, through cracks or holes, barely large enough to admit their

[2] Edinger, Ludwig, "The Relations of Comparative Anatomy to Comparative Psychology" (translated by H. W. Rand), *Journ. of Comp. Neurology and Psychology*, Vol. XVIII., No. 5, 1908.

bodies. Under such circumstances a slight error in muscular coordination would be fatal, and I have found fully grown and presumably young birds lying dead beneath such openings, where it was evident from the wounds received that death was accidental, and due to lack of precision in flight. The common swift also moves with astounding rapidity, as if heedless of consequences, but usually avoids every obstacle in its path, even in waning light. It gathers the materials for its twig nests while darting through the branches of a tree, with barely a pause, as it bends to seize in its bill the twig, which is snapped off by the momentum thus gained. Yet mistakes are sometimes made even by the master swift, and I have known a case where a bird of this kind, and possibly a young one, impaled itself on the sharp point of a lightning rod.

The toothed birds of the Cretaceous period, of which *Hesperornis* is a type, are known to have possessed a brain more nearly approaching that of the reptiles in form, with large olfactory lobes. It thus seems evident that the olfactory sense has lapsed and become rudimentary in most modern birds. Edinger, however, maintains that since birds possess true, though small olfactory lobes, they must smell, but behavior seems to afford the better criterion in such a case. Whatever the advocates of the eye and the nose may have to offer in the future in regard to the habits of buzzards and other old and new world scavengers, repeated experiment has convinced me that the common birds of the country, can not detect their young at a distance of three feet, unless they either see or hear them. In fact, all of the close-at-hand, "as-near-as-you-hold-a-book-to-read" observation, carried on for the past ten years, some of which is to follow, has been conditioned upon the extremely feeble development, if not total lack of this sense.

III

The instincts of birds may be classed in a general way as (1) continuous instincts, which are needed for the preservation of the individual, such as preying, flight, concealment and fear, however subject to modification through experience, and (2) the cyclical instincts, which are necessary for the preservation of the race.

By cyclical instincts we mean those discontinuous, recurrent tendencies to action which are serial in form, and which together characterize the reproductive cycle. They may be called, with some allowance, the parental instincts, it being understood that this epithet is used in a descriptive sense, and that there is no one kind of reaction to which the term is specially applied. These instincts recur with clock-like regularity in the spring and summer in the northern hemisphere, and are subject to repetition, more or less complete, within the breeding season of certain species or individuals.

For convenience the breeding cycle may be described as made up of a series of terms as follows:

1. Migration to Breeding Area;
2. Courtship and Mating;
3. Nest Building;
4. Laying Eggs in Nest;
5. Incubation and Care of Eggs;
6. Care of Young in Nest;
7. Care of Young out of Nest;
8. Migration to Feeding Area.

Beginning at 2, 3 or 4, according to circumstances, the cycle may be repeated one or more times within the breeding season, or a new cycle may be begun, and stayed at any step from nest-building to laying of the eggs. Again, an entire cycle may be brought near the close, and then scamped, the young being left to die.

The reproductive cycle may be graphically represented by a number of tangent circles, each of which stands for a distinct sphere of influence or for a subordinate series of related impulses. It is evident that these serial instincts must be in relatively perfect harmony, or if regular perturbations occur, new and permanent adjustments must be forthcoming to meet them, if the species is to continue to exist. One act or series of related acts must be performed in preparation for that which follows. The nest must "anticipate" the eggs, and not the egg the nest. Upon the whole the serial instincts of birds are well attuned, yet disturbances more frequently occur than is commonly supposed, and by conditions of this kind much that is anomalous or eccentric in the behavior of birds can be explained, as we shall later see.

The cyclical instincts are profoundly affected by fear at terms 3 and 4, and the whole fabric of instinctive life is subject at nearly every step to the modifying influence of intelligence. In the reproductive cycle, as elsewhere, the same struggle is seen between competing or conflicting instincts, especially where attunement is imperfect, leading now to a fuller expression, and now to a total neglect of the usual activities. The number of terms, of which eight are given above, is unimportant, so long as it is recognized that they occur in serial form, and that many activities such as brooding, and feeding the young, are recurrent.

Certain subordinate instincts rise and wane during the reproductive cycle, thus adding to the complex of behavior. Song, which is primarily instinctive, often begins in the male during the time of mating, but that it is not wholly dependent upon the reproductive function is proved by the fact that it is not always coincident with the breeding period. Thus, it was shown as early as 1834 by Blackwall, that singing may cease before the nest is built, or last long after the young have flown. Again the fighting instinct usually emerges early (at 2 or 3) and is long continued. In that inbred pugnacity, which characterizes the breeding season of birds and higher animals, we possess the key, as I believe, to the origin of the instinct of incubation. According to this

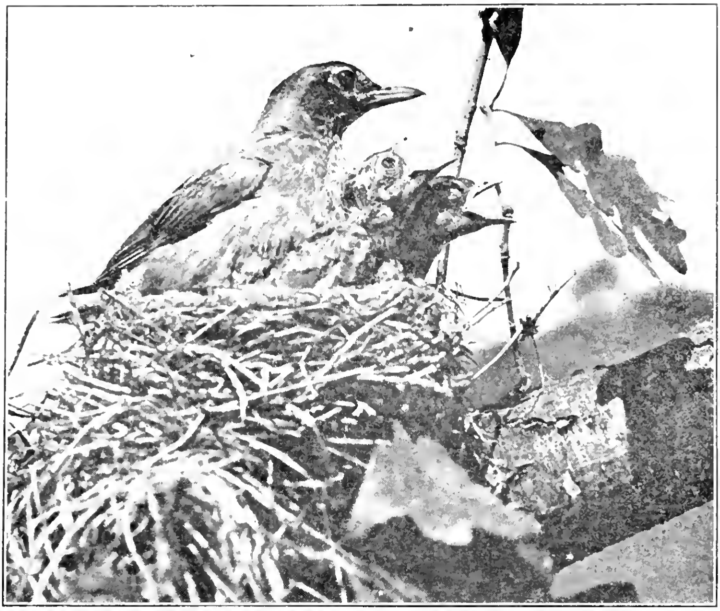

FIG. 1. FEMALE ROBIN IN A PARTIAL SHIELDING ATTITUDE, on a hot day.

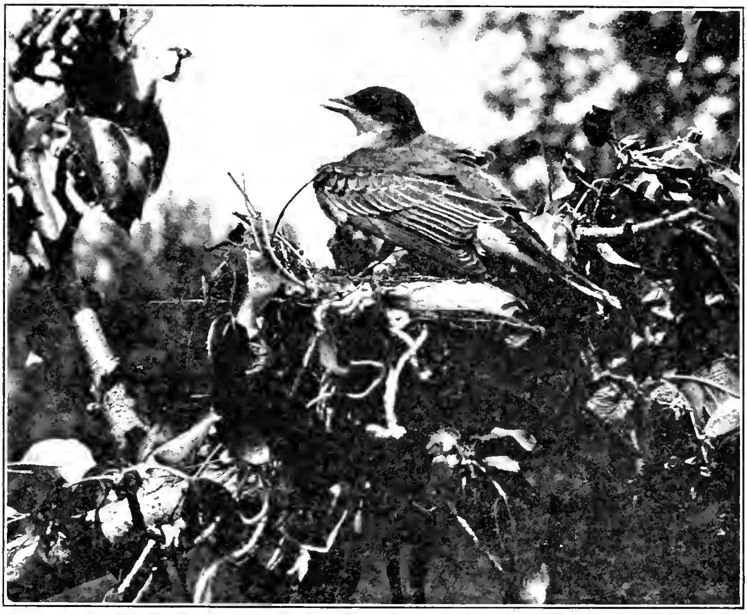

FIG. 2. KINGBIRD IN TYPICAL SHIELDING POSITION, standing over young, with wings partly spread, and feathers partly erect.

idea the guarding evoked by the fighting instinct, and supplemented by the instinct to cover or hide the eggs, is responsible for the incubating instinct, which in the modern birds is usually strongest in the female, but is not always confined to that sex.

The possible stages in the evolution of the instinct of incubation in the reptilian ancestors of birds, upon the basis of selection, may have been as follows: first burying the eggs, like the turtle; secondly, burying or concealing the eggs and guarding them, the necessary warmth being furnished by decomposing vegetable débris, as in the alligator, and not directly from the sun; thirdly, laying the eggs and sitting over them to conceal as well as to protect them,[3] in a secluded place, the necessary heat now being furnished by the body of the parent. In the first instance the eggs may not have been concealed, but it seems probable that the instincts of both concealment and pugnacity were contemporaneous, as they were certainly very early in origin.

With incubation is associated a variety of interesting and important instinctive activities, such as rolling the eggs with the bill upon entering the nest, as may be observed in the great herring gull, placing them in position, or stirring them up with the feet, to be seen also in the gull, the domestic fowls and in a great number of wild species; covering the eggs when leaving them, a common practise of the grebes, or standing over the nest and with spread wings shielding the eggs from intense heat, as I have once observed in the least flycatcher; cleaning the nest by removal of broken or addled eggs, which must frequently occur in many species, which I was once fortunate enough to witness from the tent in the least tern on one of the Weepecket islands in Buzzard's Bay. On a very hot day in July one of the eggs, during the absence of the birds, exploded with the report of a pop-gun and blew a small hole in one side. Upon her return this resourceful bird inspected the nest for a moment, and bending down, inserted her lower mandible in the blow-hole; then lifting the heavy egg in her bill, she bore it off slowly over the water and dropped it in the sea. At her next visit every particle which might defile the nest was gathered up and carried away.

The care of the young in the nest (6) embraces a number of fairly well stereotyped, recurrent acts such as (*a*) the search after prey, its capture and subsequent treatment; thus some birds regularly mince the prey or beat it into a pulp, while others, like the little house wrens, bring moths and various insects to their nest with wings and legs, or with wings alone, removed. Kingbirds have been seen to bruise unruly insects between their bills while at the nest, one assisting the other, and have been photographed in the act, while it is not an unusual sight to

[3] It is evident that pythons, which lie upon their eggs, secure in this way both protection and concealment for their offspring.

see an insect which has been inserted in the mouth of a nestling, withdrawn, minced with the bill, and offered again. When behavior is free the return to the nest (*b*), is prompt and direct, but birds will frequently pause at some point near by and look about as if for assurance. The black-billed cuckoo if timid or suspicious, will sometimes stand on such a perch with insect in bill for five or ten minutes without uttering a sound, but occasionally pumping its tail, stretching its head and looking cautiously around, or again it will remain perfectly quiet like a statuette. The actual path which is now taken to the nest is eventually

FIG. 3. ROBIN "TAKING AIM." After photograph by John B. Parker.

determined by habit. The bird flies to a certain branch, grasps certain twigs, before it finally lands on a certain part of the nest itself. Then usually follows a pause as the bird straightens up and stands over her young. If the mate is brooding, as is likely to be the case in bad weather, a call-note is sometimes given by the visiting bird, when the sitter promptly retires. This note is often heard in the absence of the mate, when it serves as a stimulus to the young. Further the sitter, if a cuckoo, always detects the approach of the visiting bird by hearing, if not by sight, so that the whole family is practically never seen together at the nest, contrary to what often happens with gulls, robins, cedar-birds, kingbirds, or some of the warblers. The young detect the approach of the parent by sight or sound, or by the vibration imparted

FIG. 4. ROBIN IN SIMILAR PHASE OF THE FEEDING PROCESS, but with young at later stage of nest-life. Illustrating type of direct feeding, where one bird only is commonly served at each visit. After photograph by John B. Parker.

to the nest itself or to the branches about it, and if hungry respond with the greatest vigor and excitement. When response is dull or lagging, however, the parent usually utters a call-stimulus, a peculiar note, of low pitch, and varying in quality in different species; if this should pass unheeded, it may become very shrill and rasping.

Feeding the young in birds is either (*a*) a passive process characteristic of certain precocious birds like gulls, in which the food is regurgitated from stomach and gullet upon the ground (Figs. 11 and 12) or (*b*) it is very direct, in which case the food is generally inserted into the throat (Figs. 7 and 8), the common practise of altricious birds. In the first instance, a young gull, the hatching of which was witnessed, received its first food, consisting of small lumps of predigested fish, when two hours old, and at the nest. Although this food was placed within easy reach of the chick, and was even picked up and held before its bill, no other encouragement was given and it was never inserted into mouth or throat.

The essence of the direct method of feeding is to test the swallowing reflex of the nestling. The food may be carried in gullet or stomach, and regurgitated from one or both to the mouth, before service, or it may be carried visibly in the bill, as in robins and passerine birds generally, and fed direct from bill to throat, one bird only, as a rule, being fed at each visit of the parent. Thus cedar-birds regurgitate mainly from the gullet (Figs. 5 and 6), and the berries or insects come out entire, but covered with slime, more than one bird being quickly served at each visit. In woodpeckers and goldfinches, which are fed at longer intervals, the food comes up in the form of a "pap" or "mash," probably from the stomach in part, to judge from the outlines of the neck, and all are fed rapidly as before.

The nestling gives the "opening" response, and shows its "food-target," while the parent, if a robin, vireo or one of many altrices, "aims" (Figs. 3 and 4) and inserts the food deep into the throat, presses it gently down, and watches it, watches, we may say for the swallowing reflex of the throat. If not quickly taken, the food is whisked out and passed around, one bird after another being tried in succession, until a throat with the proper reaction-time is found. There is commonly no distribution of food among the offspring, on any other basis than this. The youngster which can react most promptly, is thus favored, because he holds up most of the food; accordingly he grows fastest, and outstrips his competing nest-mates. The young cowbird drives the children of its nurse quickly to the wall because it reacts with greater vigor from the first, and interferes with any proper distribution of the food. It is not uncommon to see the same bird, usually the larger and stronger one, fed two or three times in succession, but the full gullet checks the swallowing reflex, and thus automatically applies a brake to the greediness of a nestling, which might otherwise gorge itself to suffocation.

FIG. 5. CEDARBIRD AT NEST WITH FULL GULLET. First stage in reaction of young.

It must be noticed, however, that the goldfinches, referred to above, afford a partial exception to this rule. The young at the two nests of this species, which I have studied, were invariably fed with a white or greenish, sometimes frothy, semi-liquid seed-pap, each bird getting some, and at times from two to four doses, at each visit. Such birds react with great uniformity, and are remarkably uniform in their growth (Figs. 9 and 10). The feeding is extremely rapid, and so little of the pap is ever lost, that on only one or two occasions have I been able to get a drop of it for examination. It consisted of very small, immature seeds of some plant like the bull thistle or mullein.

FIG. 6. CEDARBIRD BEGINNING TO REGURGITATE. Final stage in reaction (opening response) of young. Feeding is by regurgitation and direct, several being fed at each visit.

While all the common passerine birds of the country feed their young in the way described, at nests of the cuckoos a most singular and remarkable performance may be witnessed, for these interesting birds not only test the throats of their clamoring brood in the usual way, but practise what may be called *mouth-feeding* also. Thus we have repeatedly seen the female black-billed cuckoo bring to her nest caterpillars, or larvæ of some of the larger moths, from two or three inches long, already limp, and pinched at a point just behind the head. At the food response or opening reaction, she would lay the insect in the mouth of the young one, and without relaxing her grip, hold it there, mother and child standing immovable from two to five minutes by the watch, until suddenly the machinery would begin to work, and the long body of the larva would slide down the throat of the nestling, as if greased. The insect was laid crosswise between the mandibles, which closed upon it, but not always with sufficient force to hold it, for when the parent relaxed her grip, on more than one occasion it fell on the nest, and was picked up and offered again in the same manner. During this period of suspense, the mouth of the little bird would water copiously, and now and then the insect would be moved slightly by the parent, or withdrawn and returned to the same bird.

When the feeding is over, inspection (*e*) follows with clock-like regularity, provided always that behavior is free, and with head inclined to be prone, the parent inspects young and nest, with a view of cleaning them (*f*) which means the removal of the excreta, or of any particles of food which may have escaped the young. The cleaning instinct is very wide-spread among the whole class of birds, which from the human standpoint are probably the cleanest of all vertebrates which live out of water.

The study of the cleaning instinct in birds offers many surprises, and shows us plainly that besides the question of sanitation, which might be assumed to be of paramount importance, there is the element of concealment, which in the smaller and more timid species really counts for more, while of lesser significance is the value of the excreta as food for the adult. A young bird ordinarily mutes shortly after the food taken reaches its stomach, or at least after it is swallowed, and in so doing instinctively turns so that the raised hinder end of its body is directed toward the margin of the nest. Consequently the sac, when allowed to fall, usually lands on the nest-rim, when it does not reach the ground. The excreta in cuckoos, and in most passerine birds, to mention but two prominent orders, are in the form of tenacious, mucous sacs, which are snapped up as they leave the cloaca of the nestling, and are either eaten or removed (Fig. 14). This sac resembles a rubber water bottle with thin transparent walls closed on all sides, which can be rolled or picked up without soiling bill or fingers. Digestion is very rapid in nestlings, and remains of insects have been found in a sac from a black-billed cuckoo but four hours old. But while the digestive process is rapid, it is often very imperfect, and compact fruits like the blueberry will sometimes pass the alimentary tract without change. This in part explains the use of the excreta as food, and suggests that whether they are to be eaten or removed it is only a question of hunger at the moment. Robins, when they do not devour the sacs outright, carry them away, flying low with depressed head, and drop them a few rods from the nest, but are sometimes seen to peck at them after reaching the ground. In some species, like cedar-birds, and again in certain individuals only, the excreta are more regularly and continuously eaten than in others, and there can be no doubt that habit often decides the question. Fear, however, is another variable to be reckoned with, for if this sense is aroused at the moment the bird has seized a sac to bear it from the nest, it seems to be eaten as the easiest solution of the difficulty. Perhaps a counterpart of this sort of behavior is seen when a bird with food in bill suddenly encounters the naturalist, or any other fearsome object, for it immediately sounds the alarm, and promptly swallows the insect. When more than one sac is taken, all are usually eaten. It is not an uncommon sight to see a bird walk around the nest and take a "white marble" from three birds in succession, for in muting, a bird is sometimes followed by one or more of its mates, and anything which soils the nest is quickly removed. More than once I have seen a sac, which had dropped from a nestling snapped up by the old bird before it had fallen two feet in the air; and birds will even descend to the ground for the sacs, if necessary. Twice I have seen the male chestnut-sided warbler take a sac to carry it off, and the hungry female snatch it from him, devour it and settle down to brood.

Removing the excreta piecemeal and dropping them at a safe distance is the common instinctive method not only of ensuring the sanitary condition of the nest itself, but, what is even more important, of keeping the grass and leaves below free from any sign which might betray them to an enemy. Bluebirds and redwing blackbirds often carry the sacs a long distance before letting them fall. Crow blackbirds sometimes drop them in the water, and house wrens and nuthatches implant them on the bark of trees. This instinct, like so many others in the reproductive cycle, after running its course, begins to wane, and even before the close of nest-life, so that it is not correct to say that the nest of the cuckoo or the flicker is always sweet and clean. I examined a hoopoe's nest in upper Egypt, near Luxor, on March 26, which was filthy in the extreme, but hardly worse from a sanitary standpoint than is a woodpecker's hole at a corresponding period. This nest of the hoopoe was on the ground in the midst of a pile of sun-dried brick, and was composed wholly of weeds and lentil-pods. The five young ones, which were at this time nearly ready for flight, showed their fear by erecting their beautiful crests and crawling down among the bricks to hide. There is the further curious anomaly regarding this practise, that some of our most attractive birds, which have delicate and artistic nests, of which I can mention the American goldfinch, do not appear to possess the cleaning instinct at all, or the attendant instinct of inspection, and shortly after the young emerge their surroundings become encrusted with filth. This singular fact is, I believe, correlated with the method of feeding described above. The young are fed at rather long intervals; at one period, of nearly seven hours, the average was once every twenty-five and one half minutes, and all are rapidly, and repeatedly fed at the same visit. Indeed the movements are so rapid that it is not certain that they are effective in every case. These conditions lead to irregular muting, and to practical difficulties in regard to the sanitation of the nest, or more particularly of the nest-site.

To the acts recorded above we have to add (*g*) incidental behavior at the nest, more or less related to care of the young, as brooding, shielding or spreading over the nestlings in heat (Figs. 1 and 2), or rain, whether sitting or erect, bristling, puffing or swelling out the throat,—possibly with air-sacs distended,—preening, gaping in hot weather, stretching and yawning, with the guarding and fighting in-

FIG. 7. BLACK-BILLED CUCKOO APPROACHING NEST WITH FOOD. First stage in reaction of nestlings; wings vibrating in young which gives most vigorous response.

stincts, called into evidence as occasion may arise. Sporadic additions are sometimes made to the nest, and I have seen the white-bellied martin return to her nest-box a feather which the wind had blown out (Fig. 13). Eagles and hawks will occasionally bring fresh sprays of hemlock or seaweed to their eyries and the great herring gull while incubating or brooding will sometimes bend over and pull fresh grass and weeds within the reach of her bill, and tuck them under her body. Most of these acts are probably instinctive in origin, but they are far from predictable.

It would be safe to affirm that the cuckoo or the cedarbird which we happened to be watching, would in the course of time come to a certain branch, look about, advance to the nest along a certain path, marked out previously by habit, test the throat of one of the eager young, watch for the swallowing reaction, inspect and take the sac, if forthcoming, in the bill, but here no one could say whether the sac would be borne away, and the bird return thereafter with food, or whether it would be eaten, and the bird remain at the nest to brood. Here association and other elements seem to enter. My records for the cuckoo show that the brooding intervals, as to their length and fre-

FIG. 8. CUCKOO PLACING FOOD IN THROAT ("testing" the throat); wings of nestling at rest. One bird only receives food.

quency, seem to depend upon the intensity of the light and the activity of the male. During the early period of nest-life many birds brood through the night, but at intervals only during the day. When the sun becomes suddenly obscured with dense clouds, or it grows dark with the approach of rain, brooding is likely to begin, and if the male ceases to bring food, the brooding intervals are prolonged. Thus, during a heavy rain storm I have known the black-billed cuckoo to brood for the space of one hour and forty minutes, and only retire at last at the approach of her mate with food. After his task was accomplished, the female returned with an insect, and resumed her brooding again.

The instincts of the parent and young are of the lock and key order. Each acts as a stimulus to the other, and the reward of satisfaction to the child is no greater than that of pleasure to the parent. The coordinated instinctive responses of the young begin in many of the precocious birds, like the great herring gull, before birth. The egg is starred and pipped, and the bill of the little bird is seen, and its call note heard, for several hours before the shell is cracked open. The

FIG. 9. GOLDFINCH FEEDING SEED-PAP BY REGURGITATION. Note uniformity of response.

split may occur with a certain degree of uniformity in the direction of the minor axis of the egg, thus dividing it into two equal or unequal parts, and when the chick crawls out it leaves, besides the shell and its membrane, the allantois, and what looks like a residue of the albumen. The shells which now encumber the nest are carefully removed by some birds, and dropped, presumably at some distance away, while in others they are brushed aside, or crushed by the brooding bird and receive no further attention. This removal of the shells so common in the Passeres and other orders, must be attributed to the cleaning instinct, and I have noticed that in the cuckoo, which removes the shells of the first two or three young to hatch in succession, is apt to leave those of the last when the cleaning instinct is on the wane. The allantois is sometimes picked out of the shell and eaten, as has been seen in the case of the gull.

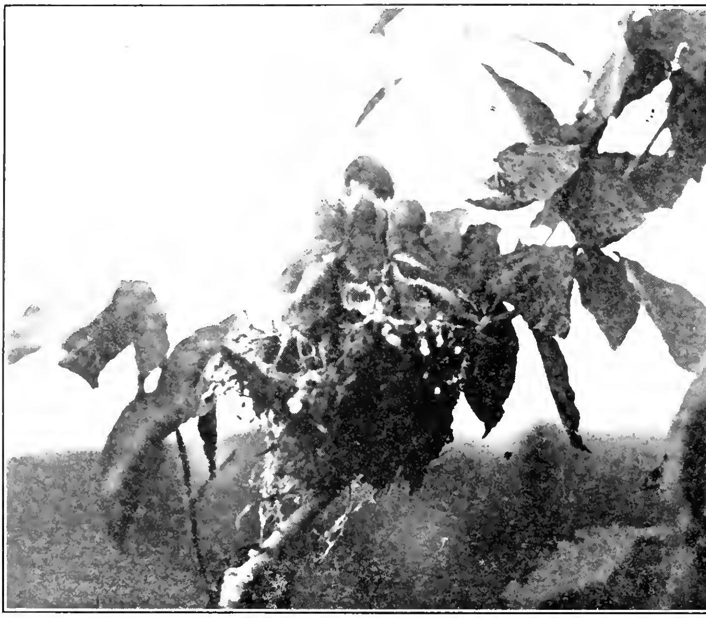

FIG. 10. GOLDFINCHES PYRAMID OF FIVE YOUNG AND ONE ADULT AT LATER STAGE IN NEST-LIFE. Type of direct feeding by regurgitation, where all birds are served at each visit, and some more than once. Note uniformity in response and in size of the nestlings.

The initial instincts of the young depend upon the degree of development attained at birth, and are manifested in every phase from a precocious bird like the snipe, which is born seeing and with a full coat of down, to the altricious cedar waxwing, which is stark naked, and is blind up to the second or fifth day. The precox emerges with feathers wet with the amniotic fluid, and remains at the nest at least long enough to dry off, while the more slowly maturing hawk or eaglet, though down-clad and alert from the first, is tended for weeks or months at the nest. MacPherson, who has described the home life of the golden eagle, which he carefully watched on a cliff in the highlands of Scotland, found that the young were fed at the eyrie eleven weeks before they were ready for independent flight.

The initial responses of the altrix, of which the cedarbird, and, with some qualification, the cuckoo, may be taken as a type, to be seen at birth or shortly after, are (*a*) the power of orientation, (*b*) the grasping reflex of the feet, (*c*) the food-response, (*d*) the call note, and (*e*) the characteristic actions in muting, following feeding, as a result of the stimulus of food, and possibly of the attitude of inspection assumed by the adult. Later follow other specific call and alarm-notes, pecking, gaping, stretching, spreading in response to heat, preening, bristling and certain attitudes expressive of fear, flapping and flight.

After leaving the nest, we observe the more perfect performance of activities already begun within it, as pecking, crouching, standing erect with head upturned so admirably illustrated in the cuckoo, and especially in the cedar waxwing, where its use for concealment is obvious, as well as following, hiding, play, imitation, preying, and the more perfect expression of flight, finally followed by migration in late summer or fall, which may be performed, as in the cuckoos, quite independent of the parents.

IV

The description of the reproductive cycle given above is a composite, and applies most completely to the altricious birds, which are born blind and would quickly perish but for timely care of their parents. There are many special instincts in the twelve thousand or more species of known birds, but few of which have been adequately studied, and there are many minor variations in every term of the series, the discussion of which would require a volume.

The power of the parental instincts to banish fear in all classes of the higher animals has been recognized and admired from antiquity, and nowhere is this more clearly seen than in the brooding bird. The ancient Israelites were forbidden to take the mother bird with her young, because at certain times, as one commentator has observed, she will not avail herself of her power of concealment and flight, the ob-

FIG. 11. GREAT HERRING GULLS ON PRESERVE; chicks on feeding spot, watching old bird, and following her movements.

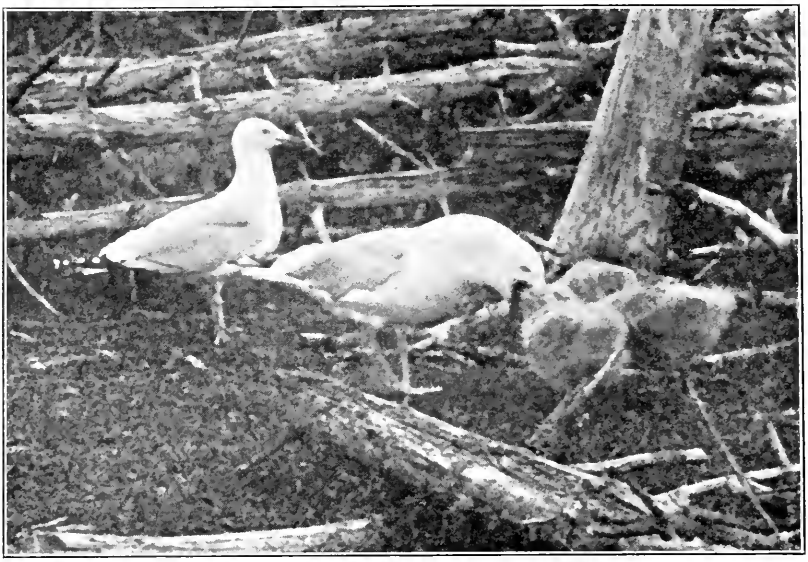

FIG. 12. GULL REGURGITATING, and the young seizing the shrimp, squid, or fish as they leave the mouth or fall to the ground. Type of indirect feeding by regurgitation.

ject of the law being not merely to preserve the game, but to signalize the sanctity of this instinct.

The brooding instinct rises like a fever, reaches a culmination at the time the eggs hatch or shortly after, and then rapidly subsides. At the same time there is a corresponding depression of fear, which returns with the waning of the brooding impulse. Thereafter brooding becomes more intermittent, being determined in some degree by the intensity of light, and weather conditions, with the difference that fear is now in the ascendent, and the element of intelligence, at the plane of association at least, is not lacking. At its first manifestation it affords a beautiful illustration of a pure instinct, adapted to the preservation of the offspring, though attended at times by what blind and costly sacrifice of life can well be imagined.

At the command of the brooding instinct, or at the sight or touch of the eggs, and later of the young, the whole nature of the bird is quickly changed. In his experiments with noddy and sooty terns, Watson[4] found that while neither bird recognized its own egg, the habits of a laying noddy could be almost immediately changed into those of a "sitter" by placing an egg in its nest. Before the appearance of the egg, this bird is shy and easily disturbed, but contact with an egg, and an artificial one at that, seemed to change its disposition

[4] Watson, John B., "The Behavior of Noddy and Sooty Terns," Pub. No. 103, Carnegie Institution of Washington, p. 223, Washington, 1909.

at once, for it would then stay by its nest and strike angrily at an intruder. The reverse of such behavior was further seen when the egg of a "sitter," even after several days of incubation, was summarily removed.

The cedarbird, ordinarily so timid that it will promptly abandon its new made nest if disturbed in the slightest degree, in the course of a few days becomes so "bold" as to submit to any change which the experimenter chooses to make. I have known this bird to stand on its displaced nesting bough, which had been sawn from a tree and mounted on stakes in a field for close-at-hand study, to permit the writer and a companion to approach within three feet and inspect bird and nest at leisure, while the adult assumed that curious bold upright attitude, with beak pointed to the zenith, in which nature seems to transform the actor into a part of the tree itself.

In my work on "The Home Life of Wild Birds" numerous illustrations of the action of this remarkable instinct are given. In one case a flicker, before so wary, for a few days after the young were born, would permit of any liberties, even to the sawing of a large window in the side of her nesting tree, without budging a feather, not even to shake the sawdust from her back, and allowing herself to be enclosed in the hand. In the Bahama Islands I have taken both the yellow-

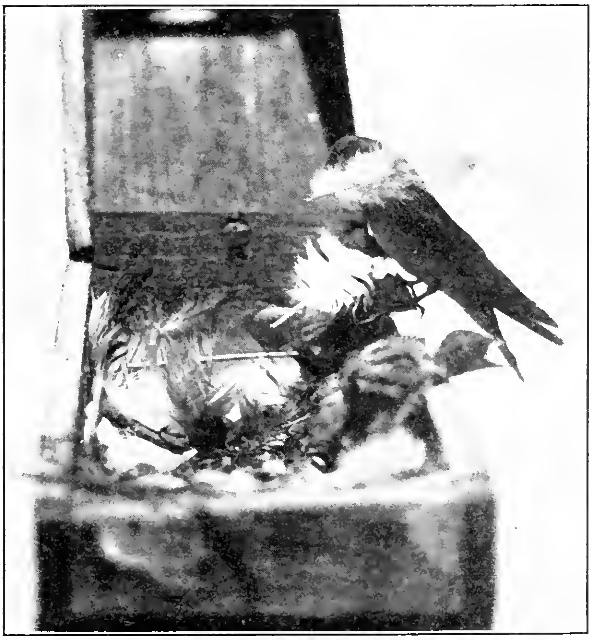

FIG. 13. WHITE-BELLIED MARTIN returning a feather to her nest, from which it had been blown by the wind the moment her nest-box was opened.

billed tropic bird and the sooty terns from their nests, but was careful in the case of the former to avoid the thrusts of their sharp, stiletto-like bills.

To keep within the more familiar species, and nearer at home, on July 18, while fishing a trout-stream, I passed two robin nests in apple trees, each with three eggs, more or less incubated. Note the difference in behavior on the part of their occupants, doubtless due in part to difference in individuality. In passing within a few yards of nest No. 1, the sitter immediately flew out in a great state of excitement, and shot off her characteristic emphatic alarms. At nest No. 2 I could

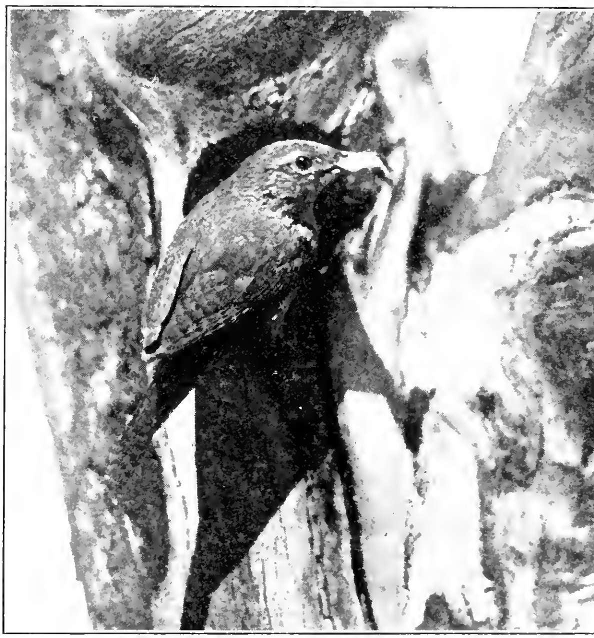

FIG. 14. NEST-CLEANING IN THE HOUSE-WREN, which has the practise of removing the sacs and implanting them on the bark of trees.

see the tail of the sitter projecting over the edge of the nest, as I walked under her tree. This was poked with the fishing rod, but with no response. Then I separated her tail-feathers with the tip of the rod, and poked harder. At this the old robin faced about and pecked angrily at the rod, and snapped her bill with the address of a flycatcher. Then I ruffled her already erect crest and back-feathers, only to receive more thrusts and snapping from the bill, and it was only after the roughest kind of treatment that this bird was finally dislodged, so that I could examine her nest.

To give a final illustration of the working of this instinct, on July

19, at eleven o'clock, I discovered a black-billed cuckoo in the act of brooding one young bird, a day old, and three eggs, in a small sapling pine, about three feet from the ground. The sitter, thus surprised, quietly retired and sounded her alarm from a distance. Twenty-four hours later, when I visited the scene, and when, as afterwards appeared, a second young bird had emerged, fear was more in abeyance, and the behavior different. I was allowed to approach as close as possible, and stood for twenty minutes, with the eye of the sitter not over twenty inches from my own, and only finally sent her off by trying to take her in the hand. Under these circumstances the cuckoo behaves much like the cedarbird, raising its head, though in a less marked degree, and remaining perfectly quiet, the only motions visible being those of breathing and the momentary flick of the third eyelid or nictitating membrane across the pupil.

V

The dawn of avian intelligence in the nestling, if one of the altrices, begins at about the third day, and in relation to the feeding reaction. Resting upon its huge pot-belly, as a central pillar, the little bird raises its trembling head, rather feebly at first, and supporting itself also, it may be, with its wings, and opening its mouth to the widest extent, thus displays its food-target. If the sign is unanswered, the head drops, the mouth closes, vibration ceases, and the bird lies prone, as if exhausted, the whole operation, which seems to call into play the entire body, lasting three seconds, more or less, according to the strength of the original stimulus.

This kind of behavior is a typical illustration of compound reflex action or instinct, and, when feeding follows, the reflexes assume more completely the chain form. When not due to hunger this response may be evoked at will by any suitable stimulus, whether tactile or auditory, whether the bird is in its nest or out of it, and regardless of the parent. The nestling now reminds one of an electrical toy, the action of which is purely automatic. Place the little bird on a piece of cloth or fold of your clothing and "press the button," that is scratch the cloth with the finger or a lead pencil, and behold this complex feeding response. When the nestling has not been fed to repletion, within the limits of fatigue, this reaction may be as automatic, uniform or stereotyped, and therefore predictable, as that of an electric bell.

Initial responses of this sort are relatively perfect. Consequently they can have nothing to do with past experience. They represent the hereditary powers of a hereditary mechanism. Now the point of greatest interest is that this inherited tendency to respond, in the course of a few days becomes replaced, as it were, by an acquired tendency. Instinct becomes "modified" by association. The mind or intelligence begins to take the reins, though feebly at first, into its own hands. Out of many experiments made upon the young of our common wild birds I select by way of illustration the brown thrush and black-billed cuckoo. In July 24, a nest of this thrush which I had been watching contained three birds, the youngest of which barely had its eyes open, and was from twenty to thirty hours old. When taken from its nest, at 3:15 P.M., and tested in the way suggested above, I obtained one hundred food reactions in thirteen minutes, each representing the entire complex of movements already analyzed, and each lasting from three to fifteen seconds, according to the strength of the stimulus received. A test immediately following gave fifteen reactions to the minute. The reaction time, which was very rapid at first, seemed to slow down only as a result of fatigue, but there was not a single failure to react upon the given stimulus. The same reaction was produced by clapping the hands, touching the bird, or holding its head between the fingers. On this day the two older birds, which were from two to three days old, would react while in the nest, but not when out of it. Now, upon the next day, about twenty-four hours later, as well as upon subsequent days, when the same tests were made with the same birds none of them would react when removed from the nest, with the exception that one feeble response was obtained from thrush No. 3, on July 25.

The same result was obtained with cuckoos. I was unable to get a single food-response from a black-bill, four or five days old, during the twelve hours or more that it was held a captive away from its nest. It would have starved rather than open its mouth of its own accord, and it even regurgitated the food which was pressed into its throat and gullet. Its whole conduct showed conclusively that the sense of fear had not yet appeared, but the moment this hungry bird was returned to its nest, and its feet touched the familiar twigs, it seemed to expand, as by magic, into a new creature, for standing erect, with every feather tube raised, and with vibrating wings, the neck trembling like a tuning fork, it opened its mouth and gave the food-reaction with all the vigor of which it was capable, and gave it repeatedly, loudly calling.

Edinger speaks of the modification of behavior described above, as an acquired habit, by which nestlings assure themselves against impending danger, and compares their attitude with that of an old bird coming hesitatingly to the nest, and looking about as if in anticipation of trouble. A simple experiment, however, like that just given upon the cuckoo, shows that this modification has nothing to do with assurance, for it begins long before there is any decided evidence of fear, and the little bird does not begin to look about in a suspicious manner until it is six or seven days old, when fear is arising. Moreover, all the attitudes, expressive of this instinct, both in young and adult, must, I believe, be considered as instinctive and not acquired.

What association seems to do for the young bird in the first instance is to eliminate a lot of useless reactions, by limiting its responses to those which count, for the amount of energy which goes to waste in this direction, especially up to the time of the later manifestations of fear, near the close of nest-life, must be very great. The pleasure of getting the food seems to lead to an association with the nest itself, the place where the food is received, and with the parent, the active agent, together with her calls and the vibrations of the nest or branches which attend her visits. Association with the nest seems to be strongest, for nestlings up to a late period respond freely to the call-notes of other birds, which happen to pass near, to sudden gusts of wind, at an early period especially, and to violent sounds of every description, like the distant whistle of a locomotive. A more curious sight, which illustrates the indefinite character of this association, is often witnessed up to the very last days of nest-life in many, if not all, of the common altricious birds of the country. Not only does the casual excitement of one bird arouse all the others into action, when, as it were, "the pot begins to boil," and then subsides, but the nestlings often respond to one of their mates, precisely as to the parent, for which it is plainly mistaken, crowding eagerly around it begging to be fed, and in their vain attempts to nestle under it, almost pitching it out of the nest.

In early nest-life, any sudden jarring of the nest or the branches about it will elicit the food-response as readily as when the vibration is imparted by the touch of the parental foot, but discrimination comes in this direction also, at any rate in certain species or individuals, and is often well-nigh perfect at the advent of the instinct of fear.

VI

The acquired habits or tendencies which have been described may in time become very uniform and more or less "stereotyped," but they are widely different from those instinctive characters which alone are inherited.

We have been obliged to speak frequently of fear, which in its origin must be regarded as an instinct in birds. It should not be forgotten, however, that if very young animals of any kind are separated from their parents, so that their natural environments and experiences are changed, we may look for a modification of this instinct, both as to the degree and manner of its expression, and as to the time of its appearance. In all the common altricious birds fear, in its later stages, is attuned with the instinct of flight, or, as in the case of the cuckoo, with the power of helping itself by entry upon a climbing stage, when seven days old. In a cedar waxwing, on the contrary, it is not well matured until the thirteenth or fourteenth day, when the entire brood, standing on their nests with heads upturned, suggest a gun, loaded, capped and primed, ready to go off as soon as some one pulls the trigger, which is of the hair variety. When this instinct is ripe, the plucking of a single leaf, or any unusual sight or sound will send all off in a panic. They scatter in every direction, making flights both long and good for a first effort, or, if less mature, down they all go flapping to the ground and, if robbins, squealing their danger-signals in high-pitched voices, indicative of that fear which shows in every attitude and note. Correlation, however, is not always perfect, and in consequence of the prematurity of fear many young birds flutter out of their nests in a helpless condition, to meet certain destruction from their numberless enemies on the ground.

That fear in birds may be connate, or present at the time of birth, seems to be clearly implied by an interesting experience reported by Hudson.[5] He was fortunate in finding a nest of the La Plata jacana (*Parra jacana*) on a small mound of earth in a shallow lagoon, with four eggs the shells of which were already chipped. Dismounting from his horse, he picked up one of the eggs and held it for a moment in the palm of his hand, when, as he says:

> All at once the cracked shell parted, and at the same moment the young bird leaped from my hand and fell into the water. I am quite sure that the young bird's sudden escape from the shell and my hand was the result of a violent effort on its part to free itself; and it was doubtless inspired to make the effort by the loud screaming of the parent birds, which it heard while in the shell. Stooping to pick it up to save it from perishing, I soon saw that my assistance was not required, for immediately upon dropping into the water, it put out its neck, and with the body nearly submerged, like a wounded duck trying to escape observation, it swam rapidly to the second small mound I have mentioned, and escaping from the water, concealed itself in the grass, lying close and perfectly motionless like a young plover.

In this remarkable case the whole complex of behavior is as plainly expressive of fear at every step, as it is evidently the free gift of heredity.

[5] Hudson, W. H., "The Naturalist in La Plata," pp. 111–112, London, 1892.

TWO PREVENTABLE CAUSES OF INSANITY

By Dr. THOMAS W. SALMON
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A FEW successful skirmishes in the interminable conflict with disease happened to take place recently on American soil. We saw the weapons of defense which scientific research had forged for us valiantly wielded by some of our countrymen and a new interest in preventive medicine, which has spread far beyond the ranks of the medical profession, was the result. Such discoveries as the detection of the part played by the mosquito in the transmission of yellow fever and by the rat flea in the spread of bubonic plague were interesting enough to gain a place in the news of the day but it was the fact that the first demonstrations of their surpassing practical value were given by medical officers of the American Army and Marine Hospital Service in our own land that gave rise to the present widespread confidence in the achievements possible in the domain of public health. It is natural, perhaps, that this newly awakened interest in the prevention of disease should center in the infectious diseases, in which the relation between cause and effect is often so obvious and the means of prevention are so logical. The school children of New Orleans easily grasped the simple facts in the case against the yellow-fever mosquito and they became efficient recruits in the memorable campaign of 1905. Much of the success in the present general movement against tuberculosis, the most formidable of all our unseen foes, is due to the fact that nearly all we know of its transmission can be reduced to half a dozen maxims, each of which can be expressed in as many words. It would be unfortunate, however, if popular interest in the battles for the public health should not extend to those diseases in which the relation between cause and effect is one step farther removed.

It is essential that the front presented to the common enemy should be as wide as our present knowledge justifies. There need be no fear of disaster from advancing in extended order, for an attack upon one position of the adversary will not infrequently disclose an unsuspected weakness in another. Since May, 1907, every effort has been made by the combined federal and city forces to rid San Francisco of bubonic plague. With victory assured, the results of what has been done are being counted up and it is found that measures undertaken for the extermination of plague have brought about a sanitary regeneration of the city and that the mortality from all diseases has been reduced to an unprecedented figure. We know that efforts for the public welfare often produce results where they were least expected, and so, the different fields of preventive medicine, special as some of them seem to be, are really inseparably related. Contrary to general belief, the prevention of insanity is not a matter which depends upon such special factors that it does not concern us all. It is, instead, only a phase of the general warfare against preventable disease; it has points of contact with many familiar problems of sanitation and, as will be shown, it bears a fundamental relation to two social questions which are occupying a very large place in the public attention at the present time.

The prevention of insanity is a matter well worthy of some consideration, for it is doubtful if any other human infliction can produce keener distress. A better conception of the nature of disorders of the mind and a kindlier attitude toward the insane have done a great deal to improve the lot of the sufferers themselves, but nothing can do much to lessen the unhappiness which insanity brings to others. It is difficult to tell exactly how prevalent insanity is. A few years ago some writers, who failed to take account of factors which greatly modified their statistics, startled the public in England by showing that the total number of the insane was increasing at a much more rapid rate than the general population, and one of the more gloomy of these writers did not hesitate to predict that insanity would ultimately engulf the race. It was, of course, absurd to ignore the effect, in increasing the aggregate number of insane persons under treatment, of an increasing readiness to seek institution treatment on account of the enormous advances in standards of care, of the earlier recognition of mental diseases and of the effect of building more hospitals, thus affording ready access for cases not often committed to distant institutions. At the close of 1908, there were 30,456 patients in the public and private institutions for the insane in New York state; about one in 280 of the general population of the state. This is approximately the ratio which exists in neighboring states and, it happens, exactly the same as the ratio in England. This number is not, fortunately, a satisfactory index of the prevalence of mental diseases, for the reason given and because the duration of some mental diseases is so great, in patients who do not recover, that the aggregate number under treatment at any given time represents, in large measure, the accumulation of unrecoverable cases admitted in former years. A patient died recently at the Utica State Hospital who had been admitted in 1843; she had been counted in 65 annual enumerations. The number of patients *admitted for the first time to any hospital for the insane* during a specified period is a much more trustworthy guide. Last year 5,301 patients were admitted for the first time to any hospital for the insane in New York state; one in 1,600 of the whole population or one in 1,000 if only those above the age of sixteen are considered. Here, then, is our problem in the prevention of insanity. Was it possible, by means at our command to have saved any of these unfortunates from becoming insane last year? Must an equal number, the population of a large town, be admitted next year, another 5,000 in 1912 and so on in the years to come? Are there facts at hand which point to practical measures of prevention or are the causes of mental disease so little understood or so deeply rooted that this sad toll of 5,000 new cases in a single state must be paid each year without hope of reducing it in the future?

Those who are responsible for the care of the insane in the various states are deeply impressed with the necessity of being able to give definite answers to these questions. In preventive medicine accurate knowledge must precede action and so statistics are being carefully gathered and analyzed in order that reliable information may not be wanting in this field of the prevention of disease. The New York State Lunacy Commission, which is charged with the care of nearly one fifth of all the insane in the United States, has recently adopted a greatly improved method of obtaining statistical data regarding new patients and already sufficient material is available to permit the accurate statement of some conditions which could be presented previously only in a general and rather unconvincing way. So, in this discussion of two preventable causes of insanity, it is worth while to examine the records of the 5,301 "first admissions" in New York state for the year which ended September 30, 1908.

At the very outset of any consideration of insanity, it is necessary to make it plain that we have to do not with one disease, manifesting itself in different ways, but with a number of diseases, differing very greatly from each other in many important respects. What is true of the causes or of the clinical characteristics of one mental disease may be entirely untrue of another. Various mental diseases, or "insanities" as it would be quite permissible to call them, are grouped together because of some similarity, and all these groups make up insanity as that term is generally used.

The mental diseases of one such group have the common characteristic of depending upon a preceding infectious disease. Permanent or transitory mental impairment may follow typhoid fever, influenza and some other acute, infectious diseases and it is obvious that these mental disorders are preventable in just the measure in which the diseases upon which they depend are preventable. The number of these cases is not large, and yet, when the cost of the needless prevalence of typhoid fever is estimated, these more remote effects should be considered.

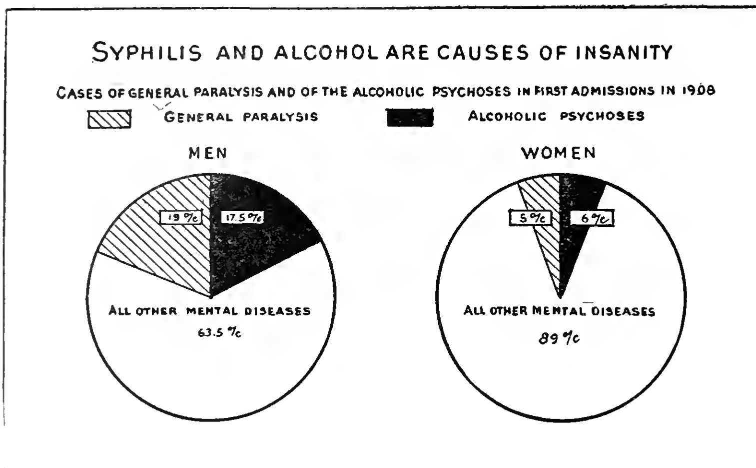
There is, however, one mental disease depending upon a preceding infectious disease which overshadows all others in importance. This is general paralysis or "general paresis," "paresis" or "paralytic dementia" as it is variously known. Almost invariably fatal within a few years after its onset, often a danger to the reputation or to the happiness of whole families in its earlier stages and distressing in its final phases, this disease occupies a place of its own in the interest of physicians and of others who chance to become familiar with it. Six hundred and sixty-four patients, or 12 per cent. of all the 5,301 new cases admitted to the New York state hospitals last year, had general paralysis. Some comparisons with the prevalence of other more familiar diseases may make the significance of this number clearer. Last year there were 1,368 deaths from typhoid fever in New York. Half as many persons died of general paralysis. Cancer of the breast is a relatively common and a much-dreaded disease, yet there were more deaths from general paralysis than from cancer of the breast. Angina pectoris is another frequent cause of death, but more people die of general paralysis. More people died in 1908 in New York from general paralysis than died from smallpox in the whole registration area of the United States in that year and the three preceding it.

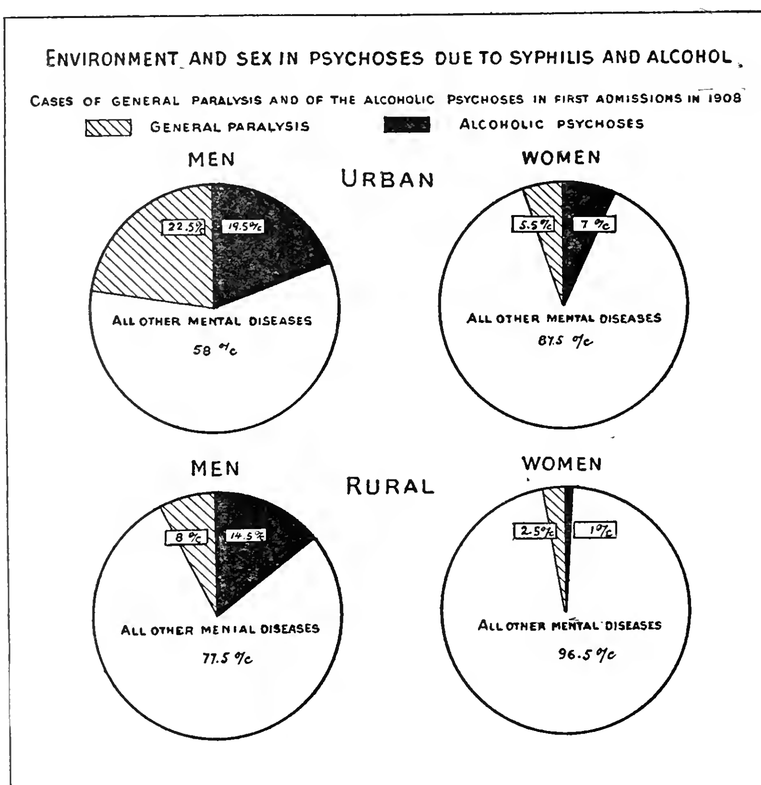
The fact about general paralysis which is of the greatest importance is that it depends upon previous infection with syphilis. To just what extent it is not possible to say, but, whatever other causes may combine to produce general paralysis, testimony is increasing that syphilis is essential. In other words, if these 664 men and women had not had syphilis, very few of them would have had general paralysis.

Whatever is to be accomplished in the prevention of disease by the medical profession and an enlightened public will be brought about by concerted action. Without authoritative information and skilled leadership, popular movements in this field will be unlikely to succeed and may even result in harm, and, without popular support, the efforts of doctors will end in academic discussion and in plans incapable of execution. In this alliance frankness is essential; there must be no secrets or half-hidden truths between allies in the battles which are to be fought together for the public health. So the prevalent belief that syphilis is a menace only in an underworld of criminals, prostitutes and the utterly depraved must be abandoned, and the truth realized that it is a peril from which no class of society is exempt and to which the thoughtless, the innocent and the immoral are equally exposed. Three fourths of the 664 cases of general paralysis were married and 69 per cent. of them were in comfortable or affluent circumstances. The most unfortunate feature of general paralysis is that it occurs most often in the third and fourth decades of life; frequently in those who have long since abandoned the immoral or heedless mode of life which led to their infection and have become responsible for the support of families and of economic value to their communities. It not infrequently means that an innocent mother must be taken from her home, and even from the cradle of her baby, to pay, in mental darkness, a dreadful penalty for her faith in the man who became her husband.

Turning again to the cases we have selected to examine for preventable causes, we find that there were a very large number of patients in whom alcoholic intemperance was the cause of their mental disease. There is no subject which needs to be discussed with so much conservatism or with such scrupulous regard for accuracy as the effects of alcohol. So much in the relation of alcohol to social and bodily ills is the subject of bitter controversy, and so much damage may be done a worthy cause by careless or ambiguous statements that it seems desirable to define very precisely what we mean when we speak of alcohol as a cause of mental disease. Alcohol has been assigned as the cause, directly or indirectly, of more than one half the admissions to hospitals for the insane by Kraepelin of Munich, a very great leader in psychiatry and perhaps the foremost worker in Europe in the cause of temperance. In order to remain upon unassailable ground in this important matter, we will consider separately those cases in which alcohol is *directly* responsible and those in which it was a controlling and probably the only cause. So the facts relating to the "alcoholic insanities," those in which to name the disease is to give the cause, will be presented first. In our series of 5,301 first admissions there were 638 such cases, or about 12 per cent. of all.

There were together, then, 664 cases of general paralysis (depending upon syphilis) and 638 cases of the alcoholic psychoses (all due to intemperance) or *more than one fourth of all first admissions due to these two preventable causes.* Before considering any measures of prevention, it is desirable to examine a little in detail these 1,302 cases because there are some matters of sex and environment which are particularly significant. It is seen in the smaller chart that, as would have been supposed, both these causes affected men to a much greater extent than women. A factor which bears directly upon preventive measures is shown in the larger chart, which indicates the residence, as "rural" and "urban," of patients admitted with general paralysis and of those with alcoholic psychoses. It is seen that in the case of male admissions environment did not have a very marked influence upon the prevalence of the alcoholic psychoses, but that the percentage of cases of general paralysis in men was nearly three times as great in the admissions from cities as in those from the country. For women, this chart shows that the percentage of cases of general paralysis from cities was twice that from rural communities, but that the percentage of admissions with alcoholic psychoses was seven times as great for


SYPHILIS AND ALCOHOL ARE CAUSES OF INSANITY
CASES OF GENERAL PARALYSIS AND OF THE ALCOHOLIC PSYCHOSES IN FIRST ADMISSIONS IN 1908
GENERAL PARALYSIS
ALCOHOLIC PSYCHOSES
MEN
19 %
17.5 %
ALL OTHER MENTAL DISEASES
63.5 %
WOMEN
5 %
6 %
ALL OTHER MENTAL DISEASES
89 %


ENVIRONMENT AND SEX IN PSYCHOSES DUE TO SYPHILIS AND ALCOHOL.
CASES OF GENERAL PARALYSIS AND OF THE ALCOHOLIC PSYCHOSES IN FIRST ADMISSIONS IN 1908
GENERAL PARALYSIS
ALCOHOLIC PSYCHOSES
URBAN
MEN
22.5%
19.5%
ALL OTHER MENTAL DISEASES
58 %
WOMEN
5.5%
7 %
ALL OTHER MENTAL DISEASES
87.5 %
RURAL
MEN
8 %
14.5%
ALL OTHER MENTAL DISEASES
77.5 %
WOMEN
2.5%
1%
ALL OTHER MENTAL DISEASES
96.5 %

cities as from rural communities. This is eloquent testimony to the influence exerted by the back room and the "ladies' entrance" of the city saloon. The most striking fact shown by these charts, however, is that *42 per cent. of all the male admissions from cities were for general paralysis and the alcoholic psychoses.* Where are "the nervous tension of the cities" and "the mad rush of modern life," of which we speak so glibly, compared with syphilis and drunkenness as the real dangers of city life? But for the undue prevalence of insanity due to these two causes, the ratio of the insane to the population would actually be greater in the quiet countryside than in the cities, in spite of their congestion of population, their unequal share of immigrants (an important factor in the prevalence of insanity) and their increased economic stress.

All through the etiology of other types of mental diseases than those which we have considered, appears the trail of syphilis and intemperance; sometimes unmistakable and sometimes faint but recognizable. A considerable percentage of the 5,301 first admissions were for mental diseases arising upon a basis of congenital mental defect or epilepsy. Some of these psychoses are temporary attacks in epileptics and in imbeciles and some are really terminal stages of such conditions. The tremendous effect of alcohol in the parents as a cause of mental deficiency has been pointed out by many competent observers and there are many very interesting studies which could be mentioned if space permitted. Alcoholism in parents has nearly as great an influence in the causation of epilepsy as of mental defect in descendants. Dr. R. E. Doran found that the parents of 257 of 1,300 epileptic children admitted to the Craig Colony had been confirmed alcoholics. A group forming about one tenth of all admissions to state hospitals is made up of patients with psychoses dependent upon gross disease of the brain. In these mental diseases there is destruction of cells of the brain, resulting from arterial changes, the effects of hemorrhages, the pressure of new growths and similar causes. In a very large proportion of such cases it was syphilis or alcohol which first attacked the integrity of the blood vessels or in other ways laid the train which was destined to lead finally to insanity.

So, if we care to go beyond the field of what is demonstrable by absolutely trustworthy statistics and can be shown by tables and charts, we find that alcohol and syphilis are factors in the production of mental diseases which have no equal. If we prefer to confine our attention to general paralysis and the alcoholic psychoses, we find that these diseases, due *directly* to syphilis and alcohol, are responsible for nearly one fourth of the sad procession of new patients entering the hospitals of a single state at the rate of more than a hundred a week.

The lesson of these statistics is full of hope and encouragement.

A large proportion of all cases of insanity are found to be due to causes within our own control. We have come across the trail again of two formidable enemies, but they are old foes and we know their strongholds; we have been gathering evidences of their depredations in other directions and there are already movements on foot against them. We have gained the tremendous advantage of being able to talk about both of them in public and before any hearers. Instead of vague tales of the ravages of these enemies of the race, in one direction or another, we have come to statistics, tabulations, investigations with reference to specific effects and to the widest publicity. This is why it is justifiable to speak of syphilis and alcohol as two *preventable* causes of insanity.

THE INDIAN FAIRY BOOK

By SPENCER TROTTER
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AFTER our boyish occupation of following cows home from pasture, along brambly ways where delay was often invited by some untimely mocker in the shape of a bird that lured us into pursuit, we would go up in the gathering dusk to the house on the hill and listen through the hour before supper to the stories in the Indian Fairy Book. Stillness and an autumnal glimmer of western light; crisp air laden with the smoke of smouldering brush fires—these ever after to be blent, by the subtle alchemy of memory, with the tales of an ancient people. Beyond the sunset light lay the land where these stories had been wrought, yet a country that none might reach by traveling in mortal fashion, for, like the old Phæacian land, it belonged in those dim regions of the past that only the eye of fancy may behold. We had mapped it out in our minds—its lakes and wide prairies, its farthest verge of forest—but no explorer we knew would ever find it. He might stand on the marge of some far western lake, never before seen by a white man, and gaze across its waters, yet this elusive land would ever be another day's journey beyond his last camp fire.

In this Indian Fairy Book were gathered the folk tales of aboriginal America—Algonquin and Dakota legends, that might fairly hold a place with those old Celtic tales—the Mabinogion—that have come to us out of so remote a past. Indeed, they have many points in common. Magic weaves its web through the adventures of the men and women who seem more than mortal beings and who yet give to the wonder tales in each of the two groups their vital human interest. In each also there are great personages, cast in heroic mould. There is the same overcoming of evil influences, the same mystical union of men with natural things. Both are of that Juventus Mundi—that far away period over which a strange, dim light broods. It is this effect of subdued light, the strange half light, half dark of a shadowy world, that a reader of these aboriginal tales feels most. A "twilight" effect, Mr. Havelock Ellis calls it in writing of the Celtic tale, which lends a peculiar "glamour." And, as this writer has further shown, the effect of "remoteness" as to time and place, of being very far removed from the present or even the medieval world, is another element that adds to this glamour of the old Celtic stories. Sidney Lanier says:

> I think it curious indeed to note *how* curious those old romances, or Mabinogion, seem to us in spite of the long intimacy and nearness between Welsh and English. They impress most readers with a greater sense of foreign-

ness, of a wholly different cultus, than even Chinese or other antipodal tales; and over and above this there is a glamour and sleep-walking mystery which often incline a man to rub his eyes in the midst of a Mabinogi, and to think of previous states of existence.

It is this sense of strangeness, this "sleep-walking mystery," as Lanier calls it, that haunts the aboriginal American tale. It is of the same cultus as the Celtic, and both loom above the horizon of later English culture as distinctly aboriginal and belonging to preexistent races that occupied the soil ages before the transplanting of the dominant English type in Britain and America. Like the vanishing fauna of an invaded land, these ancient culture tales linger in remote places, amid aboriginal surroundings, elusive, and disappearing with the encroachment of the newer life.

In the early years of the last century Henry Schoolcraft gathered a number of Algonquin folk tales taken directly from aboriginal story-tellers around lodge fires in the then remote wilderness of the Northwest—about the upper lake region and the headwaters of the Mississippi. These form the basis of his "Algic Researches," first published in 1839, and of later editions and compilations, one of which is the Indian Fairy Book. What Geoffrey of Monmouth did for the Celtic romances in his "History of The Britons," Schoolcraft has done for these Algonquin legends—given them an enduring place in the literature of English-speaking peoples. Both sources of legend have lent their matter to the verse of later English poets—Idylls of the King, the Morte d'Arthur and Hiawatha—reset fragments from an earlier period of epic the sources of which lie far back in the dim, mythopœic past.

The likeness of the primitive mind in two so widely separated culture areas as Britain and aboriginal North America, as revealed in both sets of tales, is seen in the overcoming of obstacles, often of superhuman character, by feats of prowess aided by magic. Indeed, magic plays the chief part, as it does in the tales of all primitive folk. In an Ojibwa story—The Red Swan—a younger brother sets forth in quest of a mysterious bird that he has hit with a magic arrow. He traverses wide stretches of country, coming on the evening of the second day to the lodge of an old magician who feeds him from a magic kettle and who encourages him to go forward in his enterprise. "Often has this Red Swan passed," the old man tells him, "and those who have followed it have never returned: but you must be firm in your resolution, and be prepared for all events." On the evening of the third day he reaches the lodge of another old man, similar in every respect to the first, and in like manner a third old man entertains him the following night, each with the same magic kettle. When the youth has finished eating this last old man thus addresses him:

Young man, the errand you are on is very difficult. Numbers of young men have passed with the same purpose, but never returned. Be careful, and if your guardian spirits are powerful, you may succeed. This Red Swan you are following is the daughter of a magician, who has plenty of everything, but be values his daughter but little less than wampum. He wore a cap of wampum, which was attached to his scalp; but powerful Indians, warriors of a distant chief, came and told him that their chief's daughter was on the brink of the grave, and she herself requested his scalp of wampum to effect a cure. . . . The warrior's coming for it was only a cheat, and they now are constantly making sport of it, dancing it about from village to village; and on every insult it receives, the old man groans from pain. . . . The Red Swan has enticed many a young man, as she has done you, in order to get them to procure it, and whoever is the fortunate one that succeeds will receive the Red Swan as his reward.

This is the key-note of the tale. The youth by magic assumes various forms—a humming-bird, a bit of floating down, a hawk—secures the scalp and restores it to the old magician who immediately becomes a young man and ultimately bestows upon his benefactor a maiden of wondrous beauty, the erstwhile Red Swan.

This tale has in it many points of resemblance to a Mabinogi. In the old Welsh story of Kilhwch and Olwen, for example, there is the same overcoming of difficulties by means of magic, the same transformation of men into animals and objects of nature, the same gaining of some object of vital importance, and the ultimate bestowal of the prize—a maiden of radiant beauty—upon the successful one. There is much circumlocution and repetition in all of these primitive tales. The difference seems mainly in the setting—the environmental influence, one may call it—not in the substance of the tales themselves.

In the Dakota legend of Strong Desires and the Red Sorcerer we have the story of a youth (it is always youth that figures so heroically in these tales, both Celtic and American) taunted for his timidity, who becomes master of himself by accomplishing the death of an evil spirit in human guise, and who gains his end through the same magical influences that are woven so closely with all the events that take place in this strange world of the past. So in other of these aboriginal American folk tales—The Vanishing Little Men (the origin of the fairy people), The White Feather, The Magic Bundle, The Enchanted Moccasins, The White Stone Canoe, The Summer Maker, to quote but a few in passing, one is impressed with their close similarity to the Celtic cultus. In many of the Welsh tales and in such old Irish stories as the Fate of the Children of Lir and The Fate of the Children of Turrenn, there is the same changing of men and women into beasts and birds that one finds so often in the tales of American aborigines. Many of these tales, in fact, belong to that class of curious beast stories that are so widely spread in the culture of all primitive folk. There is hardly a story in which an animal of some kind, with human attributes, does not appear. Men pass into animals or animals take on the speech and ways of men as a matter of course in this land of enchantment. In both the Celtic and American stories, too, there are men of heroic figure. Manabozho, the Hiawatha of the Iroquois, while given, as related in certain Algonquin tales, to mischief of a more or less harmless character, was a being of lofty nature, and, save for the ruder surroundings of his life, a personage quite as imposing as Arthur himself. Indeed, in the conception of each as a power for good—and this is the real essence of their natures—there is little, if any, difference.

The modern world can not but miss the drift of these stories, for the mind that conceived them belonged to the youth of a race. Men of to-day have so far forgotten this period of racial childhood (as they have forgotten their own individual childhood), have so far put behind them the childish things, that they largely fail to grasp the real meaning of these tales. It was the earliest glimmer of that racial self-consciousness that in after times found expression in self-narrated history and in religious belief. The type or mode of thought was the same in all races when they reached this crisis in their psychic development—a realization of kinship with the powers of earth and air, with the phenomena of nature, and with the life of animals and plants. Child-like efforts to account for the origin of things gave rise to those strange creation myths that exist as primitive conceptions in the history of every race and people. Delusions of judgment undoubtedly played a large part in the myth-making faculty of primitive men. They verily believed that they saw and heard strange forms, unembodied voices. They were overawed in the presence of elemental forces and, child-like, they saw in all the lineaments of nature mysterious powers, potent for good or evil. The sights and sounds of nature and the ways of animals were interpreted by them in terms of their own mode of thought. To the phenomena of cause and effect, to the haphazard circumstances of their own lives and those of their fellowmen—fortuitous and unfortuitous happenings—and to dreams, they imputed the agency of superhuman powers or magic. To this latter class of phenomena—dreams—we may attribute much of that curious recital of visits to the underworld. In the Red Swan, for example, the hero of the tale, after his return to his native village, journeys to the abodes of the dead, where he holds converse with the chief of the departed buffaloes. One can not help but be impressed, in reading this portion of the tale, with its resemblance to the visit of Odysseus to Hades.

These myths and folk stories have drifted down to us out of so remote a past that the period which they depict in the history of any group of peoples can never be certainly known. More than likely they are the embodiment of a slow subliminal growth that began with men of paleolithic culture in various parts of the earth as a result of the impress of their surroundings. At a later period, possibly in a neolithic stage of culture, as in aboriginal America, this body of impressions crystallized into the form of the myth and the folk tale. Homer depicts the Bronze Age, which was later than that of stone, and the Celtic tales are probably of this period also, but there are no means of knowing where the germ of any myth or story had its origin, for much new matter has likely been grafted upon an older form and the whole tale has come to represent a slow accretion from one generation to another through many phases of culture and over vast periods of time. Whether a race of dwarf men inhabited lands that were later invaded by men of larger stature and more advanced culture and gave rise to conceptions of gnomes and "little people," as suggested by Sir Harry Johnston, is a matter of purely speculative interest. As this writer has pointed out, the African forest pygmies, who represent a very ancient type of man that was once widely spread in Europe, as well as in Africa, have certain characteristics, as suddenly vanishing from sight and as suddenly appearing, that might well have given rise to folk myths. Such may have been the origin of our Santa Claus, a hyperborean dwarf-myth arising out of the reindeer-herding Lapps in that dim land beyond the Scandinavian mountains.

The gift of the mythopœic faculty belongs to childhood—individual and racial. Education in the modern sense—the education of the school—is its arch enemy. The rank, tall-growing weeds of knowledge soon choke out this joyous bloom of the aboriginal soil. We enter the school and straightway a mist drifts across our past, blotting out the early years, and the days of romance, and myth, and make-believe are speedily forgotten. Yet out of this enchanted mist—for it is enchanted, like the mist that shrouded Geraint when he left Enid to fight against the knight—some of us may still, in rare moments, have glimpses that will make us "less forlorn." As Geraint dispelled the mist by the overthrow of his adversary, so we must, if we desire these visions, break through the mist that envelops them with the magic arm of imaginative memory, for no weapon of knowledge may serve us in its stead.

The backward extension of each individual life through many generations of germ-plasm carries us all back to a common racial childhood. Much of this racial childhood is recapitulated in the first years of individual existence—old race instincts, strange primitive ways, and the love for stories about beasts, and men, and fairy people. These myths and folk tales are thus part of a racial heritage, and happy indeed are those of us who, in our maturity, can still feel with the poet when he exclaimed—

—Great God! I'd rather be
A Pagan suckled in a creed outworn;
So might I, standing on this pleasant lea,
Have glimpses that would make me less forlorn;
Have sight of Proteus rising from the sea,
Or hear old Triton blow his wreathed horn.

As we love Æsop and Uncle Remus, the Odyssey and the Celtic tales, so we love these folk stories of aboriginal America, for they are of the same lineage—the early, unsophisticated outlook upon life and the Powers of Darkness.

SCENERY, SOIL AND THE ATMOSPHERE

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THE atmosphere is commonly considered as a body of gases surrounding the globe, but hardly as a part of our sphere. We must, however, look upon it as being of the very substance of our earth, an integral part of the planet as truly as the waters or the solid crust. The geologist and the geographer, indeed, habitually speak of three envelopes of the globe, the atmosphere, the hydrosphere and the lithosphere. A certain assemblage of gases, all of which may be found in the waters and the rocks, remains in a more attenuated condition as the outer part of the earth. The degree of attenuation increases as we go from the surface of the solid part. Whether the atmosphere actually ceases a few hundred miles, or some hundreds of thousands of miles, from the lithosphere is not important to our present purpose, for its effective work is done within a few miles of altitude.

Looking at the atmosphere as a whole, its calms are exceptional and its movements are the rule. We may find the gentle breeze, the cyclonic wind or the resistless tornado, but always activity. These movements do not tamely confine themselves to horizontal paths, but the gases rise and plunge, pursue broad curves and narrow spirals, and would present, to an eye that could see them from above, a tumult, like the sea in storm. If we add to these mechanical operations the efficient chemical functions of the atmosphere, we shall be ready to agree that it is one of the most powerful agencies that help to mold the form and fashion the quality of the outer parts of our planet.

We well understand that all organic life is dependent on the atmosphere for its existence, and that interchange of materials is constant. The forms of the land are nearly as dependent upon this medium as are those of life. Manhattan Island was once a mountainous tract. The first making of the rocks that composed it was conditioned by an atmosphere. The forces that filed it down to its present forms and heights could not have worked without the gaseous envelope. The channels that invite ships to its water line are an indirect product of atmospheric activity. Indeed, the Palisades Ridge, and the submergence of the coast line are the only features of your inorganic environment that have chiefly been due to underground forces.

The atmosphere is interwoven with all forces operating on or near the surface. Other, or subterranean, energy could produce but a few types of form. We might have great and swelling ridges or domes, or cliffs due to faulting, involving fracture and dislocation, or volcanic cones, streams or sheet outflows. For such initial forms, apart from an atmosphere, gravity would seem to be the only agent of change, and its action would be narrow, for disintegrating forces must operate to make gravity effective.

With so much of introduction we are ready to look at the atmosphere in a threefold way—and consider, first, its indirect work; second, its direct work; and, third, its history.

As a means of changing the face of the earth, and of modifying its rocks to a considerable depth, no agency compares with land waters. But we are to remember that waters, if they could exist, could not move without a gaseous medium. Supply our planet with its outfit of oceans, lakes, rivers and underground waters, and, in the absence of a thermal blanket they would be frozen and silent. If they could be conceived as keeping the liquid condition, no transportation of water vapor could take place, no rainfall, and no rivers or glaciers could accomplish their tasks.

Modern geography has introduced the doctrine of the cycle. We mean by this the period in which a continent or any part of it would be reduced from its initial forms of uplift, to baselevel; in other words, the time necessary to wear out a land, and put its waste under the bordering sea. In the course of this wearing out, many land forms—mountains, plateaus, hills, plains, slopes, valleys—would come into being and disappear, in appropriate stages of youth, maturity and age. A great series of evolutionary forms of the land would characterize the passage of a cycle.

The varying amount and condition of land waters give us three types of the geographic cycle and three typical groups of resulting shapes of the surface; these are the normal, the glacial and the arid. The normal cycle is conditioned by medium temperatures and ample precipitation in the form of rains. The glacial cycle exhibits low temperatures and abundant precipitation in the frozen condition. The arid cycle is marked by higher temperatures and low precipitation—so little rain that lakes can not rise to the rims of closed basins due to warping of the crust, for the simple reason that evaporation and soakage take care of the rainfall and no rivers can reach the ocean.

We may illustrate the three kinds of cycle by three well-known parts of our own land. The southern Appalachians show us what happens in normal conditions. There are indeed at least two cycles whose results are clearly shown in this southern region, but for our purpose we simply observe that here are plentiful rainfall and moderate temperatures. Great initial uplifts have given opportunity for land sculpture on a large scale. Rivers and weathering have done the work. There are practically no closed basins, either dry or wet, no interruptions of drainage, and the soil is residual, having been chiefly made by the decay of the rocks in place.

Let us turn to New England. Here the soils are due to the weathering and organic modifications of the "drift." The drainage has been greatly interrupted, and new channels, waterfalls and lakes abound. Several types of hills of accumulation appear that we can not find in the southern mountains. The tops of hills and mountains of hard rock have a different aspect—it is the product of the glacial cycle which we are contemplating, and the geographer would only need to cast his eye upon maps of the two regions to recognize their character.

Let us go to the Great Basin. Rather is it a group of basins, flanked by the Wasatch on the east and the Sierras on the west. Its broad and arid expanse is intersected by many north and south mountain ridges, which are the up-thrown edges of great crustal blocks. The upper parts of these mountains show normal erosion. The bordering Sierras show normal and glacial types. Within the basin the summits and slopes of the mountain are shedding down their waste and streams of greater or less vigor are carving a normal topography. At the foot of the mountains, the waste, instead of going in the grasp of streams to the sea, is spread out on the inter-montane floors, raising the surface and building plains of sand, clay, salt and gypsum. The rivers become small instead of growing, and lose themselves in the atmosphere, the soil and in shallow lakes which may be permanent and salt, or intermittent and brackish. The soil is formed mechanically and with but a minor amount of those chemical changes which take place in a more humid climate. Vegetation is scant and this condition retards true soil-making and, by lack of cover, aids the action of winds. Monotony characterizes the arid type, as ceaseless variety belongs to the normal and glacial operations. The ridges that separate adjacent arid basins may be cut away, and both be merged in a single featureless plain, and thus we have a growing lake of waste, somewhat akin to closed basins of water. The only means by which such a basin can lose its material is through the winds. Central Persia offers another land of the same order, where severe conditions of aridity have for an unknown period reflected themselves in the life of man and in the very forms of the land which he makes his home.

Hill and mountain, valley and plain, thus own their dependence, in no remote way, upon the gaseous envelope. As it is wet or dry, hot or cold, so evolves the very physiognomy of our globe, and whether we cross the border of an adjacent township or journey to a far country, its handiwork is before our eyes.

No forms are more characteristic or interesting than those which the ocean makes on its borders. These forms in a minor way are due to the tides, in the major way to waves, and thus, at one remove only, are produced by the atmosphere. Likewise ocean currents, involving transfers of heat, moisture, plants and animals, are believed to be chiefly due to atmospheric movements. If we compare New York with Rome and Constantinople, or Labrador and Hudson Bay with Great

Britain and the North Sea, or the ice fields of Greenland with the ample life of Scandinavia, if we wonder at the small part which latitude seems to have with opposite shores of the Atlantic, we are at once led back to the atmosphere for light upon our problem.

Likewise for all life, the atmospheric gases are essential as a heat regulator and in the employment of their substances for organic structures. Through these structures, in turn, all soil-making is profoundly conditioned, and those organic accumulations are made possible, which we find in the mineral fuels and in most limestones.

If we turn to the direct work of the atmosphere, we shall find a group of facts, not so conspicuous, perhaps, but worldwide and important. This is one of the newer subjects in geology, and to consult any text-book written twenty years ago would yield a scant result in information.

The atmosphere is the agent of incessant chemical change, the world over, and down to the level of the ground water. Whether the water table be found close to the surface or far down, the atmosphere finds access to some parts of the rocks down to that horizon. The depth below the surface depends on the water supply, on the character of the rocks and on the surface topography, and it is different in the same place at different times, but always and everywhere the gases that surround and surmount us, are pursuing their underground activities as well. And it is scarcely proper to limit them to zones above the water table, for they communicate some measure of their efficiency to the ground waters, which in turn may go far down, and may make long journeys before they emerge, thus giving the atmosphere some share in the segregation of those metallic substances which belong in the inventory of the world's wealth.

The making of soil is a complicated process, or bundle of processes. Fundamentally it is due to the breaking down of rocks, and this is effected by change of temperature, by organisms, by the wear of running streams, glaciers and ocean waves. But when the rocks are broken down, processes more intimate and essential must be added. These more intimate agencies are the water, the atmosphere and decaying organisms. The water will accomplish solution and thus make certain minerals available for the nutrition of crops. But the water falling as rain has gathered from the atmosphere minute portions of its carbon dioxide, and has become thereby an effective dissolving agent. Most rocks contain more or less iron in a disseminated condition. The oxygen of the air combines readily with this metal, promoting the decay of the rock mass, and coloring not only the rock, but the soils that ultimately come into being. When the farmer selects a field to lie fallow he stirs the soil, gives it all possible exposure to air, water and heat, and thus speeds these silent processes which go on in some measure everywhere, with or without his ken. It is the time required to produce these fine results, that makes wanton destruction of soils criminal and points the rebuke to public authorities and legislative bodies, when they halt at reasonable measures of conservation. We can not grind rocks in a mill and make soil. The operation is at once too large and too delicate, demanding the silent intervention of mechanical and chemical forces, of atmosphere, water, heat and life, through long periods of time.

When the land has suffered a glacial invasion, much of its ancient soil has been lost in the sea, and such as remains is moved from its place and mixed with a large body of drift, mechanically broken from fresh bed rock. This latter material is not soil until it has been subjected to the atmospheric and vital processes which fit it for its function of mediation between the rocky planet and the plant life of the world.

In a non-glacial region, all the soils, save along rivers, or on steep slopes, have been formed by the decay of the bed rocks in place, and this decay does indeed, and fortunately, in favored regions, proceed swiftly. It may be some compensation for people subject to disaster on the slopes of Vesuvius or Etna, that the friable lavas and ash, in that genial climate, speedily become soil. On a lava stream still warm, at the foot of Vesuvius, baskets of earth, suitably spaced for vines, have been deposited, and the lava itself in a year or two will be hospitable to the roots.

Stone from the quarry is popularly thought to be a durable building material, but only the most compact and resistant varieties, and these in a favorable climate, can make any approach to permanence. Granites are regarded as indestructible, but the title of granite to serve as the standard and symbol of strength is clouded when we remember that many beds of soft clay owe their accumulation to the decay of one of the chief mineral constituents of this rock, a decay in which the atmosphere has been a powerful agent. Granite that can be excavated with pick and shovel betokens the ceaseless activity of the gases and waters of the earth's surface.

Some of you will recall the promptness of atmospheric attack upon the obelisk of Central Park after it was transplanted from its arid habitat of millenniums. Many of the beautiful structures of the Oxford colleges, boasting not three centuries of antiquity, are under restoration piece by piece, showing an apparent hoary age through the solvent work of the atmosphere upon their unstable calcareous material. No marble monument has stood in the open air for half a century and retained its polish, and it must have been an exceptional piece of monumental stone if it does not now crack and scale and take on the look of age. Every humid climate with large temperature range introduces a ceaseless struggle with the destructive forces of the atmosphere, whose sum of hostility to the structures of man is far greater than that of flood, fire or earthquake.

The energies of the atmosphere mechanically applied, bring before us a group of results, not perhaps so nearly universal, but even more tangible and conspicuous. Many agents are at work producing mineral materials of such fineness that the winds can carry them. Oriental travelers and explorers know the sand storm as one of the most distressing and sometimes deadly visitations. In the desert mechanical disruption of rocks goes on rapidly and there is little moisture or plant life to hold the fragments down. The winds become factors of transportation in a manner little known by dwellers in moist and verdant lands. Dust storms are not confined to the Sahara, or Persia, or Turkestan. They occur in considerable numbers in our arid regions, where they sweep for hundreds of miles, last for many hours and carry incredible loads. Sand drifts a foot high have gathered in a half hour on railway tracks; thirteen cars of sand were taken from a single depot platform in Colorado; the same careful student who reports these facts estimates from 160 to 126,000 tons of sand carried in a cubic mile of air. This for a single storm may give us hundreds of millions of tons borne for hundreds of miles. Under such conditions the redistribution of surface materials by the atmosphere can no longer be held trivial.

We are now to remember that desert conditions furnish but a minor part of the dust that is available. Wherever in all geologic time there have been explosive volcanic eruptions, dust has been expelled, often in prodigious amounts, covering leagues of sea with floating pumice, littering the decks of vessels hundreds of miles away, destroying crops, darkening the atmosphere across wide seas, and enriching the sunset glows, it is believed, around the globe. Every rain storm purges the air of dust, much of local origin, no doubt, but some from remote and subterranean sources. Here is ceaseless accretion for all land surfaces and for all sea bottoms, and we have an impressive illustration of the interdependence and the cosmopolitan efficiency of every part of the earth's machinery.

Man never uncovers a soil surface with the plow or by the passage of hoof or vehicle, without exposing material to atmospheric migration, and it is some years since an expert road maker, in a highway convention, set forth the havoc wrought on macadam roads by winds.

From the point of view of natural scenery the winds' most conspicuous product is the dune. Many have seen a single example of a belt or field of sand hills, but the student of the earth finds in them no phenomenon of small range. He looks for them on the lee side of every river in a desert region and along all sand shores. He finds them invading the olive orchards of Palestine, the vineyards of France, the meadows of Holland, the forests of the Great Lakes and the fields of Cape Cod. The hand of man is put forth to stay the ravages of these flying cohorts and the organized skill of a government department joins in the task. Search is made for sand-binding grasses, in the same spirit in which the agricultural explorer hunts for wheat suited to arid fields or palms for the future orchards of Arizona.

The wind-blown sands are not only materials of accumulation, they are agents of erosion. Deserts abound in bare and unprotected rock surfaces, which occupy thousands of square miles in the Bad Lands, in the ridges of the Great Basin, in northern Africa and in western and central Asia. The impact of sharp-edged grains of quartz, maintained in every wind storm age after age, becomes no small means of wear and destruction, producing a natural sand blast whose principle is now used in many and ingenious ways in the arts. We have interest in Thoreau's quaint story of the clergyman of Cape Cod, frequently setting a fresh pane of glass to preserve the transparency of at least one fragment of window surface, but if we look more widely we find a large and significant phenomenon. Small lake basins have been excavated by the wind, and the sand of desert basins, eroding on its long journey, may come to rest at some remote point, as truly "exported" as if sent across the boundaries of a foreign land.

Before passing from these direct accomplishments of the atmosphere, we must include those peculiar deposits of fine and silty material known to the geologist and the physical geographer as loess. Much has been said of their origin, often in the field of debate, sometimes in the realm of controversy. But these great sheets of material, typically found in the Mississippi Valley, and in the central parts of Asia, have impressed many observers as being in whole or in part the work of winds blowing over vast fields of aridity, or sweeping widely the fine-grained outwash from areas of glaciation.

If we add now the transport of organisms, particularly of seeds, insects and birds, and the influence of winds on the migration of higher animals and man himself, through the medium of ocean currents, we shall see how the face of the organic world gathers its lineaments as broadly and depends on the atmosphere as intimately as the contours of a continent. The organic in turn reacts on the purely physical and we recognize at last that, touch the globe where we will in scientific inquiry we pick up some link in an endless chain.

The climates of the world have not always been what they are to-day. If we go as far back as the records will carry us, we find rocks and fossils that betray the climates of their time. These geologic climates are parts of ancient geographies which, in a long series, lead up to the geography of our own age. Throughout this succession, the atmosphere, its constituents, movements and temperatures held the same influence over the rocks of the crust and the forms of the land, which we now see. The atmosphere has had a history, and its qualities and activities have been among the chief factors in the evolution of the earth's surface.

Geology recognizes many periods of prevailing warmth, in which genial conditions were so wide-spread as almost to amount to a disregard of latitude. These temperate and subtropical conditions in high latitudes belong not only to ancient, but to the middle and modern ages of the world, and geologists long ago surrendered the notion that they could be due to supposed stores of the earth's primal heat.

There have been periods of notable dryness, so that deposits of rock-salt were formed through the evaporation of marine waters. From New York westward occur beds of salt, due to a dry climate, in a region where the rainfall is now abundant and where the basins of the Laurentian lakes are filled to their brims.

Not many years ago, the ice invasion of the Pleistocene was regarded as simple in character and unique in time. We now accept, among the commonplaces of glacial geology, that the late ice invasion was composite, marked by great advances and recessions, and by interglacial times of genial climate. And we recognize further, among the accepted facts of the science, the existence of vast glacial sheets in Permo-Carboniferous times, in India, Australia and South Africa, in regions which are now either warm or warm-temperate, and in lands of no great elevation.

Yet more remote, in the Cambrian, in an age of early life forms, an age recognized by the older geology as having almost ubiquitous warmth, the evidences of extensive glaciation have been brought to light. We must remember that humidity, precipitation, great or slight, and variations of temperature, are intimate questions of meteorology, whether we raise them in Cambrian or Miocene or present times. The meteorology of the passing age is related to geologic climates precisely as the physiography of existing lands is related to the rocks and rock structures of the past. The atmosphere has undergone a prolonged evolution in close association with the progress of the solid earth. As a part of the earth's history the study of the atmosphere is somewhat belated, but its importance is now recognized, and it will fill a large place in the geology of the future.

The present atmosphere therefore has not always existed and is but the latest term in an evolutionary series. We find two leading assumptions concerning this history.

There is a widely prevalent geological doctrine that our atmosphere is a residuum from a more dense or a more extensive body of gases. On this view it once contained all, or much, of the carbon dioxide whose carbon is now wrapt up in the coal and the limestones of the earth's crust. Thus Dana refers to the "purification of the air and waters through the making of limestone" as commencing in later Archean time and continuing through the Cambrian.[1] Accepting, as he does, the idea that all the carbon of the coal and of many rocks was originally in the air and the waters, he still finds difficulty, for in early Paleozoic time life shows an atmosphere not too heavily charged

[1] "Manual of Geology," fourth ed., p. 484.

with this gas, notwithstanding the fact that great coal beds and many great limestones had not yet been formed.

Geikie recognizes a continual abstraction of carbon dioxide since land plants began to live, but only allows that the amount in the air in Paleozoic time may have been somewhat greater than now. Davis thus expresses the view which has been long current:

> Some of the more volatile mineral substances in the rock-crust of the earth presumably at an early time made a part of the atmosphere, but all these have long ago left it. Nearly all of the water that must have once been boiled off in the steaming atmosphere of early times has now condensed upon the cooled surface of the earth, forming the deep oceans. Some of the gases themselves, particularly the oxygen of the air, must have been much diminished by combining with the surface rocks of the earth's crust and rusting them.[2]

These views, it will be seen, follow naturally upon the nebular hypothesis, with its mass of heated gases undergoing consolidation.

We find under discussion at the present time the view that the atmosphere is not greatly different from that of early geological periods, but has been subject to important fluctuations in the amounts and proportions of its constituents. These changes are believed to be due to many causes, some effecting loss and some bringing about renewal. Various interchanges are postulated, on the one hand, between the earth and outside spaces, and on the other between the atmosphere and the crust or the interior of the globe. This line of investigation has been recently pursued by Chamberlin and others, particularly with reference to its bearing on glacial climates, and has involved new conceptions of the origin of the earth. But entirely apart from the possible validity of these reasonings, the researches have value in setting forth the changes to which the atmosphere is subject. These changes have so much to do with the earth's crust that they are germane to our theme.

It is shown that the atmosphere loses carbon dioxide in several ways; as through carbonation, that is, by the decomposition of silicates and the formation of carbonates of calcium and magnesium, in limestone and dolomites of great extent. This decomposition is extensive in times of elevation of the lands, such as have occurred widely in some geological periods. When the lands are high, the water table is farther below the surface, and the air pierces deeply, with its chemical activities, and the ground waters also have much more vigorous circulation. The carbon dioxide thus employed in making limestone is extracted from the atmosphere.

There is loss of carbon dioxide through fixation in coal, oil and in all organic matter, diffused through the sedimentary rocks. There is temporary loss of this gas through the ordinary feeding of plants, and the view has been held, that plant growth would exhaust the CO_2 of the atmosphere in one hundred years, but for the renewal through

[2] "Elementary Meteorology," W. M. Davis, p. 3.

plant decay and from other sources. All these processes would take from the air in geological time, many thousand times as much CO_2 as it now holds.

On the other hand, there have been gains through various sources of supply. These are, from the ocean, and from the interior of the earth by volcanic action, and in escape in connection with earthquake movements. Any changes involving deformation and fracture open the way for supplies of this gas from below. Van Hise lays emphasis on CO_2 as derived from volcanoes[3] and in the same passage refers to emanations from hot springs and mine waters. He quotes Lecoq to the effect that the mineral springs of the Auvergne alone give off nearly one tenth as much of this gas as is freed by the entire coal burning of Europe. The same author includes meteorites as a source of CO_2 but regards this means of gain as unimportant in later geological eras. Possible supplies may have been received from the sun, if the projection of gases from that body is sometimes so energetic as to shoot them within the orbit of our planet; and, as has been implied, there is a steady restoration of this gas through decomposition of organic matter, and through organic processes.

As oxygen combines actively with some substances, notably iron, we are to expect large losses of this gas from the atmosphere, when we remember that oxidation has been a world-wide process, throughout the history of land surfaces, down to the lowest level of atmospheric penetration. Thus Smyth concludes a brief essay on this subject by saying, "The abstraction of oxygen by iron is a factor that can not be disregarded in any attempt to work out the geological history of the atmosphere."[4]

There have also been compensating supplies of oxygen. The fixing of carbon in the crust involves the freeing of oxygen. There have been times of predominant plant life, leading to the abstraction of CO_2, and the release of O, thus notably changing the atmosphere until animal life enlarged its province, using O and freeing CO_2. Chamberlin thinks that organisms have freed more oxygen than the rocks have absorbed and that this gas therefore has had a growing part in the atmosphere.

Nitrogen, as is well known, is the inert part of our atmosphere, but is absorbed through certain bacteria, leading to modern effort to utilize it in restoring the fertility of the soil. On the other hand, some nitrogen is supplied to the atmosphere through volcanic eruptions.

These views of atmospheric inconstancy involve general doctrines of climate and earth history which are in the crucible of discussion. The efficiency of the atmosphere as a thermal blanket is held to be so dependent on the amount of carbon dioxide present, that moderate

[3] "Treatise on Metamorphism," pp. 969–970.

[4] "The Abstraction of Oxygen from the Atmosphere by Iron," C. H. Smyth, Jr., *Jour. Geol.*, 13, 319–323.

fluctuations in the quantity of this gas may go far to explain the noteworthy glacial episodes of later and earlier geological times, and those warm climates which at other periods have spread so widely over the earth.

Thus we have geographic hypotheses, and astronomic hypotheses, so it seems appropriate that we should have atmospheric hypotheses, in the laudable effort to understand and explain that great series of geologic climates, which may indeed seem remote, but with the latest of which, we should remember, we ourselves have to do.

Our interest in the evolution of the atmosphere and of climate is of no theoretical sort. We are not in the grip of forces which are in a despotic way our masters. We have a large control of organic life on the earth and of the disposition and character of all land waters. Through these means we also largely regulate the processes of denudation and we may thus in some measure modify the very constitution of the atmosphere. Van Hise, on what he regards as a moderate estimate of the coal the human race will burn per annum during the present century, estimates that in 812 years the amount of carbon dioxide in the atmosphere would be doubled.[5] According to the view of Arrhenius such a change would greatly ameliorate the climate of the world. This view of the heat-holding effects of an increase of CO_2 is not undisputed, but so large a change in the constitution of the atmosphere, by the hand of man himself, may well cause him to investigate, with serious persistence, the terrestrial consequences of his own deeds.

Van Hise has impressively set forth the work of man in lowering the level of the ground water. We do this by deforestation, by cultivation, by irrigation, by the sinking of artesian wells and by mining. For so many purposes man needs water, or needs to get rid of water, that actual and serious lowering of the water table has taken place, and will be brought about more and more with growing density of population. Lowering the ground water, as we have seen, increases the contact of the atmosphere with the rocks, and sets in motion a chain of actions which may have consequences for good or ill, quite outside our present knowledge and inviting expert investigation for many years to come. These considerations have a bearing, possibly an imminent bearing, upon all our conservation enterprises in the United States.

Scientific truth often gives us no inkling of astonishing practical results which are about to flow from it. Thus meteorology is no restricted theme for the curious. It is not merely a science of climate, though this would give it the highest interest for science and for life: it is profoundly related to the history of our planet and it is an essential part of physical, biological and human geography.

[5] "Treatise on Metamorphism," p. 464.

THE PALEONTOLOGIC RECORD

The Paleontological Society Conference Papers

By Professor JOHN M. CLARKE
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Introductory.—The birth of a new society devoted to special scientific aims counts but little for the advancement of knowledge and culture in these days of multiplex organizations if it fails to come into being and before the world with an adequate excuse and a clean-cut purpose. The Paleontological Society, which was conceived a year ago and born last winter in Boston at the meetings of the American Association, is the outcome of a conviction on the part of workers in this science that there is a common bond of interest among them all, in spite of the peculiar conditions which have stamped paleontology with their diversity and kept its devotees asunder. Students of this science have approached it along different avenues. Some, and chiefly those dealing with the vertebrates, have laid the foundations of their work in the living world; others, and here chiefly the students of invertebrates, have made their entry as geologists and have worked their way from beneath upward to the earth's surface. Among the paleobotanists good men have arrived through both approaches. As an equipment for trustworthy and lasting work, both of these lines of preparation have proved their efficiency and so all arguments bent to demonstrate the superiority of the one over the other schooling resolve themselves to a conclusion that both are essential to the best result.

Diversity in training and in the field of activity has led to diversity of sympathy, and it seemed, even to those who had long hoped for a unification of these interests, that it might hardly be practicable to obliterate these cleavage planes. The governing principles of the science are common, the bearings of paleontologic researches and results are the widest conceivable in their relation to the problems of life, whether past, present or future, and it is not likely that the magnitude of the science can be unduly stated. From some such considerations as these, the writer, chosen as first president of the new society, endeavored to bring into the foreground of the society's first meeting, by a "Conference on the Aspects of Paleontology," an introductory presentment of some of the broader factors and principles of the science, and the articles that follow herewith are the partial outcome of this conference. In every case where practicable, the themes were presented by two speakers making their approach from different fields of interest. The conference was an effort to define and emphasize the common platform on which the paleontologists must stand together; even more than this, it was a purpose to declare at the outset that the organization, though the patron of detailed researches and patient endeavor, recognizes that the sole impulse which can guarantee its usefulness and maintain its integrity is its devotion to a standard which touches close on human interests.

ADEQUACY OF THE PALEONTOLOGIC RECORD

By Professor SAMUEL CALVIN
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WHEN or how life began on our planet no one may be able to tell us; but that life has been present and has been an important factor in the world's geological development since before the beginning of the Cambrian is known to the most callow of embryo geologists taking his first course at the village high school. So far as relates to the skeleton-bearing, marine invertebrates which have lived on floors of epicontinental seas, there are remarkably complete records of this long history of living things, the order of their succession, their migrations, their geographic distribution during any given portion of geologic time, as well as of the progressive and orderly modifications which resulted in the extermination of decadent or unfit types, on the one hand, or resulted, on the other hand, in the advancement of certain types and their adaptation to the conditions prevailing in the living world to-day.

The zoologist, confining attention to living forms, gets a view of the animal creation as it exists, after ages of development and modification, during a fraction of a single faunal stage. The paleontologist, while unable to see the beginnings of life, gets the broader view which comes from a study of the organic world as it has appeared during numberless successive stages. He may trace the origin of forms and note the trend and tendency of variations in ways denied the zoologist. Neither the depth of the water nor the distance from the shore at the points where the objects of his study lived interferes with the thoroughness of his explorations. He is not limited to what he may learn by taking samples of the old sea bottom, here and there, with a dredge; he traces his life zones with practical continuity over areas of continental extent.

The faithfulness with which the paleontological record has been kept since the beginning of the Cambrian is a matter of constant surprise. No organism was too small for preservation, if only its soft parts were supported or protected by a stony skeleton of some kind; no parts of the skeletal structure were too minute to be kept practically unaltered to the smallest microscopic detail; no period of time has been so long that the records of the large or the small things of life were necessarily obliterated. The shells of such minute and delicate things as radiolaria and foraminifera, on the one hand, and that king of invertebrates, the giant *Camaroceras*, on the other, have all been kept through the ages with equal fidelity. The hinge characters of the brachiopods, their internal arm supports, their spires and loops, the distribution of the ramifying blood channels in the mantle, the surface markings of every rank and grade down to the smallest which can be observed only with the lens, and the microscopic structure of the shell itself, are other examples of the faithfulness with which details, however insignificant in point of magnitude, have been guarded, protected, preserved. Strangely enough, in respect to a very large proportion of the animal remains buried in the ancient sediments it looks as if time had been standing still; it has neither marred nor destroyed. The organic remains from the Ordovician formations are quite as perfectly preserved as those from the Tertiary.

The profusion of the life of the ancient seas is as much a source of surprise as the detailed perfection of the record. In the Mississippi Valley limestones constitute a very large proportion of the sedimentary rocks, and it is unnecessary to say that these limestones record the life and death of countless myriads of organisms. In some cases the waters of the old seas were comparatively quiet, and the shells or other hard parts, undisturbed and unbroken, remain in the positions they occupied when the individuals they represent were alive. There is a bed of marly shale carrying many thin lenses of limestone, lying between the Platteville and the Galena, from 60 to 70 feet above the base of the Mohawkian, and these lenses are made up in large part of unbroken brachiopod shells. On the surface of one of these slabs, in an area measuring 35 square inches, one may count more than 60 perfect specimens of *Dalmanella subæquata* and *Orthis tricenaria.* The rate is about 290 individuals to the square foot. The number on a square mile of such sea bottom runs up into the billions. The number of individuals of the species *Pentamerus oblongus* that swarmed on the bottom of the Niagaran sea is strikingly demonstrated in every paleontological museum. The wide geographic range of this species is well known; its range in time was such as to make possible the accumulation of beds of limestone, 70 feet in thickness, from the detritus of its broken shells. Like other persistent or widely ranging species, it gave rise to a very large number of varietal forms, some of which have been described as specifically distinct.

The Devonian formations furnish similar evidence of the wonderful profusion of the ancient life and help us to appreciate the wealth of material that the paleontologist has at his command. In the quarries at Independence, Iowa, there are beds crowded with beautifully preserved forms, mostly brachiopods, as perfect to-day in every detail of shell structure and ornamentation as when the currents of life pulsated within. A coral reef, no species lost, has been cut into by a small intermittent stream near Littleton, Iowa; and perfect coralla, wagon loads of them, are strewn along the sandy channel a quarter of a mile or more. A successor to the reef just noted, composed of different species, the corals still in place, may be seen and studied on the west side of the river opposite the village of Littleton. The state quarry beds near North Liberty are simply cemented masses of brachiopods; they illustrate the remarkable prodigality of the Devonian life, but the individuals are not in good condition for study. It is a different case that is presented by the fossils in the marly beds of the Lime Creek shales at the exposures between Mason City and Rockford. A very large proportion of the specimens here are as perfect as when the animals lived; and there is a beauty and delicacy and exquisite refinement about most of them that is scarcely matched, certainly not surpassed, anywhere among fossils of any age or time. More than 65 species occur in the Lime Creek fauna, and thousands of individuals of some of the species, illustrating wide ranges of variation, enrich the museums of the world.

Along the Aux Sables River at many points near Thedford and Arkona, Ontario, there are calcareous shales containing a marine fauna, or rather a succession of faunas which once flourished in wonderful profusion and is still preserved in equally wonderful perfection. Statistics and computations would fail to give an adequate conception of the abundance and character of the material here offered for study. No detail of the skeletal parts has been lost; and as for the number of individuals, they are simply uncountable. There lies before me a small fragment of this old sediment having a surface of less than 15 square inches and it shows 51 identifiable individual specimens, not counting stem segments of crinoids. The 51 individuals are distributed among eleven species, and these represent eleven genera—namely, *Phacops, Platyceras, Tentaculites, Spirifer, Chonetes, Hederella, Orthopora, Chætetes, Arthracantha, Striatopora* and *Aulopora*. Can any bit of modern sea bottom of similar size make a better showing? Above and below the Rocky Glen, near Arkona, from which this specimen came, there are opportunities to study continuous sections approximately 100 feet in thickness, the successive beds crowded with organic remains and revealing the historic sequence of varying organic types as the life responded to slight changes of environment. Here, as at countless other localities, the paleontologist gets a view of changes, of movements, of trend and tendency among living things ranging over a period of time equal to many millenniums.

Another life record of especial interest, typical of many scattered up and down the land areas of the globe, is furnished by the Osage division of the Mississippian at Burlington and Keokuk. Of one group of crinoids, the Camerata, these Mississippian limestones have yielded about 250 species, and of other groups a number about equally as great. The beauty and perfection of the individual specimens can be appreciated only by those who have had the good fortune to see the superb collections of Wachsmuth and Springer. Crinoids flourished here in such numbers that beds of limestone 150 feet in thickness are built practically of crinoidal remains and nothing else. The time represented was long enough to allow of a series of modifications of such extent that the crinoid fauna of the Upper Burlington is very distinct from that of the lower beds of the same formation, while the fauna of the Keokuk differs from both. Here again the paleontologist is favored, not only with a wealth of material, but with an opportunity to note the trend and tendency of things. This was the time of greatest development, of highest prosperity, among camerate crinoids. But in the midst of this prosperity the trained paleontologist may discover signs of degeneration, the prophecy of speedy extinction. The law enunciated by Beecher and quoted by Professor Woodward in his address before the geological section of the British Association at its meeting in Winnipeg last summer, is well exemplified in the Mississippian history of this particular group of crinoids. The tendency among any division of skeletal-bearing animals to run to extravagant ornamentation in the way of ribs, nodes, spines or other excesses of dead, useless, skeletal matter, is something that precedes and presages the decline and death of the race. Even in the Upper Burlington the skeleton of the crinoids is heavier than in the Lower; stronger nodes on the plates are produced; more arm plates are incorporated in the dorsal cup; the animals are weighted down with useless matter. This tendency is carried to extremes in the Keokuk limestone, a fact well exemplified by the species figured on plate 15 of Hall's "Geology of Iowa," Volume I., part II. In these species the development of massive spines and heavy nodose plates reaches its maximum. The race has come to the end of its career. When the Keokuk closes, only a few of the simpler forms of the Camerata survive, and even these shortly disappear. The paleontologist sees the operation of the same law, the same trend and tendency, among the Cretaceous Ammonoids; in many other groups of animals it is as clearly manifest; but it would not be profitable, before such a body as this, to carry the discussion farther, even if the limits of the paper permitted. Let me close by quoting from the address of Professor Woodward, to which reference has already been made:

> Geology and paleontology in the past have furnished some of the grandest contributions to our knowledge of the world of life; they have revealed hidden meanings which no study of the existing world could even suggest; and they have started lines of inquiry which the student of living plants and animals alone would scarcely have suspected to be profitable.

ADEQUACY OF THE PALEONTOLOGIC RECORD

By R. S. BASSLER

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THE imperfection or inadequacy, instead of the adequacy of the paleontologic record, has long been a favorite subject of discussion, and it is only within recent years that this heresy of an imperfect record is being abandoned by paleontologists in general. However, as many of our biologic, and even a few of our paleontologic, friends still have doubts regarding the matter, the present conference upon this and allied subjects is very opportune.

I have a vivid recollection of the joy experienced in my school days, when, during an examination in geology, the subject of an impromptu essay was announced as "The Imperfection of the Paleontologic Record." Here was a subject in which I was well grounded from text-book reading, and I remember distinctly the telling points made. The lack of hard parts causing the absence of many classes of animals; the great amount of unrepresented time in the geologic column; the metamorphism and consequent disappearance of fossils, and, when present, the frequent imperfectness of the specimens themselves, were dwelt on in great detail. Since that time, my experience in invertebrate paleontology has compelled me to unlearn every one of these supposed facts, and to come to the conclusion that, considered both biologically and stratigraphically, the paleontologic record is sufficiently adequate for all reasonable purposes.

Professor Calvin's paper tells us (1) of the detailed perfection of the record, (2) of the profusion of the material, and (3) of the broad view as to trend and tendency of biologic characters which the study of paleontology gives. His presentation of the subject is such that we must all agree with him. It therefore seems best for me to confine my remarks to the reasons usually advocated for the imperfection, namely, the lack of hard parts in many animals, metamorphism, the frequent imperfect preservation of fossils, and the unrepresented time in the geologic column.

The lack of hard parts in many animals is a serious, although not fatal, objection to their preservation as fossils. For the best results as fossils, a stony framework of some kind is desirable, as we all know, but horny, or even the most perishable materials may be preserved under favorable conditions. Mr. Walcott's work on the Medusæ, and the researches of Ruedemann on the graptolites, as well as the work of others whom we can call to mind, are examples of excellent results from material of the latter nature, not to mention the hairs of the worm so carefully described by the Cincinnati paleontologist!

The metamorphism and apparently complete obliteration of all fossil remains in the rocks of certain large areas is likewise an apparently serious objection to the adequacy of the record, but here careful searching with the structural relations in mind will reveal the fossils, if present at all. The greatly folded and cleaved slates, schists and volcanic tuffs of the Piedmont area have long been the despair of both paleontologist and geologist, but at this meeting of the Geological Society of America, the State Geologist of Virginia will tell of Cincinnatian fossils in the so-called Algonkian and other schists and volcanics of the easternmost Piedmont of that state. In this case the discovery of well-preserved fossils was quite simple. It consisted merely in finding a place where the cleavage and stratification coincided, and then working hard.

Professor Calvin has spoken of the richness and beautiful preservation of certain Paleozoic faunas. While the beauty and occasional richness of such faunas is not to be gainsaid, we must not forget the many horizons and localities affording, in comparison, specimens so poorly preserved that they might readily furnish an argument for the inadequacy of the record. Nor must we forget that in quite a portion of the geologic column organic remains are not only poorly preserved, but are, as known at present, very rare. However, these lean spots can be made most productive of paleontologic results by careful search and by methods of preparation. Several years ago the number of lower Paleozoic fossils found in the Ozarks could almost be counted on one's fingers, but we now have in the National Museum, from this formerly almost barren spot, several hundred drawers of beautiful material.

Fortunately the preparation and methods of study of paleontologic material has progressed to such a point that a poor fossil is no longer a bugbear. A specimen may be considered inadequate for study because it is covered with refractory clay. The application of caustic potash solves this difficulty. Certain limestone bands in the New York Niagaran and Cayugan are crowded with fossils, although often few of the species can be determined because of a hard, clayey covering. In preparing some specimens for exhibition, the treatment with caustic of a single slab, about three inches wide and five inches long, enabled me to bring out over a hundred species on one surface alone, not including the ostracods and other microscopic organisms. How often will the present sea bottom furnish such results?

Nature is very kind in preparing fossils for us. The Onondaga limestone, at the Falls of the Ohio, although only a few feet in thickness, has yielded seven hundred or more species of exquisitely preserved fossils. Examine the freshly quarried limestone and you may be able to crack out perhaps two dozen species of poorly preserved material, but go to the neighboring field where solution of the limestone and silicification of its contained fossils has occurred, and a host of beautiful forms awaits you. Strata, which under ordinary circumstances would yield very poor fossils, can, if silicification has commenced, be made to afford excellent specimens. By exposure to the weather for a year or so, the silicification can be advanced to such a stage that etching with acid will free the fossils. The beautiful etched material from the New Scotland of New York is a familiar example of this style of preparatory work. Most of the Cambrian and Ordovician formations of the Appalachian Valley yield shells which, as they occur in the limestone, are almost impossible as subjects for study, but as silicified pseudomorphs, all the beauty and detail of the original shell are reproduced.

Thin sections are a valuable aid in identifying the merest fragment of certain classes of organisms, and their use here is indispensable. A thin section of an otherwise undeterminable fragment of a Cambrian protremate brachiopod will distinguish the horizon. Other methods of preparation and study might be mentioned, but time forbids, although I can not refrain from speaking of the several whitening processes. The use of a coating of ammonium chloride or anilin chloride on fossils for photographic purposes is well known, but the excellent results obtained from the use of the same process in the study of poor material may not be so apparent to all. A trilobite indistinctly outlined in the rock under ordinary circumstances, flashes into bold relief when covered with the ivory white film of ammonium chloride. Casts and molds of fossils too indistinct to show any structure ordinarily, will reveal many characters when so whitened. Recently occasion arose to study a species of Cambrian phyllopod which had already been described and figured. The specimen was practically nothing but a film upon the rock, and apparently the last word had been said upon it. It was suggested that the specimen be whitened and then photographed with the sun's rays nearly parallel to its surface. The result was most gratifying as structures which could not be proved to exist by the aid of the eye alone, came into plain view in the negative. All these various methods of preparation and study make available a vast amount of material which formerly was thought too imperfect to be fully considered in determining the adequacy of the record, hence the great value of such methods to the paleontologist is obvious.

The real adequacy of the record, if it might be so called, lies in the imperfections or gaps in the stratigraphic column. Measured according to the sections of twenty-five years ago, the number of these gaps is growing greater and greater, yet with the discovery and intercalation of new formations, the aggregate of which at the present day has almost doubled the thickness of Paleozoic rocks in the last decade, manifestly the great breaks are being reduced. It was not so many years ago that the Potsdam sandstone was supposed to be the oldest fossiliferous sedimentary rock, yet now we know that many thousands of feet of much more highly fossiliferous strata intervene between this formation and the Azoic, and that other thousands occur above the Potsdam and below the Ordovician as then recognized.

With the intercalation of new formations and the consequent diminution in the size of the stratigraphic gaps, it is then probably only a matter of time before the complete faunal succession can be established. The break in stratigraphy at one point will be bridged over in another area, and it is possible that in only a few regions, such as on the borders of the continent, will permanent gaps exist. Faunas are and will be traced from one area to another until in time we shall know their complete geologic history. With these data in hand, the study of their correlation will not only be greatly simplified, but also will not be hampered by time breaks in the record. While imperfect, or possibly irretrievably lost at the dawn, the faunas of succeeding times are ample for all purposes.

INTERDEPENDENCE OF STRATIGRAPHY AND PALEONTOLOGY

By Dr. W. J. SINCLAIR
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IN discussing this subject from the view-point of a vertebrate paleontologist, I am disposed to lay stress on what I believe ought to be, rather than what has been, the degree of interpendence of these two branches of geology. Vertebrate paleontology has been studied very largely from the morphological and genealogical side, a study of structure, adaptation and the evolution of phyla. Stratigraphic geology has been invoked only when it became necessary to know the order of superposition of the various horizons, to determine the true evolutionary succession of a phylum or development of an adaptation.

I have purposely presented this extreme view, not because I believe that such studies may not be classed legitimately as paleontological, but because I wish to emphasize, by contrast, the view-point which we should ever keep before us as paleontologists—the use of our materials as *Leitfossilien*. The two correlative conceptions of the faunal unit and the zone, a more or less restricted association of animals and the rock layer in which it occurs and which it characterizes, long and successfully employed by the invertebrate paleontologist, must be recognized and used by us also.

I need hardly refer to the fact that the determination of the geological age and the successful correlation of many North American formations, ranging from Mesozoic to Pleistocene, depend in large measure, if not entirely, on vertebrate fossils. I need only contrast the American series of Pleistocene glacial and interglacial stages, determinable at present only by the strictly stratigraphic method of superposition, with the carefully worked-out series in Europe, where each epoch of ice advance and retreat is characterized by its particular fauna and flora. That even the beginnings of stratigraphic paleontology, as contrasted with the morphological, will lead to immediate and valuable results, is strikingly shown by Professor Calvin's[1] recent paper in the *Bulletin* of our parent society, the Geological Society, in which he describes the Aftonian mammal fauna from the earliest of American interglacial stages.

While readily admitting that the slow-moving invertebrate, living, it may be, in the very mud which is destined to become the matrix of its fossil remains, enjoys advantages as a prospective horizon-determiner which the agile vertebrate can more readily, and does most willingly, escape, still the short life of vertebrate species, and their comparatively rapid evolution, fit them for use as index fossils quite admirably. The localization of mammalian faunas, their inability to cross barriers such as ocean basins and great mountain ranges, their dependence on temperature, etc., are comparable to similar conditions circumscribing the free migration of invertebrates. We should not expect to find in the distribution of vertebrate faunas the analogues of the cosmopolitan graptolite zones of the Ordovician or the ammonite zones of the Trias, but we can work out our major zones as recognized by the great migrational movements among vertebrates, expressed in changes in the faunas and the rock succession, which will give us a world scale, and then, by interpolation, fill in the minor and local subdivisions which we probably shall not be able to correlate at once, but which there is every reason to believe we may be able to do later.

The attempt will be accompanied by difficulties which are not appreciated by the invertebrate paleontologist, and I speak feelingly and from experience, for there is a difference between collecting, on the one hand, from a layer a few inches thick, crowded with shells, and, on the other, tramping miles up hill and down over beds hundreds of feet thick, to be rewarded by a few teeth, a lot of useless bone fragments or nothing. Horizons based on vertebrates must include larger stratigraphic units

[1] *Bulletin of the Geological Society of America*, Vol. 20, pp. 341–356, Pls. 16–27, October, 1909.

than are recognized for invertebrates, because of the scattered nature of the material and the additional probability that continental deposits, in which alone vertebrates have their chief importance as guide fossils, have accumulated more rapidly than marine beds. Similarly, conditions peculiar to their mode of deposition make it difficult, perhaps impossible, to define lithologically the limits of the zones we are attempting to characterize. And here another trouble confronts us, for the faunas are incompletely known, and we are not yet in a position to dogmatize too freely on the subject of vertebrate index fossils. But that the method of zonal studies is the correct one is very clearly shown in Dr. Matthew's[2] recent monograph on the Carnivora and Insectivora of the Bridger Eocene, and will be demonstrated with equal force when Professor Osborn's volume on the titanotheres is published.

Various attempts have been made at the correlation of European and American mammal horizons, their measure of success depending entirely on the degree of closeness with which these correspond to true zones. At present, we are attempting to correlate subdivisions, both faunal and stratigraphic, of all orders of magnitude, the majority including many faunules and many zones. Evidently, this tendency must be corrected by careful zonal studies, if vertebrate paleontology is to have any standing as an aid to stratigraphy in the correlation of our non-marine formations.

BIOLOGIC PRINCIPLES OF PALEOGEOGRAPHY

By Professor CHARLES SCHUCHERT
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IN deciphering the ancient geography as to the position of the marine waters and the land masses, we as pioneers in this work must be controlled primarily by the known fossilized life and secondarily by the character and place of deposition of the geologic formations. This record is most extensive and best preserved in the deposits of the continental and the littoral region along the continental shelves of the oceanic areas. Back of these two principles, however, there is another that eventually will become the primary guiding factor. It is the principle of diastrophism—one seeking to explain the causes for the periodic movements of the lithosphere.

In our study of the ancient seas with their sediments and entombed life we have safe guidance in the phenomena of the present. Ludwig in 1886 estimated the species of animals then known to naturalists as upwards of 312,000, and in 1905 Stiles thought this great total had increased to about 470,000 forms. Of this sum fully 60 per cent. are insects, and of the remainder, the writer concludes that about 25 per

[2] *Memoirs American Museum of Natural History*, Vol. IX., Part VI., 1909.

cent., or 115,000 species, live in the sea, and 71,000 have their habitat on the land or in the waters of the land. Of the 115,000 kinds of known animals inhabiting the seas nearly 70 per cent. are Cœlenterata, Echinodermata, Molluscoidea and Mollusca, the types of organisms most often found by the stratigrapher and on which he is largely dependent in deciphering the ancient geography.

Let us now examine into the number of available fossil forms made known by the paleontologists. As early as 1868, Bigsby in his "Thesaurus Siluricus" listed 8,897 species from the strata beneath the Devonic, and in his "Thesaurus Devonico-Carboniferous" of 1878, he further enumerated about 5,600 Devonic and 8,700 Carbonic forms. In 1889 Neumayr concluded that there were then known about 10,000 Jurassic species. We may therefore estimate that the paleontologists of to-day have access to at least 100,000 species of fossils. Their numbers in the geologic scale are about as follows: Cambric 2,000, Ordovicic 8,000, Siluric 8,000, Devonic 9,000, Lower Carbonic 7,000, Upper Carbonic 8,000, Permic 4,000, Triassic 6,000, Jurassic 15,000, Cretacic 10,000 and Tertiary 25,000. The end of species-making is not at all in sight, and the day will come when paleontologists will deal with ten times as many species as are now known.

Stiles tells us that zoologists know but from 10 to 20 per cent. of the living forms, and there should therefore be from 3,760,000 to 4,700,000 different kinds of animals alive to-day, ranging from the protozoa to man. Now let us compare the abundance of living animals with those of the geologic ages, and especially with the Jurassic period, of which life we have probably a better knowledge than of any time back of the Tertiary. The European Jurassic has long been divided into 33 zones (Buckman hints at a probable 100), and if we hold that each one of these times had only one quarter as many species as in the lowest estimate of the present world, there must have lived during the entire Jurassic something like 31,000,000 kinds of animals. Yet paleontologists have described not more than 15,000 Jurassic forms. The great imperfection of the extinct life record is thus forcibly brought to our attention, and we learn from these estimates that for each kind of animal preserved in the rocks more than 2,000 other kinds are utterly blotted out of the geologic record.

Much of this more apparent than real imperfection, however, is due to the vast number of insect species now living—animals that must have been comparatively few in the Jurassic, due in the main to the absence of flowering plants. From these figures, however, we must not conclude that the geologic record is equally imperfect throughout; for the paleontologist studying marine fossils well knows that he can not, as a rule, hope to study other than those kinds of animals that have hard and calcareous or siliceous external or internal skeletons. Of such there may be in the present seas about 250,000 kinds, of which about 25,000 have been named. Therefore on this basis we can say that the student of Jurassic faunas knows 1 species in every 54 of shelled animals that lived during this period.

This admittedly great imperfection of the life record needs to be further explained so that the reader will not arrive at the erroneous conclusion that modern stratigraphy rests upon very insecure foundations. The stratigrapher in determining the age of a given deposit, and in the identification of it from place to place and from country to country, and even across the great oceans, deals in his work not with quantity of species, but with comparatively small numbers of constantly recurring hard parts of certain species that are more often of marine than of land origin. Many of these forms have but local value but others have spread thousands of miles, and some of the long enduring species range over the greater part of the earth. Some of the best guide fossils in the Paleozoic are the brachiopods because they are present in nearly all the strata of this era. The writer in 1897 listed 1,859 forms then known from these rocks of North America. Of these about 28 per cent., or 537 species, had great geographic distribution. 117 species are found in the Rocky Mountain area, the Mississippi valley and the Appalachian region, and of these 36 are also known to occur in foreign countries. The number of species common to North America and other continents, however, is 121. It is upon faunal assemblages of this quantity and nature that the stratigrapher relies most in deciphering the former extent of the continental seas.

In the making of paleogeographic maps or in the determination of geologic time, using fossils as the essential basis, we have guidance in those of marine faunas, and the floras and faunas of the land and its fresh waters. Of these widely differing realms or habitats we now know that the fossils of the marine faunas are the more reliable not only because there are so many more of them than of the land dwellers, but more especially because their geologic succession is far more complete. The conditions of preservation, that is, appropriate burial in sediments, are always at hand in marine waters, but on the land entombment occurs only exceptionally, whereas the life of fresh waters is very meager and almost unchanging during geologic time. Then, too, marine life is "less affected by meteorologic factors, and more dependent upon conditions which affect the whole hydrosphere rather than small areas of it. The struggle for life is less intense, the food supply generally more adequate, enemies less vigorous, and dangerous fluctuations of temperature far less frequent, in the sea than on land. The same features make the land fauna more clearly indicative of minor divisions of the scale, and of the progress of organic evolution in the general region concerned; while less conclusive as to the contemporaneity of widely separated though analogous faunas."[1]

In regard to the probable geographic position of the shore lines we rarely have safe guidance in the fossils, and for this depend on the nature of the deposits. Greatest dependence is placed upon the geographic position of sandstones and especially on conglomerates to indicate the probable former shores. Limestones of uniform character and wide distribution are indicative of greater distance from land. Shallowness of the continental seas is proved by a rapid change in the character of the sediments both laterally and vertically, and by the oolite and dolomite deposits. Intraformational conglomerates, coral reefs, ripple marks, and shrinkage cracking furnish further evidence to the same conclusion. Storm waves are known to plough the present sea-bottom to depths of 160 feet. Calcareous muds are now forming in tropical and subtropical waters at sea-level around coral reefs, and elsewhere in these latitudes at depths from 200 to 600 meters. It is probable that all of the ancient great limestone deposits are of warm waters, and, if so, are an additional aid in discerning the geologic times and regions of milder climates.

Phosphatic concretions form in the littoral region where the temperature changes are rapid, as off the coast of the New England states, and periodically cause much destruction of the individual life. The carcasses decompose at the bottom of the sea, making nuclei for the accretion of phosphate of lime, and because of the irregular periodicity of accumulation come to be arranged in definite stratigraphic zones. Old Red sandstone fishes are also usually found in clay nodules but abundantly only in limited zones (Scaumenac, Canada and Wildungen, Germany). Have these also been killed by rapid changes in the temperature of these waters? In any event the fish-bearing beds are always found near the shore lines of Devonic seas.

Scour of sea bottom is met with in the present seas where great streams of water are forced through narrow passages, as the Gulf Stream in the Floridian area; or where such streams impinge against the continental shelf, as north of Cape Hatteras, or flow across submerged barriers "a few miles broad," as the Wyville-Thomson ridge connecting the British and Faeroese plateaus (Johnstone, 1908, 31). Strong currents preventing sedimentation also occur in long and narrow bays, as that of Fundy, where the undertow caused by the very high tides of this region sweeps the bottom clean. These exceptional and, after all is said, rather local occurrences can not be the explanation for the many known breaks in the geological sedimentary record, the disconformities of stratigraphers. These breaks are at times as extensive as the North American continent (post Utica break), and are usually

[1] Dall, *Jour. Geol.*, 1909, 494.

of very wide extent. Scour of the bottom by the currents of the ancient continental seas will not explain away the presence of these truly land times, but it is to be sought in the oscillatory nature of the seas of all time which is probably caused by the periodic unrest of the earth's crust due to earth shrinkage. We agree with Suess that "Every grain of sand which sinks to the bottom of the sea expels, to however trifling a degree, the ocean from its bed," and every movement of the sea-bottoms and the periodic down fracturing of the horsts causes the strand lines to tremble in and out, be they of a positive or transgressive or of a negative or land-making character.

The ancient marine life had similar zoogeographic arrangement to that of the present. It can be grouped into local faunas and these combined into subprovinces, provinces and realms. Their distribution is governed primarily by the presence or absence of land barriers, and secondarily by temperature and latitude. In the present seas temperature is one of the main factors controlling the distribution of the species, but during the geologic ages the climate was, as a rule, far more uniform than now, as we are living under the influence of polar ice caps and a passing glacial period, or possibly even an Interglacial period.

The faunas with which the stratigraphic paleontologist works appear in many instances as suddenly introduced biotas. Our collaborators of half a century ago explained them as Special Creations, but since their time we have learned that the suddenly appearing faunas are not such in reality but only seem to appear rather quickly due to the slowness of sedimentary accumulation. Ulrich estimates that the American Paleozoic has less than 100 mapable units or formations, each with a duration of probably not less than 175,000 years. Accordingly, each foot of average sedimentary rock has taken not less than 833 years to accumulate. Our knowledge regarding the average rate of sedimentary marine accumulation is, however, as yet very insecure, and to make this clear some of the remarks made by Sollas, President of the Geological Society of London (1910), will be quoted. He was led to make these remarks after the reading of a paper by Buckman correlating the Jurassic sections of South Dorset. He said, "The correlation of thin seams with thick deposits was a matter of great importance. . . . It might afford some hints as to the order of magnitude of the scale of time. If we assumed that one foot of sediment might accumulate in a century, in an area of maximum deposition, then in the case of the seam two inches thick, which was represented by 250 feet in the Cotteswolds, the rate of formation would be less probably than 1 foot in 150,000 years." What Ulrich's estimate of time necessary for the accumulation of one foot of average sediment means to migratory faunas may be illustrated by the spreading of *Littorina littorea*. In the last century this edible European gastropod was introduced at Halifax, Nova Scotia, and in 50 years attained the Delaware Bay and north to Labrador. Taking this dispersion as the basis for calculating faunal migrations, we learn that they may spread 500 miles, while one sixteenth of an inch of average sediment is depositing, or 8,000 miles during the time of one foot of sedimentary accumulation. If, therefore, Paleozoic faunas migrated "only one fiftieth as fast as this living shell, then we may reasonably assert essential contemporaneity for stratigraphic correlations extending entirely across the continent." We have here an explanation for the apparently sudden distribution of the Ordovicic brachipod *Rhynchotrema capax,* that everywhere holds an identical geologic horizon from Anticosti to the Big Horns and from El Paso, Texas, to Arctic Alaska. *Spirifer hungerfordi* spreads during the first half of Upper Devonic time from the Urals to Iowa, and another brachiopod, *Stringocephalus burtoni,* migrates during the last third of Middle Devonic time from western Europe to Manitoba.

The life of the present seas extends from the strand-line to the deepest abyss, but by far the greatest quantity and variety lives in the upper sunlight, photic or diaphanous region. Photographically the light of the sun is detectable in exceptionally clear-water tropical seas to a depth of about 2,000 feet, but Johnstone places the average depth for all waters at 650 feet, beyond which there is more or less of total darkness, the aphotic realm.

Sunlight is the first essential for the existence of life. Where it penetrates, there plant life is possible, and this life is the substratum on which all animal life is ultimately dependent for food. Near the surface of the sea lives the plankton, sometimes referred to as the "pastures of the sea" and compared with the "grass of the fields." Most of this plankton consists of diatoms that at present are by far more prolific in the cooler polar waters. At times of greatest abundance in Kiel Bay as many as 200 of these "jewels of the plant world" are contained in a drop of water, and in the Antarctic seas there is an area of ten and one half million square miles where diatom ooze is accumulating. They are the principal food supply for most of the sessile benthos, or bottom life, among which the mollusca and brachiopods are of the greatest importance in paleogeography.

Geologic deposits rich in diatoms are sometimes regarded as those of the deep sea, at least as of deeper waters than those of continental seas. The English Carbonic deposits, rich in diatoms, have a fauna whose species are all of the shallow water kinds. The vast Miocene diatom deposits of California, described by Arnold, have living bottom types of foraminifera that, according to Bagg, do not indicate a depth of over 500 fathoms.

From the present distribution of marine life we learn that the greatest bulk of invertebrates are restricted to the bottom of the shallow seas within the depth to which sunlight readily penetrates, that is, a depth on the average not over 600 feet. The value of this observation to the paleogeographer and the student of fossil marine life lies in the confirmation of paleontologists that continental seas are shallow seas, to the bottom of which in most places sunlight permeates. These seas are to be compared with the littoral regions of the present oceans, and they are the areas that are most exposed to climatic and physical changes, due to their proximity to the atmosphere and the lands. The life of these waters is, therefore, subject to an environment that is more or less changeable, and one of the basic causes underlying organic change. It is the invertebrates of the littoral and shallow seas that the paleontologist studies.

In the tropical and subtropical shallow seas one meets with the greatest variety of life and with the brighter colored and more ornamental shelled animals, but we are much surprised when told that the greatest number of individuals occur in the colder shallow waters of the temperate and polar regions. Johnstone states, "There is little doubt that the distribution of life in the sea is exactly opposite to that on the land. The greatest fisheries are those of the temperate and arctic seas. . . . Nowhere are sea birds so numerous as in polar waters. The benthic fauna and flora are also most luxuriant." The Bay of Naples has a "richly varied, but (in mass) a scanty fauna and flora," and "at the very least the amount of life in polar seas is not less than in the tropics."[2]

Marine life is also more prolific near river mouths of the temperate zones, probably because of the great quantities of dissolved "salts of nitrous and nitric acid and ammonia, and other substances which are the ultimate food-stuffs of the plankton." Just outside of the estuary of the Mersey in Lancashire there were "not less than twenty, and not more than two hundred animals varying in size from an amphipod (one fourth inch long) to a plaice (eight to ten inches long) on every square meter of bottom" (Johnstone, 1909: 149, 176, 195–6). Finally the quantity of life in the shallow waters of the sea is not directly governed by favorable habitat, such as shallow sunlight waters in constant circulation and of equable temperature, but seems to be primarily controlled by the amount of the minimal food elements. Sea-water may be regarded as a dilute food-solution having the essential materials on which life is dependent. Of these nitrogen and the compounds of silica and phosphoric acid are present in the smallest amount. Johnstone tells us that "The density of the marine plants will therefore fluctuate according to the proportions of these indispensable food-stuffs" (234). "It is only the protophyta among the

[2] "Life in the Sea," 1908, 201–205.

plankton which can utilize the CO_2 and the nitric acid compounds, and so we see that upon these rest the greater part of the task of elaborating the dissolved food-stuff of the sea" (239).

Undoubtedly much of the land-derived nitrogen, estimated at 38 million tons per annum, is used up in the shallow areas by the plants. We therefore arrive at the conclusion that shallow seas bordering naked, cold, or arid lands should have the smallest amount of life, and that those of temperate regions adjacent to low lands under pluvial climates should have the greatest number of individuals. This conclusion, however, may be decidedly altered by the oceanic currents in that they distribute far and wide the salts of the sea.

These factors also suggest that during "critical periods" the faunas should be least abundant and varied, and that at the times of extreme base levels and sea transgressions they ought to be at their maximum development. These suggestions are borne out by the small Cambric, Permic and earliest Eocene faunas and the large cosmopolitan biotas of the Siluric, Jurassic and Oligocene times.

Sessile algæ are not common on muddy or sandy grounds, and these areas in the present seas have been compared with the desert areas of the lands. That muddy grounds are now nearly devoid of algous growth has particular significance in stratigraphy, because in the geologic column at many levels and in nearly all regions occur black shale formations that are not only devoid of plant fragments but are also usually very poor in fossils of the sessile benthos. When the latter are present it is seen that they are usually thin-shelled and small forms, or are types of organisms that live in the upper sunlight realm and are either of the swimming plankton or the floating nekton. As examples of such deposits may be cited the widely distributed Utica formation of the Ordovicic extending from southern Ohio to Lake Huron and east to Montreal, and the Genesee (Devonic) of New York. In these cases what appears to be of the sessile benthos is thought to belong to the nekton attached to floating seaweeds or other floating objects, and eventually all of the life of the nekton and the plankton sinks to the bottom of the sea. Therefore the carbonaceous matter of the black shales may be of algous origin like that of the New York Genesee, but it is far more probable that it is largely of animal origin, as the crude petroleum of such deposits usually has the optical properties of animal oil and especially those of fish oil.[3] Plants may be torn from rocky bottoms of the shallow areas by the action of the storms and then carried by the currents into eddying areas like the present Sargossa Sea, which has among its algæ a very characteristic assemblage of animals. It is probable, however, that black shales having wide distribution were more often the deposits in closed arms of the sea (cul

[3] Dalton, *Economic Geology*, 1909, 627.

de sacs), or when of small areal extent, as the result of fillings of holes in the sea bottom. In all such places there is defective circulation and lack of oxygen resulting in foul asphixiating bottoms.

These are the "halistas" of Walther and the "dead grounds" of Johnstone. To-day such are the Black Sea and the Bay of Kiel, where sulphur bacteria abound in greatest profusion. These decompose the dead organisms that rain from the photic region into such suffocating areas, or the carcasses which are drawn there by the slow undertow from the higher ground. These bacteria in the transforming process deposit in their cells sulphur that ultimately combines with the iron that is present and replaces the calcareous skeletons of invertebrates by iron pyrite or marcasite. In this way are formed the wonderfully interesting pseudomorphs of *Triarthrus becki,* the Utica trilobite preserving the entire ventral limbs, and of the other well preserved but small invertebrates from the Coal Measures black shale of Danville, Illinois.

Brackish-water and especially deep-sea shelled animals tend to have thin shells, while increase of salinity tends towards the thickening and roughening of the calcareous shells. It is a well known fact that in the dolomite-depositing continental seas like that of the Guelph (Siluric), all of the molluscs have ponderous thick shells. These have been interpreted as reef-living species but actual reefs in the Guelph are unknown. The molluscs are often common but corals are represented by but a few species. Similar conditions are known to occur in other dolomite faunas. Further, the Guelph was of a time of decided progressive emergence and restrictional seas under an arid climate, and therefore the waters must have been abnormally salty.

Rivers constantly discharge into the sea great quantities of plant material, but as a rule little of it other than the wood is swept far out to sea. At present the rivers of northern Siberia float into the sea vast numbers of logs that drift with the currents to Spitzbergen, East and West Greenland and Arctic America. This wide dispersal of wood by the sea is met with only in the cold regions, whereas in tropical waters the wood is rapidly decomposed. Single leaves are rarely transported far from their place of origin, and when of good preservation in geologic deposits, give decisive evidence of the nearness of the shore. On the other hand, tough palm leaves have been seen in the sea 70 miles from land and rafts of leaves are often met with 200 or more miles beyond the mouths of the Kongo and the Amazon. Proximity to shore is also indicated by the presence in marine faunas of land molluscs, insects and bones of land vertebrates.

With tillites now known in the Lower Huronian of Canada, in the Lower Cambric of northern Norway, China, South Africa and Australia, and in the Permic of India, South Africa, Australia and Brazil, we observe the recurrence of glacial climates. The Siluric and Devonic coral reefs occurring in Arctic regions, the sponge, coral and bryozoa reefs in the Jurassic of northern Europe, the rudistid and other cemented pelecypods in reefs of wide distribution in the Cretaceous, and the almost world-wide distribution of the Nummulitidæ (north of Siberia) in the late Eocene and Oligocene point as clearly to warm waters and mild polar climates. Further the widely distributed Carbonic foraminifers of the family Fusulinidæ that swarmed in temperate and tropical regions are unknown to Arctic and Antarctic regions. In other words, long before we have a fossil record the earth had climatic zones, and for long periods the climate was mild to warm, punctuated by shorter intervals of cold to mild climates.

The volume of sea water to-day is very great, but we must ask ourselves: Has this quantity always been such or was it even greater, as some geologists still hold? We no longer agree with Laplace and Dana that the earth passed through an astral stage, but rather agree with Chamberlin that it always has had a more or less cold exterior. Through volcanic activity much juvenile water from the interior of the earth was extruded in geologic time and was added to the vadose waters of the surface. Suess states that "the body of the earth has given forth its oceans and is in the middle phase of its gas liberations." Accordingly, the Paleozoic oceans must have been quantitatively smaller than those of the present, and the gradual increase in the volume of vadose waters has been accommodated by the periodic increase of oceanic depth.

We also agree with Walther that the oceans of Paleozoic and earlier time did not have the great abyssal depths they now have. The accentuated deepening of the permanent oceanic basins did not begin until the Triassic, for in none of the great depths of the present oceans are found traces of Paleozoic organisms, and all here are of Mesozoic or Tertiary origin. In the shallow regions, however, are still found a few Paleozoic testaceous-bearing genera of brachiopods, tubicular annelids, pelecypods, gastropods, *Nautilus*, and *Limulus*. The deepening of the Pacific, the Indian, and especially the Atlantic oceans has been at the expense of the lands or horsts, for the ancient continents, Gondwana and Laurentia, have each towards the close of the Mesozoic been broken into several masses. We may therefore speak of permanent oceans, and transgressed, fractured, and partially down faulted, continents or horsts.

These are some of the factors that control the making of some of the modern paleogeographic maps.

BIOLOGIC PRINCIPLES OF PALEOGEOGRAPHY

By Dr. F. H. KNOWLTON
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CONSIDERING the breadth and intricacy of the subject assigned me, and the limited time that can be given to its consideration, it has seemed best to me to restrict my remarks to two or three of the obviously more important phases of the problem.

Aside from the study of the rock-masses themselves—which are often difficult of interpretation—reliance for an interpretation of paleogeography must be placed in the former life found entombed, and of the two biologic elements, plants undoubtedly hold a very high—probably the highest—place.

In making use of plants in the study of paleogeography we may first consider distribution. If we find two fossil floras identical or similar in all essential or important details, we feel justified in regarding them for all practical geologic purposes as contemporaneous. In order that we may be certain that the two floras are identical, they must be composed of types that are readily identifiable, that is, forms so well characterized that they may be easily and certainly recognized. As examples of such floral elements mention may be made of many ferns and fern allies, most cycads, conifers and peculiar, well-marked or characteristic dicotyledons. Having settled the contemporaneity of the floras, inquiry may next be made as to the probable manner in which the separated or isolated areas were reached by these floras. Here again we must carefully consider the character of the flora and the means for its natural dispersal. The living flora, and for that matter probably the floras from at least the beginning of the Tertiary progressively to the present time, has developed in many ways means for the comparatively rapid and wide-spread dissemination of their reproductive parts (seeds, etc.). For example, a large percentage of the members of the dominant living family of seed-plants—the Compositæ—have developed seeds with an attachment of soft, fluffy hairs which serve to float them in the air, often to great distances. In many other living groups there are similar, or at least as effective, devices for dissemination, but as we go back in time adaptations calculated to be of aid in distribution grow less and less, and soon even seeds of any kind are unknown, or known but imperfectly, and reproduction is normally by means of spores, that is, reproductive bodies in which there is no embryo already formed when they leave the parent plant. It is obvious that plants that are reproduced by seeds, in which there is both an embryo and a supply of food for use during germination, must possess a decided advantage over those reproduced by means of spores.

In the groups of spore-bearing plants ordinarily found fossil, the spores are not known to have developed any particular devices for their wide dissemination, such as flotation in air, attachment to animals, etc. They are produced in vast quantities, and depend upon a few reaching situations favorable for successful germination. Their vitality is also of apparently exceedingly limited duration, and it is doubtful if they could long survive immersion in salt water.

The bearing of the above digression is apparent. Given a fossil flora made up of ferns or fern allies, exclusive of what are known to belong to the cycadofilices, and when such flora is found in two or more separated areas, we are justified, in my opinion, in arguing a practically continuous land connection. They were incapable of crossing very wide reaches of open water, particularly salt water. Fresh-water streams have been to some extent avenues of distribution, but many fossil floras—and living floras as well—are too widely spread to be explained by this means. When, as is usually the case, identical floras occupying different areas are mixed floras, the bearing on the means of reaching the various areas is more complicated. An example may better serve to bring this out. Thus, the Jurassic flora is practically world-wide in its distribution, ranging from Franz Josef Land, 82° N., to Louis Philippe Land, 63° S. It is composed of ferns, fern-allies, cycads and conifers, a large percentage being true ferns. The probability of a close land connection argued on the basis of the true ferns, has already been alluded to. The cycads—the Jurassic is called the age of cycads—were abundant in individuals and numerous in forms. On the basis of our knowledge of living types, it may be stated that cycad seeds germinate immediately on falling from the cone without any necessary resting period. They are not known to retain their vitality for a longer period than three years, and usually but two years. They sink promptly in fresh water and as the stony coat is easily penetrated by water, they either germinate or rot at once. In salt water they will probably sink and decay even more quickly. Therefore, the probability of their being transported for any great distance over open water is reduced to a minimum. The conifers of the Jurassic were reproduced by seeds. They belong to types not known to enjoy any special means for transportation, nor is it probable they could better withstand fresh- or salt-water immersion than the cycads. All classes of vegetation present in the Jurassic, therefore, argue for a practically continuous land connection.

In considering the bearing of any flora on the paleogeographic problem the process is similar to that outlined above. That is, an analysis of the composition of the flora, a study of the means of natural dissemination which includes duration of vitality, and finally a judgment as to its probable means or avenues of transportation, involving a land connection or otherwise.

A word may be said as to the presence of land plants in marine deposits. That the trunks of trees may float for a considerable time and to great distances is undeniably possible, but unfortunately the study of fossil wood has not yet reached that degree of refinement in most cases that will permit of its general use, and reliance in identification must be placed largely in foliar and reproductive organs. The delicate fronds of ferns, leaf-clad branchlets of conifers and the leaves of seed-bearing plants are incapable of long withstanding the immersion and wave action of salt waters. In my judgment, therefore, the presence of fronds, leaves and similar organs in marine deposits argues very near-by land.

The only other point I shall consider is the bearing of plants on the interpretation of *climate*. Since it is generally acknowledged that plants furnish the most reliable data for this phase of the subject, an inquiry as to the kinds of plants that have been found most valuable in this connection may be of interest. Obviously our interpretation of the probable conditions under which the plants of past geological ages grew, must be on a basis of a knowledge of present conditions found to obtain for similar or closely related groups. That we may occasionally err in this is possible, especially if reliance is based on too few forms, but when all the various elements of a flora are considered, the results are thought to be within a close approximation of the truth. Thus, since *Artocarpus*—the bread-fruit tree—only grows at the present day within 20° of the equator, it follows that when *Artocarpus* is found fossil in Greenland, 72° N., the conditions at the time it flourished there must have been tropical or subtropical, and this conclusion is confirmed by the tree ferns and cycads associated with it. Palms can not flourish with a temperature below 40°; a fossil flora, rich in palms of well-defined types, could hardly have grown under very much cooler conditions. Tree-ferns are practically confined to within 30° of the equator and a temperature of approximately 60°. A fossil flora, such, for example, as the Triassic of Virginia, that contains numbers of tree-ferns, must have grown under tropical or subtropical conditions. A fossil flora rich in types, the living representatives of which can withstand a temperature of — 40° to — 60°, or even lower, must have been at least cool-temperate. Cycads are now found only within 30° of the tropics; a rich cycad flora argues then for a tropical or at least a subtropical climate.

Examples of this kind could be multiplied almost indefinitely. In interpreting geological climate selection is made so far as possible of the plants or groups of plants, that are confined at the present day within relatively narrow limits of temperature, be this high, medium or low.

THE CASE OF HARVARD COLLEGE[1]

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THE free elective system, three years of college in preparation for the professional school, personal freedom for the student, these are tenets that Harvard has made familiar to us all. But the pendulum now swings backward. It is already decided that the work of the student is to be concentrated and dispersed by faculty decree; that preparatory schools are to be established for freshmen. We are told that the four-year college course should not be shortened, that "every college graduate ought to be equipped to enter any professional school" and that "the professional schools ought to be so ordered that they are adapted to receive him." "College students are amateurs, not professionals"; they should study "a little of everything," and though each should also have "a firm grasp of some subject," it should lie "outside of his vocation." "The college may be regarded as the last period of play."

The scheme on which the president, fellows, overseers and faculty of arts and sciences of Harvard University have united has one merit; they announce that they do not intend to enforce it. Compulsory concentration is useless and compulsory dispersion is bad. Neither good students nor those who do not want to study will be helped. Any such scheme breaks down under the load of its artificiality. The field of knowledge is divided into four divisions for purposes of dispersion, but no faculty can put asunder what God has joined together. According to his interests and needs the student may find his concentration scattered through the four divisions and his dispersion within a single department, as well as the reverse. In my own subject he can find boundless dispersion—witness the fields tilled at Harvard by Professors James, Münsterberg, Royce, Palmer, Santayana and Yerkes—or he can choose a unified and consistent course by innumerable combinations of studies.

Ten years ago a committee from the Harvard department of education made a detailed study of the programs of study of 372 members of the class of 1901. It was concluded that only 7.8 per cent. appeared open to the charge of undue specialization, of whom one third

[1] An address read after the annual dinner of the Harvard Teachers' Association in the Harvard Union on March 12, 1910.

specialized in history and political science preparatory to the study of law. Only 4.5 per cent. seemed to show a lack of proper concentration of energy, and of these one sixth received the A.B. *magna cum laude*. But circumstances alter cases. We are now told that more than half the students concentrate too much or too little. It is said that only one seventh of the students graduating from the law school *cum laude* concentrated too little in college, whereas the medical students did not concentrate nearly so much. It is not likely that medical students are inclined to specialize less than law students. The fact is that Harvard College provides the courses in English, history and political science needed by students of law and does not provide the courses in anatomy, physiology and pathology needed by students of medicine.[2] Instead of requiring students preparing for the medical school to take courses which they do not want, the college should offer the courses which they need.

The free elective system may be a partial failure; but it is doubtful whether, apart from the professional school, a better plan has been devised. The group system is better in so far as it is a professional school within the college; it is no better as a factory for the manufacture of cultivated gentlemen. Sequences and combinations of studies in the college should be planned which give adequate preparation for different kinds of work in life, not only for the orthodox and semi-orthodox professions, but also for business and affairs, and for such special performances as those of the Sanskrit scholar, the psychological expert or the economic entomologist. The courses should be planned by those engaged in these callings, rather than by a college faculty, and they should be elected by the student after proper counsel, rather than forced upon him.

The boy of eighteen or nineteen either should know what he is going to do in life and give at least part of his time to direct preparation, or he should have a working hypothesis. The professions differ in their demands. Medicine and engineering require manual dexterity and much special information; they should be begun in good season. Law and theology are less exacting of special training; a medical or engineering course would not be a bad preparation for the bar or the church, but the converse is not true. A lawyer who becomes a university president may not unnaturally fancy that the preparation suited to a lawyer would also be fit for the physician or engineer. But when he says:

> Many professors of medicine, on the other hand, feel strongly that a student should enter their schools with at least a rudimentary knowledge of those

[2] President Lowell in reply said that the study of Latin is the best preparation for a scientific career, but that the proper preparation for the profession of law is learning to reason. If the lawyer can be taught to reason, there is certainly a valid argument for that much compulsion in college.

sciences, like chemistry, biology and physiology, that are interwoven with medical studies; and they appear to attach greater weight to this than to his natural capacity or general attainments,

one wonders where those professors of medicine are who attach greater weight to rudimentary knowledge of certain sciences than to natural capacity, and whether any one holds that that natural capacity precludes scientific training or conversely.

The special training of a group or professional course is not its only advantage. An expert Sanskrit scholar is better fitted to become an entomologist than an amateur who has studied a little of everything. Any kind of an apperceptive mass—to use the slang of psychology—is better than none at all. The Columbia College faculty in requiring every freshman to take six or seven studies unrelated to one another and largely unrelated to his past or future work prescribes a method which not one member of the faculty would be so foolish as to adopt in his own work. The collective unwisdom of a college faculty is not often exceeded by an undergraduate student. Nor, it may be added, is the skill of a faculty in devising restrictive regulations equal to the ingenuity of the student in dodging them. As Mr. Eliot has recently said, while the word "must" may be heard hereafter more frequently at Cambridge, "I feel a very strong confidence in the ability of the youths that come to Harvard College to take that word with apparent submissiveness, but without allowing it to have any inconvenient effects on the individual."

It is doubtless true that students should not spend four years in electing elementary courses; it is well to persuade them and it may be desirable to compel them to do a certain amount of consistent work in some direction. The problem is largely social rather than educational; it is not serious in the colleges of the great state universities. They have all sorts of programs and curriculums; but as a rule the student does his work because it is of concern to him. He has a major subject; he has already begun, or will take up in a year or two, agriculture, medicine, engineering or some other life work, and in the meanwhile he is preparing for it. The air of the place is saturated with honest work. If these young men and women are crude, it is because their homes are but a generation from the frontier, not because their work in college is real. They not only learn more, but make more progress in polite manners and broadening interests than do the boys in the colleges of the Atlantic seaboard.

Before the section of education of the American Association for the Advancement of Science a year ago, addresses were made by Professor Royce and Professor Tufts on "The American College and Life," which emphasized the need of giving reality to the work of college students by breaking down the artificial barriers between culture and professional work. Professor Tufts discussed the importance of a "reconstruction of the college ideal of liberal culture . . . by a greater introduction of the vocational element and spirit into college work." Professor Royce said:

> Let us seek to assimilate college work more rather than less to that sort and grade of professional work which calls out a young man's energies just because he feels that in such work something is at stake that is, for him, personally momentous. . . . Let us beware of those theorists who, in the name of what they call the American college, want to sunder afresh what the whole course of our modern American development has wisely tended to join, namely, teaching and investigation, the more technical training and the more general cultivation of our youth, as well as the graduate and the undergraduate types of study. I should abhor the name college if this mere name ever led us into such a backward course as some are now advocating.

Our ideas of culture are inherited, primitive and conventional. There is a hierarchy of those who wear celluloid collars, those with linen collars and those with non-detachable collars. Each class looks down on that below it; but scarcely considers what the wearing of a collar symbolizes. He carries a non-detachable collar who believes that American college students must be forced "to study a little of everything, for if not there is no certainty that they will be broadly cultivated." There are various kinds of culture nowadays—microbes propagating in gelatine, turnips with twenty tons of manure to the acre, and boys at Harvard studying a little of everything.

As a matter of fact, boys at Harvard may be compelled to take all sorts of courses and even to be coached for examinations on them, but they do not of necessity study at all. They react normally to the futility of the scheme. There are many kinds of boys in a college community—grinds and sports, scholars and entrepreneurs. One difficulty is that they divide themselves into social cliques when they ought to mix, and are mixed in the courses when they ought to be grouped with reference to their abilities, interests and future work.

The years from eighteen to twenty-five are precious beyond all measure. A boy of eighteen is the rawest of material; within seven years the pig-iron must become steel and the blade must get its finest edge or it will never cut deep. But we bookmen must remember that words and books and scholarship are not the only things in the world. The pen may be mightier than the sword, but it is feeble beside the workman's tool. An Achilles who has no Homer is not therefore less great. We who talk and write have undue opportunity to exploit our own trade. If we expect others to respect our scholarship, we should in turn honor their performances. The fundamental fault of our whole educational system is that we try to train to superficial scholarship and conventional culture those who should be learning to do their share of the world's work.

The traditions of scholarship attaching to the college are indeed somewhat threadbare. From the monastery, by way of Oxford and Cambridge, came the American college. So long as it was controlled by the clergy for the education of the clergy and the church was a real part of the life of the people, the college was vital, as are to-day the schools of medicine, engineering and law. When intending lawyers and teachers—concerned like the clergymen with words, books and traditions—became a large element among college students the scholastic curriculum was not inept. Six or eight years' study of the elements of the classical languages—scarcely ever reaching so far as reading them with ease or writing them with correctness—did not accomplish so very much in the way of broadening interests and enlarging sympathies, but it gave a good drill and a common stock of knowledge and quotations, which made for the social homogeneity of a class. Poetry and art have so completely based themselves on the classical and biblical traditions that they are in danger of waning together.

Science has in the course of the past century caused a revolution in human life. Its applications have made democracy and universal education possible by enabling one man to do what formerly required ten. Science has created new professions and has at the same time provided the economic conditions which permit large numbers to follow them and to undergo a long period of unproductive apprenticeship. The same economic conditions have permitted the wealthy and potentially idle classes to increase to a vast horde largely lacking the traditions of an aristocracy. The lower death rate due to science is followed by a lower birth rate. Women partly freed from manual work and child-bearing can be idle, go to college or engage in sedentary occupations. Then science has directly reformed our educational system by the new material which it has supplied and by the new method which it has made supreme.

The English and American colleges have but partially and imperfectly adjusted themselves to this new life. The ghost of the obsolescent scholastic system still hovers about the place; it is still haunted by the phantom of the gentleman who hunts over his country estate and drinks two bottles of wine for dinner, but whose son may become a curate or the proconsul of an empire. Oxford and Cambridge have, as a matter of fact, more nearly fitted themselves to the conditions of British society than have our seaboard colleges to American democracy. The B.A. may mean little more than a public-school education and three six-months of residence at the university, but the young men have on the whole a high sense of honor and duty, of traditions to be maintained. In addition to the poll men, there are honor courses at the universities which are strictly special and professional—preparatory to medicine, law, politics, etc., or giving expert training in subjects such as the biological sciences or the classics. A student may devote three years to exclusive and intensive work in mathematics; and the training has proved excellent, having produced not only many of the ablest mathematicians of the last century, but great men in all departments of activity. The English system of public schools and scholarships selects for the universities a large share of the ablest and most earnest young men of the country; Oxford and Cambridge have continuously sent forth their men to lead the nation. None the less it is true that in numbers, in resources and in educational methods they have remained nearly stationary, while the great movement in higher education in England has been the establishment and growth of the metropolitan and provincial universities. These are essentially trade schools, similar to our own state universities, and having but little in common with our country clubs of the North Atlantic states.

It is not desirable to support at public expense certain country clubs or detention hospitals in which rich boys may be segregated. The idle rich and the lazy poor we have with us always and everywhere. Colleges only contribute their share to the failure to solve a problem at present insoluble. It may be that these rich boys cost society more than they are worth; it may be that their value is a minus quantity. They will, however, occupy a far more important place in society than others. From the vast numbers born in the cottage, there are a few who grasp "the skirts of happy chance" and live to shape a "state's decrees," but in the main those who eat at the high table of the palace are born there or in its dependencies. Thanks to heredity and opportunity combined, there are more dominant personalities, such as Mr. Theodore Roosevelt, Mr. Pierpont Morgan and Mr. Lawrence Lowell, from this small upper class than from the working millions. Whether or not we should be better off without such men is not the question. Until opportunity can be equalized we shall have them; the college must bear its share of responsibility for what they do in the world.

These rich boys are as a rule nice boys and many of them will become leaders in their own class and in the community. The luxury to which they are inured at home does not especially hurt them in college. The difficulty is twofold—they set false standards for the boys who are not rich and they do not themselves profit greatly from their college work and life. The college community is more democratic than any other; but as an institution increases in size sets are formed, and the rich are segregated in dormitories, clubs and fraternities. They enjoy the social life which the idle classes maintain after reaching years of discretion, and are turned in that direction rather than to ideas of useful work and service. They do not see the use of the college courses, but study as little and pay their coaches as much as may be necessary to pass examinations. The president of a large college told me that he could not consider a certain man in connection with the chair of philosophy, because he was said to have leanings toward socialism and there was too much of that kind of thing among the students already. As a matter of fact, this president probably had his eyes on his trustees rather than on his students, and there is altogether too little enthusiasm for ideal ends—wise or foolish—among our college students. On the continent they are the radicals and revolutionaries; here they are too often the premature club men.

A class endowed by the public can only be tolerated if it performs public services. Assuming that the class will last for a time, how can it be taught its responsibilities? Not surely by the Harvard plan of studying a little of everything, but nothing concerned with work in life. Even professional football is better than amateur scholarship. Your true lover is no amateur, but a professional in deadly earnest. Each boy at Harvard, rich or poor, should have some end to which he devotes himself. Those who do not care for scholarship should be given a chance to become interested in business or politics or social affairs, or else the university should be closed to them. But many will become absorbed in scholarly work if given a chance, and this can best be offered by letting them do serious work in some direction and leading them to associate with those already interested in such work.

The plan just now adopted at Harvard of establishing residence halls for freshmen traverses all that I have written. Groups of the most immature students, likely to be classified by the amount they are prepared to pay for rooms and board and the schools from which they come, will be segregated, required to study a little of everything under the supervision of celibate masters, and told that they are entering on a "period of play." If, as is said, "the change from the life of school to that of college is too abrupt at the present day," then let us make the schoolboy more of a man, not the college student less of a man. The groups in college should be formed on a plan exactly the opposite of that proposed, social, local and age distinctions being ignored, and the main grouping being in accordance with the aptitudes and life interests of the students. The ideal is the zoological hall of the old Harvard, where apprentices of a great man and a great teacher lived together. This is told of again in the charming autobiography of Shaler. A boy from the aristocratic southern classes, with ample means and good abilities but no fixed interests, fell into this group. There he discovered his life work and pursued it with boundless enthusiasm. Nor did the fact that he devoted himself exclusively to professional work in natural history in college prevent him from writing Elizabethan plays in his old age. The number of men of distinction given to the world from this small Agassiz group is truly remarkable.

The president of Harvard tells us that the engineering student "labors without a groan on mathematics, which most college undergraduates shun like a pestilence," and most curiously he holds that the engineering student gets no culture from his mathematics, while the college student does, and must by force be exposed to the pestilence he shuns unless he chooses philosophy as the milder disease. If culture is "a little knowledge of everything" and "those things which ordinarily educated men around a dinner table are expected to know"— to quote again—it has little more real significance than the white shirts and black coats of these gentlemen. But surely the intangible trait that we should like to strengthen by our education is almost the reverse of this—something that makes the white shirts and gossip of the dinner table insignificant, seen at times in primitive peoples, in seafaring and farming folk, in hereditary nobles, in scholars—a certain detachment from the here and now and the narrower self, the quality of greatness in a man. This is almost unconcerned with any kind of information, but to a limited degree comes from mastery in one's own field, from historical perspective, from appreciation of the forces of nature.

There are three things that the university would do—represented by the college, the professional schools and the graduate faculty. Through the college it would give men broader interests and wider sympathies, through the professional schools it would teach the routine methods of practise, through the graduate faculty it would improve these methods and enlarge our knowledge. But while the partial separation of these three objects in the university has a historical explanation, it has no real justification. Every child and every man should unite continuously in his education and in his life what the university artificially separates—he should always be doing and learning to do his share of the world's work, he should try continuously to improve the methods of doing it, and he should learn to appreciate the work of others.

In our actual courses we can not do much more than teach efficient methods of routine work. The student can learn to do something in particular, not things in general. Hence our professional schools are on the whole more successful than our colleges or our graduate faculties. Routine research and routine scholarship can be taught in the graduate faculty, which is at present essentially a professional school for university teachers. For original research and productive scholarship we must wait for the man, or possibly search for him, give him a chance and let him alone. But we should welcome him and give him opportunity in whatever department of the university he may be found. The right way to give a man interests that are broad and permanent is not to put him in elementary courses in all sorts of subjects, but to encourage him to learn to do well his work in life and to connect with this by natural associations the larger world in which he may live.

Fortunately no president and no university can confine culture to the college, professional work to the professional school and research work to the graduate school. Each will be found everywhere according to the measure of those who teach and those who learn.

The courses intended to impart "a little knowledge of everything" should, we are informed, be lecture courses by the leading men in the department supplemented by drills from subordinates. In my opinion this is exactly the wrong use of lecture courses. Books and small classes should be used for elementary instruction. Lectures may be needed for special work not to be found in books and are useful as emotional exercises. When used for the latter purpose, the student should not be quizzed or examined on them, but can properly be credited toward his degree for the number of hours he sits in the lecture room.

Futile and somewhat anti-moral is the plan proposed of trying to improve scholarship by persuading students to compete for class rank. We are told that "the free elective system in college has reduced the spirit of competition in scholarship to a minimum," and that "there is a close analogy between outdoor sports and those indoor studies which are pursued for intellectual development, especially in regard to the question of stimulus by competition." As a matter of fact, men pull together in a boat for the glory of their college; the man who plays for his own oar or hand is not esteemed there or elsewhere. There is some excuse for the student's opinion that "C" is the gentleman's grade. To try to make dull and profitless work interesting by competition puts the smell before the automobile.

This does not mean that competition is not a factor of immense importance in life; or that it is out of place in the university. When the best men graduating from the medical school receive the hospital appointments, and the best men in the engineering school find big jobs waiting for them, it is a powerful stimulus to good work. When the first and second wranglers at Cambridge have been assured of fellowships which may be worth $50,000, the attainment has been eagerly sought and highly honored. It should be noted, however, that Cambridge has this year abandoned the ranking in the mathematical tripos, because it was regarded as on the whole injurious to scholarship. If the men who do the best scholarly work in college are properly rewarded for it during their course, on graduation and in after life, their scholarship will be respected even by those who are not scholars.

A proper way to encourage students to do good work is to credit them for the quality of their work as well as for the number of hours of class work which they attend. The Harvard plan of letting the same number of courses be taken either in three or in four years does not accomplish this. The student may do work of the same amount and quality in a year whether he attends ten or thirty hours of class work. But if the points for the degree are weighted as well as counted, the able student or the diligent student will make more rapid progress. If he can do in two or three years the work for which the poorer student requires four years, there is no reason why he should not go forward to the professional or graduate school. It would also be just and a proper stimulus to let good students pay lower and poor students higher fees in proportion to the quality of their work. The good students who profit themselves and contribute to a better spirit in the institution should receive a larger part of the subsidy contributed for college education, while the students who learn but little and may be a public nuisance should not be supported at college at public expense.

But the best reward for scholarly work is adequate recognition of the work as preparation for a career in life. At Columbia University a man takes his doctor's degree at the average age of 27 years. He is fortunate if he receives immediately an instructorship at $1,000 a year; the increments of salary are $100 a year for ten years, so that at the age of 37 he receives a salary of $2,000. In a commercial community the imagination is not stirred by such figures. The university is a parasite on the scholarly impulse instead of a stimulus to it.

The first need of our universities and colleges is great men for teachers. In order that the best men may be drawn to the academic career, it must be attractive and honorable. The professorship was inherited by us as a high office which is now being lowered. Professors and scholars are not sufficiently free or sufficiently well paid, so there is a lack of men who deserve to be highly rewarded, and we are in danger of sliding down the lines of a vicious spiral, until we reach the stage where the professor and his scholarship are not respected because they are not respectable.

I should myself prefer to see the salaries, earnings and conveyings of others cut down rather than to have the salaries of professors greatly increased. When a criminal lawyer—to use the more inclusive term for corporation lawyer—receives a single fee of $800,000, our civilization is obviously complicated. Every professor who is as able as this lawyer and who does work more important for society can not be paid a million dollars a year. But neither is it necessary to pay him so little that he can not do his work or educate his children. I recently excused myself somewhat awkwardly for not greeting promptly the wife of a colleague by saying that men could not be expected to recognize women because they changed their frocks. She replied: "The wives of professors don't." It is better to have wit than frocks; but in the long run they are likely to be found together.

The first step of a really great university president would be to refuse to accept a larger salary than is paid to the professors. The second step would be to make himself responsible to the faculty instead of holding each professor responsible to him. The bureaucratic or department-store system of university control is the disease which is now serious and may become fatal. This subjection of the individual to the machinery of administration and to the rack wage, is but an invasion of the university by methods in business and in politics from which the whole country suffers. We may hope that it is only a temporary incident in the growth of material complexity beyond the powers of moral and intellectual control, and that man may soon regain his seat in the saddle. Certainly Harvard has led the way. It has adopted a scale of salaries independent of superficial supply and demand, and has placed them outside the influence of intrigue and favoritism. The bureaucratic system is less dominant than elsewhere. And it has its reward; for I find in an objective study of the distribution of the scientific men of the country that no less than one fifth of those most eminent are here.

It has been said more than once that the college is in danger of being crushed between the upper millstone of the professional school and the nether millstone of the secondary school; those who have used this simile do not appear to realize that this is the way fine flour is made. The trouble with our educational system is that the college has not only exploited its frivolous amateurism and its futile scholasticism at home, but it has imposed them on the high school and even on the grades. When we have high schools fit for the people and professional schools of the right sort, the college will be molded into proper shape.

President Lowell closed his inaugural address with the words:

> It is said that if the temperature of the ocean were raised, the water would expand until the floods covered the dry land; and if we can increase the intellectual ambition of college students, the whole face of the country will be changed. When the young men shall see visions the dreams of old men will come true.

If the temperature of the ocean were raised sufficiently, Cambridge and its university would be submerged, while the great continent with its state universities would stand untouched. But if the intellectual ambition is sound and the visions are sane Harvard College can be saved.

I trust that I have not exceeded the privileges proper to a guest or the freedom allowed by an after-dinner address. Those men and those institutions which are too great for compliment are still subject to honest criticism. It would be impertinent for me to praise Harvard University and its leaders. Harvard stands apart from and above all our other universities, secure in its past and in its future, one of the great contributions made by America to the civilization of the world.

THE PROGRESS OF SCIENCE

THE SALARIES OF PROFESSORS

At the eleventh annual conference of the Association of American Universities Professor G. H. Marx, of Stanford University, presented an elaborate study of the problem of the assistant professor. It appears that assistant professors in the leading universities are of an average age of thirty-seven years, and have an average salary of $1,800. Four fifths of them supplement their salaries from outside sources and many are in debt. They have on the average one child. There seems to be considerable difference in the status of the assistant professor in different universities. In some institutions they have nearly the same influence as the full professor in faculty legislation and departmental control, while in others they state that they are practically ignored. The larger salaries paid to professors are about the same at Harvard and Columbia, but at Harvard the minimum salary of the assistant professor has recently been increased to $2,500, while at Columbia it has been placed at $1,600.

The higher cost of living and the cost of higher living combined—the increase in the price of the necessities of life and the more exacting standards of comfort—bear heavily on those having fixed wages, and perhaps university professors suffer more than any other class. Railway employees can threaten a strike; they are paid more, and rates for passengers and freight are increased, not to the advantage of the professor. Even the clergyman and his congregation can adjust matters. But the university has an income which does not increase automatically, and the larger the number of students the poorer does it become. With the best of will the administration can not obtain an adequate number of teachers and pay them adequate salaries. In the course of the last ten years salaries have remained stationary, while the cost of living has increased fifty per cent. and the standards of living have probably increased in an equal degree. The effective salary of the professor is only about half what it was ten years ago.

While professors are underpaid in comparison with successful men of business or leaders in the other professions, it is not certain that this is the case in comparison with the great mass of their fellow citizens. They are the least privileged members of the privileged classes. There is but little abstract justice in the rewards which the world gives. People get what they can, and what they can get depends on extremely complicated conditions. Lord Kelvin received several million dollars for his inventions and engineering advice, a modest salary as a university professor and nothing at all for his great contributions to mathematical physics. Probably his services to society were the most in the work for which he was not paid and the least in the work for which he was paid the most. But even in the latter case he produced far more wealth than he received. In like manner Mr. Alexander Agassiz earned several million dollars as the result of three or four years devoted to mining, but paid large sums to carry on his scientific work which is of such high value to society.

Society has no way of paying men such as Faraday or Darwin for their immense services. The competitive system applies to teaching, but not to original research and productive scholarship. The importance of teaching.

however, as compared with other professions, is now underestimated. The rich man who employs a lawyer and a physician who charge at the rate of $50,000 a year, regards a thousand dollar a year teacher as good enough for his children. The teacher is not as a rule underpaid, but is a man of inferior ability and character.

The difficulty in the case of the relatively small salaries paid to assistant professors and professors is not so much that they are underpaid, as that universities and colleges are satisfied with men who are worth so little. It is, however, true that these institutions depend on the dignity and prestige of the position to attract men, and use this motive in place of salary. The result of this policy, however, is to lower the prestige of the position, so that it can not permanently be used in this way.

But while we may depend on the competitive system to adjust the salaries of teachers and only try to increase in the community the appreciation of the importance of having able and well-trained men, there still remains the problem of how we are to encourage and pay for original research and productive scholarship. These are in the main a by-product of the work of the teacher and are not paid for directly. Institutions want the credit of having men of scientific distinction and men value the honor which follows scientific achievement. But these motives are not sufficient, and become less so as the total number of scientific men increases. While the average salary paid to teachers may be about the same as in the other professions, the leaders do not receive salaries commensurate with the incomes of the leading lawyers, physicians, journalists or even clergymen. Under existing conditions it is probably desirable that they should receive larger rewards in order that society may have the ablest men in its direct service and may give them the strongest motives to do their best work. It is certainly little less than a scandal that the effective salaries of university professors should have been greatly reduced in the course of the past ten years.

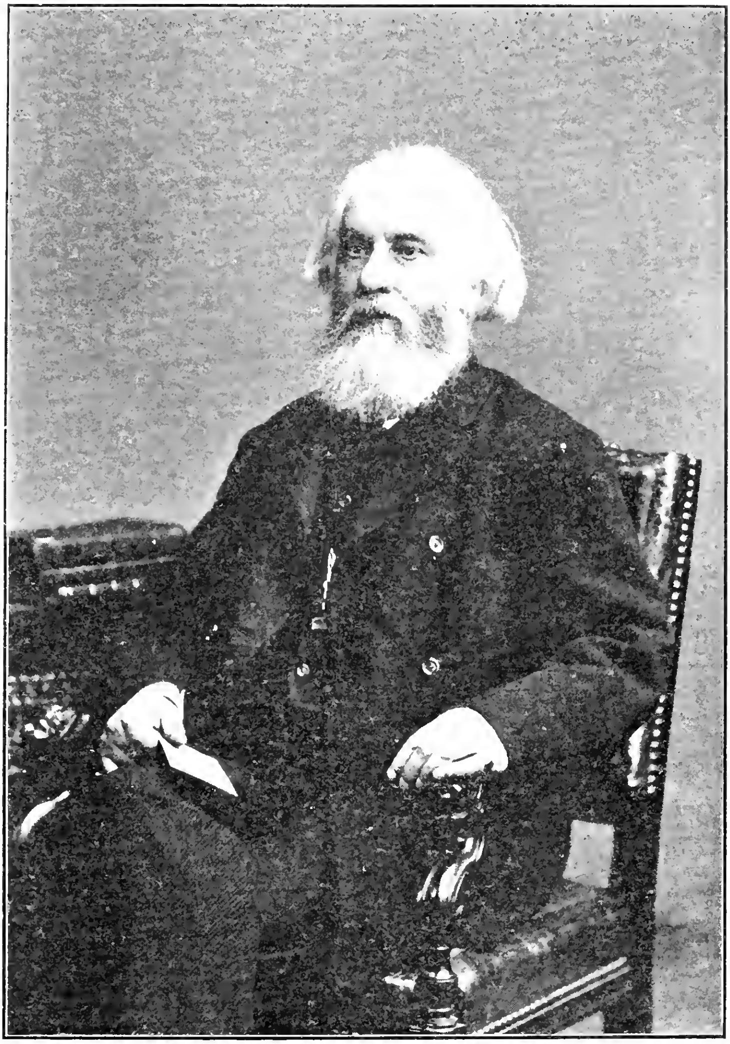
SIR WILLIAM HUGGINS

Death has taken one more of the great men who gave distinction to the Victorian era. Hooker, Wallace, Lister and Galton are left, but the period is now closing which gave Great Britain such distinction in science as has seldom been equaled in any field or in any country. It is indeed possible that the science of Great Britain in the nineteenth century is the greatest achievement of our race.

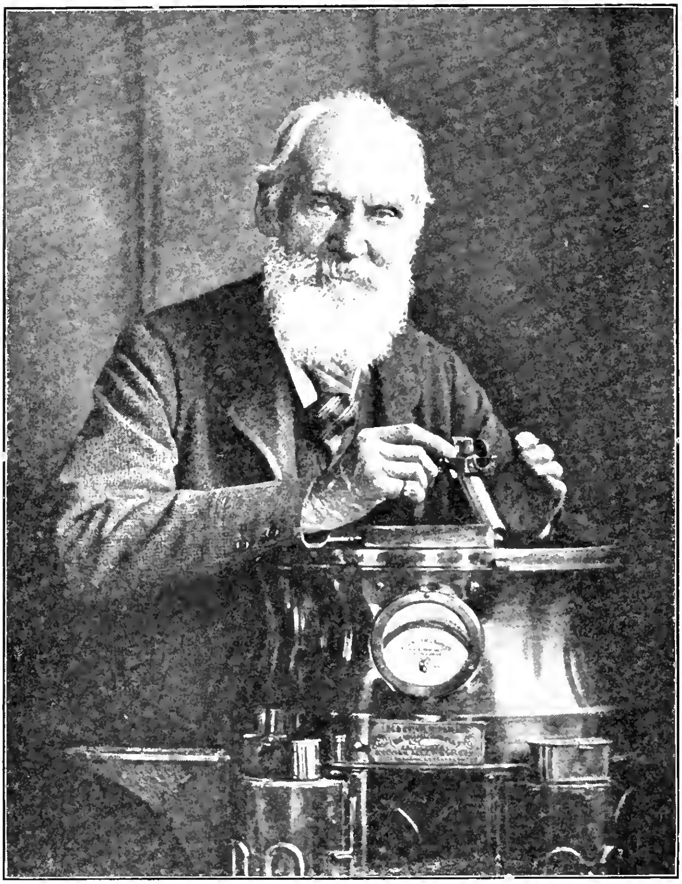
Huggins was born in London in 1824. He was privately educated, and held no university or other position, but with ample means erected for himself in 1856 an observatory at Tulse Hill. He took the lead in applying the spectroscope to astronomy and may be regarded as the founder of the science of astrophysics. In his work he had the constant assistance of Lady Huggins. He was president of the Royal Society and one of the five scientific members of the order of merit. We hope to give in some subsequent issue an appreciation of his great contributions to science.

LORD KELVIN

An adequate life of William Thomson, Baron Kelvin of Largs, has been written by Professor Silvanus P. Thompson and published by Macmillan and Co. Although an editorial note on Lord Kelvin's life and work was published in a recent issue of the Monthly (November, 1909), too much honor can not be paid to one of the greatest geniuses of the nineteeth century. We reproduce two from the many interesting portraits which are included in the volumes and Professor Thompson's final paragraph. After describing the funeral in Westminster Abbey, he writes: "For once, in the

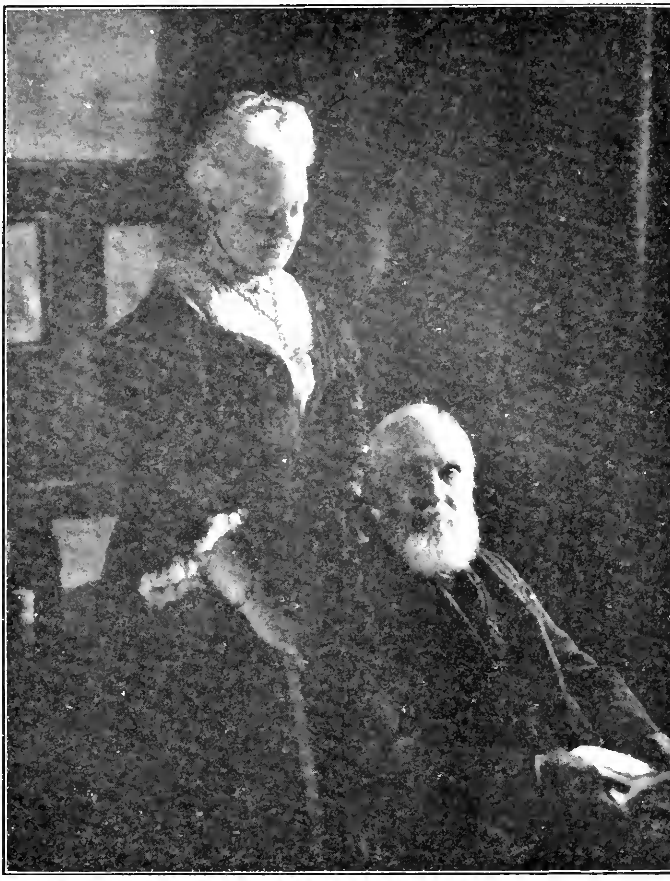


Sir William Huggins.



LORD KELVIN WITH HIS COMPASS.

universal tribute rendered to the memory of Lord Kelvin, there seemed to be some revival of recognition of what the nation owes to science and to her great men. That which impressed Voltaire nearly two hundred years ago at the funeral of Newton was the public recognition which the England of that day accorded to the great representative of science. To-day the man of action looms larger in the world than the man of thought; and mankind which worships success is apt to heed little the thought and toil without which success is not achieved. In an age which has been preeminent over all that ever went before for the advances of science, the fashion of glorifying the warrior and the orator seems a grotesque anachronism. Mr. Gladstone's dictum, 'that the present is by no means an age abounding in minds of the first order,' did but reveal that he too shared the general blindness. The fact is that there never was an age so rich in minds of the first order in science. The nineteenth century has, intellectually, been the golden age, not of drama or of adventure, but of science. It has been an epoch distinguished by a galaxy of men who made it great, and who, whether the world recognizes it or not, were great men. Though Lord Kelvin was not the last of these, he was assuredly the greatest; and his name will be revered and



LORD AND LADY KELVIN IN 1906.

his memory cherished long after those who sat at his feet and listened to his voice shall have passed away. His words, his thoughts remain. And not his thoughts only; for though he was essentially a man of thought, he was also a man of effort to whom came the high privilege of achievement. That laborious humility for which he was conspicuous, that unceasing activity which drove him, as by an internal fire, from success to success, mark him as a man of purpose. In an age that threatens, now to fester into luxury, now to swell into the degenerate lust of bigness, now to drivel into sport, such a strenuous career as his, and such high ideals of intellectual endeavor as illuminated his whole life, are possessions not lightly to be lost."

SCIENTIFIC ITEMS

WE record with regret the deaths of Dr. H. T. Ricketts, of the University of Chicago, who had been in Mexico conducting research on typhus fever and died from that disease; of Dr. Eugene Hodenpyl, the pathologist, of New York City; of Professor William Graham Sumner, of Yale University, eminent for his contributions to sociology and economics, and of Sir Robert Giffen, the British statistician.

MEMBERS of the National Academy of Sciences have been elected as follows: Forest Ray Moulton, assistant professor of astronomy in the University of Chicago; William Albert Noyes, professor of chemistry in the University of Illinois; Thomas Burr Osborne, research chemist in the Connecticut Agricultural Experiment Station; Charles Schuchert, professor of paleontology in Yale University; Douglas Houghton Campbell, professor of botany in Stanford University; Jacques Loeb, professor of physiology in the University of California, who will become head of a department in the Rockefeller Institute for Medical Research, and John Dewey, professor of philosophy in Columbia University.

Sir William Ramsay will be president of the British Association for the meeting to be held next year at Portsmouth.—Dr. John Trowbridge, who retires this year from the active duties of his chair at Harvard University, has been appointed honorary director of the Jefferson Physical Laboratory. Dr. Abraham Jacobi, emeritus professor of the diseases of children in the College of Physicians and Surgeons of Columbia University, celebrated his eightieth birthday on May 6. On April 23, exercises were held at the Mount Sinai Hospital in his honor. A bronze bust was presented to the hospital by the medical and surgical staff, and a new library named in his honor was given by the board of directors. At a dinner given the same evening by the trustees of the German Hospital announcement was made that the new children's ward which Mrs. Anna Woerishoffer has given to the hospital will be known as "The Dr. Abraham Jacobi Division for Children."

The will of Alexander Agassiz, dated September 17, 1906, was filed at Newport, on April 14. He bequeathed $200,000 to Harvard University, half for the Museum of Comparative Zoology and half for its publications. The university also receives scientific apparatus and books, and will ultimately receive the further sum of $12,000. Mr. Agassiz further bequeathed $50,000 to the National Academy of Sciences and an equal sum to the American Academy of Arts and Sciences. $25,000 is left to the Newport School of Manual Training, to which ultimately $6,000 will be added. Mr. Agassiz's will further provides that in the case of the death of any one of his three sons without issue his share of the estate shall ultimately go to Harvard University for the Museum of Comparative Zoology.

More than $2,000,000 has been contributed to Washington University, St. Louis, for the medical department. The donors are Messrs. William K. Bixby, Adolphus Busch, Edward Mallinckrodt and Robert S. Brookings. Added to this are the resources of Barnes University, recently absorbed; the Martha Parsons Hospital and the original endowment fund of the university. New appointments have been announced as follows: Dr. George Dock, of Tulane University; Dr. John Howland, of the University and Bellevue Hospital Medical College; Dr. Eugene L. Opie, of the Rockefeller Institute for Medical Research, and Dr. Joseph Erlanger, of the University of Wisconsin. Construction of new buildings, to cost more than $1,000,000, will begin at once.

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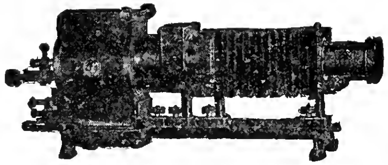

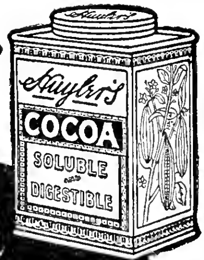

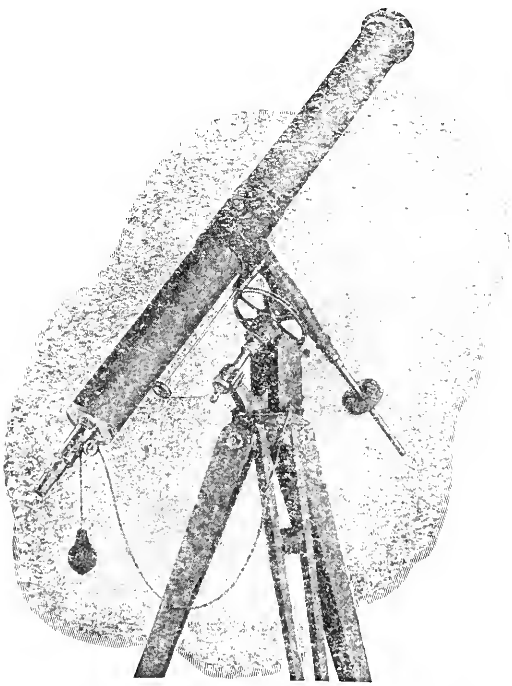

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