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Yours very truly,
James E. Keeler

THE POPULAR SCIENCE MONTHLY.

NOVEMBER, 1900.

CHAPTERS ON THE STARS.

BY PROFESSOR SIMON NEWCOMB, U. S. N.

BINARY AND MULTIPLE SYSTEMS.

SIR WILLIAM HERSCHEL was the first to notice that many stars which, to the unaided vision, seemed single, were really composed of two stars in close proximity to each other. The first question to arise in such a case would be whether the proximity is real or whether it is only apparent, arising from the two stars being in the same line from our system. This question was speedily settled by more than one consideration. If there were no real connection between any two stars, the chances would be very much against their lying so nearly in the same line from us as they are seen to do in the case of double stars. Out of 5,000 stars scattered at random over the celestial vault the chances would be against more than three or four being so close together that the naked eye could not separate them, and would be hundreds to one against any two being as close as the components of the closer double stars revealed by the telescope. The conclusion that the proximity is in nearly all cases real is also proved by the two stars generally moving together or revolving round each other.

Altogether there is no doubt that in the case of the brighter stars all that seem double in the telescope are really companions. But when we come to the thousands or millions of telescopic stars, there may be some cases in which the two stars of a pair have no real connection and are really at very different distances from us. The stars of such a pair are called 'optically double.' They have no especial interest for us and need not be further considered in the present work.

After Herschel, the first astronomer to search for double stars on a large scale was Wilhelm Struve, the celebrated astronomer of

Dorpat. So thorough was his work in this field that he may fairly be regarded as the founder of a new branch of astronomy. Armed with what was, at that time (1815-35), a remarkable refracting telescope, he made a careful search of that part of the sky visible at Dorpat, with a view of discovering all the double stars within reach of his instrument. The angular distance apart of the components and the direction of the fainter from the brighter star were repeatedly measured with all attainable precision. The fine folio volume, 'Mensuræ Micrometricæ,' in which his results were published and discussed, must long hold its place as a standard work of reference on the subject.

Struve had a host of worthy successors, of whom we can name only a few. Sir John Herschel was rather a contemporary than a successor. His most notable enterprise was an expedition to the Cape of Good Hope for the purpose of exploring the southern heavens with greater telescopes that had then been taken to the southern hemisphere. Herschel,

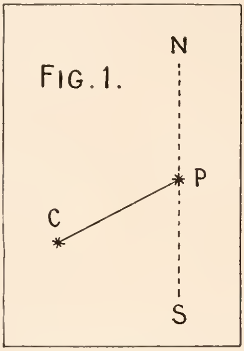

FIG. 1. POSITION-ANGLE AND DISTANCE OF A DOUBLE STAR.

South and Dawes, of England, were among the greatest English observers about the middle of the century. Otto Struve, son of Wilhelm, continued his father's work with zeal and success at Pulkowa. Later one of the most industrious observers was Dembowski, of Italy. During the last thirty years one of the most successful cultivators of double-star astronomy has been Burnham, of Chicago. He is to-day the leading authority on the subject. Enthusiasm, untiring industry and wonderful keenness of vision have combined to secure him this position.

The particulars which the careful observer of a double star should record are the position-angle and distance of the components and their respective magnitudes. To these Struve added their colors; but this has not generally been done.

Let P be the principal star and C the companion. Let N S be a north and south line through P, or an arc of the celestial meridian, the direction N being north and S south from the star P.

Then, the angle N P C is called the *position-angle* of the pair. It is counted round the circle from 0° to 360°. The angle drawn in the figure is nearly 120°. Were the companion C in the direction S the position angle would be 180°; to the right of P it would be 270°; to the right of N it would be between 270° and 360°.

The *distance* is the angle P C, which is expressed in seconds of arc.

We cannot set any well-defined limits to the range of distance. The general rule is that the greater the distance beyond a few seconds the less the interest that attaches to a double star, partly because the observation of distant pairs offers no difficulty, partly because of the increasing possibility that the components have no physical connection and so form only an optically double star. With every increase of telescopic power so many closer and closer pairs are found that we cannot set any limit to the number of stars that may have companions. It is therefore to the closer pairs that the attention of astronomers is more especially directed.

The difficulty of seeing a star as double, or, in the familiar language of observers, of 'separating' the components, arises from two sources, the proximity of the companion to the principal star and the difference in magnitude between the two. It was only in rare cases that Struve could separate a pair of distance half a second. Now Burnham finds pairs whose distance is one-quarter of a second or less; possibly the limit of a tenth of a second is being approached. It goes without saying that a very minute companion to a bright star may, when the distance is small, be lost in the rays of its brighter neighbor. For all these reasons no estimate can be made of the actual number of double stars in the heavens. With every increase of telescopic power and observing skill more difficult pairs are being found without a sign of a limit.

The great interest which attaches to double stars arises from the proof which they afford that the law of gravitation extends to the stars. Struve, by comparing his own observations with each other, or with those of Herschel, found that many of the pairs which he measured were in relative motion; the position angle progressively changing from year to year, and sometimes the distance also. The lesser star was therefore revolving round the greater, or, to speak with more precision, both were revolving round their common center of gravity. To such a pair the name *binary system* is now applied.

There can be no reasonable doubt that the two components of all physically connected double stars revolve round each other. If they did not their mutual gravitation would bring them together and fuse them into a single mass. We are therefore justified in considering all double stars as binary systems, except those which are merely optically double. For reasons already set forth, the pairs of the latter class which are near together must be very few in number; indeed, there are probably none among the close double stars whose brightest component can be seen by the naked eye.

The time of revolution of the binary systems is so long that there are only about fifty cases in which it has yet been determined with any certainty. Leaving out the 'spectroscopic binaries,' to be hereafter described, the shortest period yet found is eleven years. In only a small minority of cases is the period less than a century. In the large majority either no motion at all has yet been detected, or it is so slow as to indicate that the period must be several centuries, perhaps several thousand years.

There is a great difficulty in determining the period with precision until the stars have been observed through nearly a revolution, owing to the number of elements, seven in all, that fix the orbit, and the difficulty of making the measures of position angle and distance with precision. It thus happens that many of the orbits of binary systems which have been computed and published have no sound basis. Two cases in point may be mentioned.

The first magnitude star Castor, or α Geminorum, can be seen to be double with quite a small telescope. The components are in relative motion. Owing to the interesting character of the pair it has been well observed, and a number of orbits have been computed. The periodic times found by the components have a wide range. The fact is, nothing is known of the period except that it is to be measured by centuries, perhaps by thousands of years.

The history of 61 Cygni, a star ever memorable from being the first of which the parallax was determined, is quite similar. Although, since accurate observations have been made on it the components have moved through an apparent angle of 30°, the observations barely suffice to show a very slight curvature in the path which the two bodies are describing round each other. Whether the period is to be measured by centuries or by thousands of years cannot be determined for many years to come.

In his work on the 'Evolution of the Stellar Systems,' Prof. T. J. J. See has investigated the orbits of forty double stars having the shortest periods. There are twenty-eight periods of less than one hundred years

In considering the orbits of binary systems we must distinguish between the actual and the apparent orbit. The former is the orbit as it would appear to an observer looking at it from a direction perpendicular to its plane. This orbit, like that of a planet or comet moving round the sun, is an ellipse, having the principal star in its focus. The point nearest the latter is called the periastron, or pericenter, and corresponds to the perihelion of a planetary orbit. The point most distant from the principal star is the apocenter. It is opposite the pericenter and corresponds to the aphelion of a planetary orbit. The law of motion is here the same as in the case of a body of the solar system; the radius vector, joining the two bodies, sweeps over equal areas in equal times. The apparent orbit is the orbit as it appears to us. It differs from the actual orbit because we see it from a more or less oblique direction. In some cases the plane of the orbit passes near our system. Then to us the orbit will appear as a straight line and the small star will seem to swing from one side of the large one to the other like a pendulum, though the actual orbit may differ little from a circle. In some cases there may be two pericenters and two apocenters to the apparent orbit. This will be the case when a nearly circular orbit is seen at a considerable obliquity.

It is a remarkable and interesting fact that the law of areas holds good in the apparent as in the actual orbit. This is because all parts of the plane of the orbit are seen at the same angle, so that the obliquity of vision diminishes all the equal areas in the same proportion and thus leaves them equal.

The two most interesting binary systems are those of Sirius and Procyon. In the case of each the existence and orbit of the companion were inferred from the motions of the principal star before the companion had been seen. Before the middle of the century it was found that Sirius did not move with the uniform proper motion which characterizes the stars in general; and the inequality of its motion was attributed to the attraction of an unseen satellite. Later Auwers, from an exhaustive investigation of all the observations of the star, placed the inequality beyond doubt and determined the elements of the orbit of the otherwise unknown satellite. Before his final work was published the satellite was discovered by Alvan G. Clark, of Cambridgeport, Mass., son and successor of the first and greatest American maker of telescopes. Additional interest was imparted to the discovery by the fact that it was made in testing a newly constructed telescope, the largest refractor that had been made up to that time. The discoverer was, at the time, unaware of the work of Peters and Auwers demonstrating the existence of the satellite. The latter was, however, in the direction predicted by Auwers, and a few years of observation showed that it was moving in fairly close accordance with the prediction.

The orbit as seen from the earth is very eccentric, the greatest distance of the satellite from the star being about ten seconds, the least less than three seconds. Owing to the brilliant light of Sirius the satellite is quite invisible, even in the most powerful telescopes, when nearest its primary. This was the case in the years 1890-92 and will again be the case about 1940, when another revolution will be completed.

The history of Procyon is remarkably similar. An inequality of its motion was suspected, but not proved, by Peters. Auwers showed from observations that it described an orbit seemingly circular, having a radius of about 1″. There could be no doubt that this motion must be due to the revolution of a satellite, but the latter long evaded discovery, though carefully searched for with the new telescopes which were from time to time brought into use. At length in 1895 Schaeberle found the long-looked-for object with the 36-inch telescope of the Lick Observatory. It was nearly in the direction predicted by Auwers, and a year's observation by Schaeberle, Barnard and others showed that it was revolving in accordance with the theory.

If the conclusion of Auwers that the apparent orbit of the principal star is circular were correct, the distance of the satellite should always be the same. It would then be equally easy to see at all times. The fact that neither Burnham nor Barnard ever succeeded in seeing the

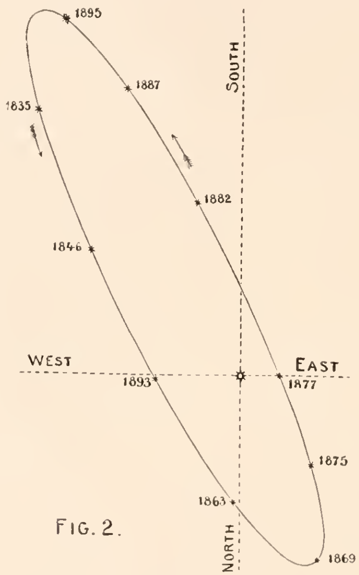

FIG. 2.

FIG. 2. APPARENT ORBIT OF α CENTAURI, BY PROFESSOR SEE.

object with the Lick telescope would then be difficult to account for. The fact is, however, that the periodic motion of Procyon is so small that a considerable eccentricity might exist without being detected by observations. The probability is, therefore, that the apparent orbit is markedly eccentric and that the satellite was nearer the primary during the years 1878-92 than it was when discovered.

One very curious feature, common to both of these systems, is that the mass of each satellite, as compared with that of its primary, is out of all proportion to its brightness. The remarkable conclusions to be drawn from this fact will be discussed in a subsequent chapter.

The system of α Centauri is interesting from the shortness of the period, the brightness of the stars and the fact that it is the nearest star to us so far as known. We reproduce a diagram of the apparent orbit from Dr. See's work. The period of revolution found by Dr. See is eighty-one years. The major axis of the apparent orbit is 32″; of the minor axis 6″.

The pairs of which, so far as known, the period of revolution is the shortest, are these:

				Years.
κ Pegasi;	R. A. =21h. 40m.;	Dec.=	+ 25°11′;	Period=11. 42.
δ Equulei;	" =21h. 10m.;	"	+ 9°37′;	" =11. 45.
ξ Sagittarii;	" =18h. 56m.;	"	— 30° 1′;	" =18. 85.
ρ Argus;	" = 7h. 47m.;	"	— 13°38′;	" =22. 00.
85 Pegasi;	" - 23h. 57m.;	"	+ 26°34′;	" =24. 00.

TRIPLE AND MULTIPLE SYSTEMS.

Systems of three or more stars so close together that there must be a physical connection between them are quite numerous. There is every variety of such systems. Sometimes a small companion of a brighter star is found to be itself double. A curious case of this sort is that of γ Andromedæ. This object was observed and measured by Struve as an ordinary double star, of which the companion was much smaller than the principal star. Some years later Alvan Clark found that this companion was itself a close double star, of which the components, separated by about 1″, were nearly equal. Moreover, it was soon found that these components revolved round each other in a period not yet accurately determined, but probably less than a century. Thus we have a binary system revolving round a central star, as the earth and moon revolve round the sun.

In most triple systems there is no such regularity as this. The magnitudes and relative positions of the components are so varied that no general description is possible. Stars of every degree of brightness are combined in every way. Observations on these systems extend over so short an interval that we have no data for determining the laws of motion that may prevail in any but one or two of the simplest cases. They are, in all probability, too complicated to admit of profitable mathematical investigation. There is, therefore, little more of interest to be said about them.

There is a very notable multiple system known as the Trapezium of Orion, from the fact that it is composed of four stars, one of which is plainly visible to the naked eye, while the others may be well seen in the smallest telescope. There are also two other very faint stars, each of which seems to be a companion of one of the bright ones. This system is situated in the great nebulæ of Orion, to be described in the next chapter, a circumstance which has made it one of the most interesting objects to observers. No motion has yet been certainly detected among the components.

SPECTROSCOPIC BINARY SYSTEMS.

Among the many striking results of recent astronomical research it would be difficult to name any more epoch-making than the discovery that great numbers of the stars have invisible dark bodies revolving round them of a mass comparable with their own. The existence of these revolving bodies is made known not only by their eclipsing the star, but by producing a periodic change in the radial motion of the star. How their motion is determined by means of the spectroscope has been briefly set forth in a former chapter. As a general rule the motion is uniform in the case of each star. We have described in a former chapter the periodic character of the radial motion of Algol, discovered by Vogel. This was followed by the discovery that α Virginis, though not variable, was affected by a similar inequality of the radial motion, having a period of four days and nineteen minutes. The velocity of the star in its apparent orbit is very great, about ninety-one kilometers, or fifty-six English miles, per second. It follows that the radius of the orbit is some three million miles. The mass of the invisible companion must, therefore, be very great.

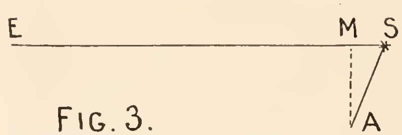

FIG. 3. RADIAL MOTION OF A BINARY SYSTEM.

A new form of binary system was thus brought out which, from the method of discovery, was called the spectroscopic binary system. But there is really no line to be drawn between these and other binary systems. We have seen that as telescopic power is increased, closer and closer binary systems are constantly being formed. We naturally infer that there is no limit to the proximity of the pairs of stars of such systems and that innumerable stars may have satellites, planets or companion stars so close or so faint as to elude our powers of observation. Still, there is as yet a wide gap between the most rapidly moving visible binary system and the slowest spectroscopic one, which, however, will be filled by continued observation.

The actual orbit of such a system cannot be determined with the spectroscope, because only one component of the motion, that in the direction of the earth, can be observed. In the case of an orbit of which the plane was perpendicular to the line of sight from the earth to the star the spectroscope could give us no information as to the motion. The motion to or from the earth would be invariable. To show the result of the orbit being seen obliquely, let E be the earth and A S be the plane of the orbit seen edgewise. Drop the perpendicular A M upon the line of sight. Then, while the star is moving from S to A the spectroscope will measure the motion as if it took place from S to M. Since S M is less than A S, the measured velocity will always be less than the actual velocity, except in the rare case when the plane of the orbit is directed toward the earth. Since the spectroscope can give us no information as to the inclination under which we see the orbit, it follows that the actual orbital velocities of the spectroscopic binaries must remain unknown. We can only say that they cannot be less, but may be greater to any extent than that shown by our measures.

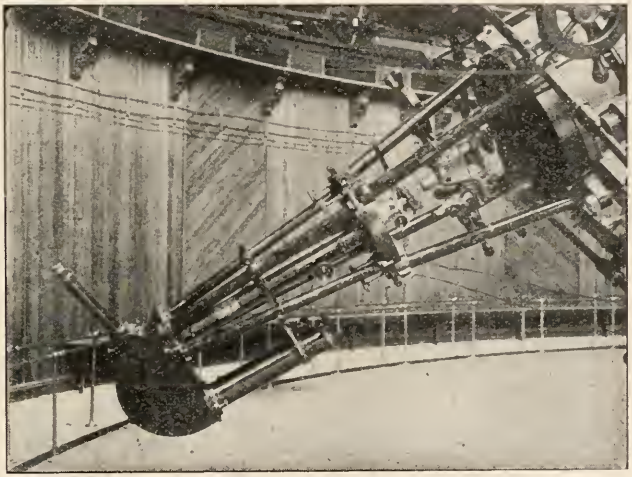

FIG. 4. THE MILLS SPECTROGRAPH OF THE LICK OBSERVATORY.

If the components of a binary system do not differ greatly in brightness, its character may be detected without actually measuring the radial velocities. Since the motion is shown by a displacement of the spectral lines and since, in any binary system, the two components must always move in opposite directions, it follows that the displacements of the spectral lines of the two stars will be in opposite directions. Hence, when one of the stars, say A, is moving toward us, and the other, say D, from us, all the spectral lines will appear double, the lines made by A being displaced toward the blue end of the spectrum and those by B toward the red end. After half a revolution the motion will be reversed and the lines will again be double; only the lines of star A will now be on the red side of the others. Between these two phases will be one in which the radial velocities of the two stars are the same; the lines will then appear single.

The first star of which the binary character was detected in this way is ξ Ursæ Majoris. The discovery was made at the Harvard Observatory. Capella is supposed to be another of the same class.

About 1896 the Lick Observatory was supplied with the best spec-

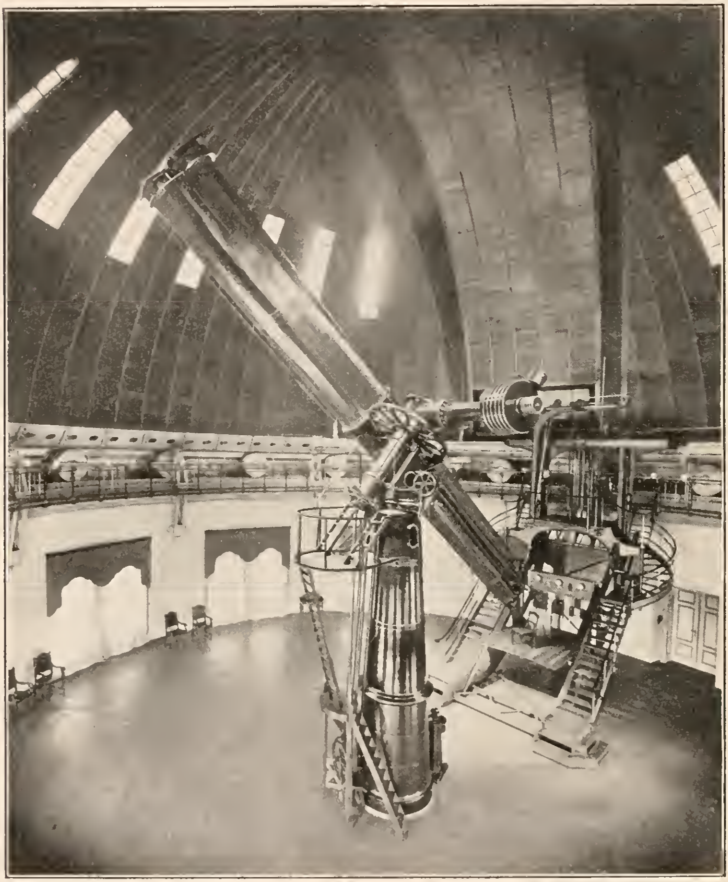

Fig. 5. The New Photographic Refracting Telescope of the Astrophysical Observatory at Potsdam, near Berlin.

trograph that Brashear could produce, the gift of Mr. D. O. Mills. In the hands of Campbell the measurements of radial motion with this instrument have reached an extraordinary degree of precision and brought to light the fact that systems of the kind in question are more numerous than would ever have been suspected. Campbell believes that the radial motion of about one star in every thirteen is affected by an observable inequality. Such an inequality can arise only through the action of a neighborhood of a mass at least comparable with that of our sun. A new field of astronomical research is thus opened, the exploration of which must occupy many years. The ultimate result may be to make as great an addition to our knowledge of the heavens as has been made during the last century by the telescope.

STAR-CLUSTERS.

A star-cluster is a bunch or collection of stars separated from the great mass of stars which stud the heavens. The Pleiades, or 'seven stars,' as they are familiarly called, form a cluster, of which six of the components are easily seen by the naked eye, while five others may be distinguished by a good eye.

About 1780 Michell, of England, raised the question whether, supposing the stars visible to the naked eye to be scattered over the sky at random, there would be a reasonable possibility that those of the Pleiades would all fall within so small a space as that filled by the constellation. His correct conclusion was in the negative. It follows that this cluster does not consist of disconnected stars at various distances, which happen to be nearly in a line from our system, but is really a collection of stars by itself. Besides the stars visible to the naked eye, the Pleiades comprise a great number of telescopic stars, of which about sixty have been catalogued and their relative positions determined. The principal star of the cluster is Alcyone or η Tauri, which is of the third magnitude. The five which come next in the order of brightness are not very unequal, being all between the fourth and fifth magnitudes. Six are near the sixth magnitude. The remainder, so far as catalogued, range from the seventh to the ninth.

In this case there is a fairly good method of distinguishing between a star which belongs to the cluster and one which probably lies beyond it. This test is afforded by the proper motion. All the stars of the group have a common proper motion in the same direction of about seven seconds per century. The first accurate measures made on the relative positions of the stars of the cluster were those of Bessel, about 1830. In recent years several observers have made yet more accurate determinations. The most thorough recent discussion is by Elkin. One result of his work is that there is as yet no certain evidence of any relative motion among the stars of the group. They all move on together with their common motion of seven seconds per century, as if they were a single mass.

A closer cluster, which is plainly visible to the naked eye and looks like a cloudy patch of light, is Præsepe in Cancer. It is very well seen in the early evenings of winter and spring. Although there is nothing in the naked-eye view to suggest a star, it is found on telescopic examination that the individual stars do not fall far below the limit of visibility, several being of about the seventh magnitude.

Another notable cluster of the same general nature is that in Perseus. This constellation is situated in the Milky Way, not far from its region of nearest approach to the pole. In the figure of the constellation the cluster forms the handle of the hero's sword. It may be seen

Fig. 6. The Great Cluster in Hercules, as Photographed with the Crossley Reflector of the Lick Observatory.

in the evening during almost any season except summer. To the naked eye it seems more diffused and star-like than Præsepe; in fact, it has two distinct centers of condensation, so that it may be considered as a double cluster.

The two clusters last described may be resolved into stars with the smallest telescopes. But in the case of most of these objects the individual stars are so faint that the most powerful instruments scarcely suffice to bring them out. One of the most remarkable clusters in the northern heavens is that of Hercules. To the naked eye it is but a faint and insignificant patch which would be noticed only by a careful observer. But in a large telescope it is seen to be one of the most interesting objects in the heavens. Near the border the individual stars can be readily distinguished. But they grow continually thicker toward the center, where, even in a telescope of two feet aperture, the

FIG. 7. THE CLUSTER ω CENTAURI, PHOTOGRAPHED BY GILL AT THE CAPE OBSERVATORY.

observer can see only a patch of light, which is, however, as he scans it, suggestive of the countless stars that must there be collected. By the aid of photography, Professor Pickering has nearly succeeded in the complete resolution of this cluster.

In many cases the central portions of these objects are so condensed that they cannot be visually resolved into their separate stars, even with the most powerful telescopes. A closer approach to complete resolution has been made by photography. We present copies of several photographs which have been made by Pickering, Gill and others.

The cluster which, according to Pickering, may be called the finest in the sky, is ω Centauri. It lies just within the border of the Milky Way, in right ascension, 13h. 20.8m., and declination —46° 47′. There are no bright stars near. To the naked eye it appears as a hazy star of the fourth magnitude. Its actual extreme diameter is about 40′. The brightest individual stars within this region are between the eighth and ninth magnitudes. Over six thousand have been counted on one of the photographs and the whole number is much greater.

The most remarkable and suggestive feature of the principal clusters is the number of variable stars which they contain. This feature has been brought out by the photographs taken at the Harvard Observatory and at its branch station in Arequipa. The count of stars and the detection of the variables was very largely made by Professor Bailey, who, for several years past, has been in charge of the Arequipa station. The proportion of variables is very different in different clusters. In the double cluster, 869-884, only one has been found among a thousand stars. The richest in variables is Messier, 3, in which one variable has been detected among every seven stars. It might be suspected that the closer and more condensed the cluster the greater the proportion of variables. This, however, does not hold universally true. In the great cluster of Hercules only two variables are found among a thousand stars.

Very remarkable, at least in the case of ω Centauri, is the shortness of the period of the variables. Out of one hundred and twenty-five found, ninety-eight have periods less than twenty-four hours. On the subject of the law of variation in these cases, Pickering says:

"The light curves of the ninety-eight stars whose periods are less than twenty-four hours may be divided into four classes. The first is well represented by No. 74. The period of this star is 12h. 4m. 3s. and the range in brightness two magnitudes. Probably the change in brightness is continuous. The increase of light is very rapid, occupying not more than one-fifth of the whole period. In some cases, possibly in this star, the light remains constant for a short time at minimum. In most cases, however, the change in brightness seems to be continuous. The simple type shown by No. 74 is more prevalent in this cluster than any other. There are, nevertheless, several stars, as No. 7, where there is a more or less well marked secondary maximum. The period of this star is 2d. 11h. 51m. and the range in brightness one and a half magnitudes. The light curve is similar to that of well-known short-period variables, as δ Cephei and η Aquilæ. Another class may be represented by No. 126, in which the range is less than a magnitude and the times of increase and decrease are about equal. The period is 8h. 12m. 3s. No. 24 may perhaps be referred to as a fourth type. The range is about seven-tenths of a magnitude and the period is 11h. 5m. 7s. Apparently about 65 per cent. of the whole period is occupied by the increase of the light. This very slow rate of increase is especially striking from the fact that in many cases in this cluster the increase is extremely rapid, probably not more than ten per cent. of the whole period. In one case, No. 45, having a period of 14h. 8m., the rise from minimum to maximum, a change of two magnitudes takes place in about one hour, and in certain cases, chiefly owing to the necessary duration of a photographic exposure, there is no proof at present that the rise is not much more rapid.

"The marked regularity in the period of these stars is worthy of attention. Several have been studied during more than a thousand, and one during more than five thousand, periods without irregularities manifesting themselves."

It may be added that this regularity of the period, taken in connection with the case of η Aquilæ, already mentioned, affords a strong presumption that the variations in the light of these stars are in some way connected with the revolution of bodies around them, or of one star round another. Yet it is certain that the types are not of the Algol class and that the changes are not due merely to one star eclipsing another. That such condensed clusters should have a great number of close binary systems is natural, almost unavoidable, we might suppose. It will hereafter be shown to be probable that among the stars in general single stars are the exception rather than the rule. If such be the case, the rule should hold yet more strongly among the stars of a condensed cluster.

Perhaps the most important problem connected with clusters is the mutual gravitation of their component stars. Where thousands of stars are condensed into a space so small, what prevents them from all falling together into one confused mass? Are they really doing so, and will they ultimately form a single body? These are questions which can be satisfactorily answered only by centuries of observation; they must, therefore, be left to the astronomers of the future.

NEBULÆ.

The first nebula, properly so-called, to be detected by an astronomical observer was that of Orion. Huyghens, in his 'Systema Saturnium,' gives a rude drawing of this object, with the following description:

"There is one phenomenon among the fixed stars worthy of mention which, so far as I know, has hitherto been noticed by no one, and, indeed, cannot be well observed except with large telescopes. In the sword of Orion are three stars quite close together. In 1656, as I chanced to be viewing the middle one of these with the telescope, instead of a single star, twelve showed themselves (a not uncommon circumstance). Three of these almost touched each other, and, with four others, shone through a nebula, so that the space around them seemed far brighter than the rest of the heavens, which was entirely clear, and appeared quite black, the effect being that of an opening in the sky, through which a brighter region was visible."

For a century after Huyghens made this observation it does not appear that these objects received special attention from astronomers. The first to observe them systematically on a large scale was Sir Wm. Herschel, whose vast researches naturally embraced them in their scope. His telescopes, large though they were, were not of good defining power and, in consequence, Herschel found it impossible to draw a certain line in all cases between nebulæ and clusters. At his time it was indeed a question whether all these bodies might not be clusters. This

Fig. 8. The Great Nebula of Orion, as Photographed by A. A. Common with a Four-foot Reflector.

question Herschel, with his usual sagacity, correctly answered in the negative. Up to the time of the spectroscope, all that astronomers could do with nebulæ was to discover, catalogue and describe them.

Several catalogues of these objects have been published. The one long established as a standard is the General Catalogue of Nebulæ and Clusters, by Sir John Herschel. With each object Herschel gave a condensed description. Recently Herschel's catalogue has been superseded by the general catalogue of Dreyer, based upon it.

Some of the more conspicuous of these objects are worthy of being individually mentioned. At the head of all must be placed the great nebula of Orion. This is plainly visible to the naked eye and can be seen without difficulty whenever the constellation is visible. Note the three bright stars lying nearly in an east and west line and forming the belt of the warrior. South of these will be seen three fainter ones, hanging below the belt, as it were, and forming the sword. To a keen eye, which sharply defines the stars, this middle star will appear hazy. It is the nebula in question. Its character will be strongly brought out by the smallest telescope, even by an opera-glass. Drawings of it have been made by numerous astronomers, the comparison of

Fig. 9. The Great Nebula of Andromeda Photographed by Roberts.

which has given rise to the question whether the object is variable. It cannot be said that this question is yet decided; but the best opinion would probably be in the negative. In recent times the improvements of the photographic process have led to the representation of the object by photography. A photograph made by Mr. A. A. Common, F.R.S., with a reflecting telescope, gives so excellent an impression of the object that by his consent we reproduce it.

The most remarkable feature connected with the nebula of Orion is the so-called Trapezium, already described. That these four stars form a system by themselves cannot be doubted. The darkness of the nebula immediately around them suggests that they were formed at the expense of the nebulous mass.

Great interest has recently been excited in the spiral form of certain nebulæ The great spiral nebula M. 51 in Canes Venatici has long been known. We reproduce a photograph of this object and another. It is found by recent studies at the Lick Observatory that a spiral form can be detected in a great number of these objects by careful examination.

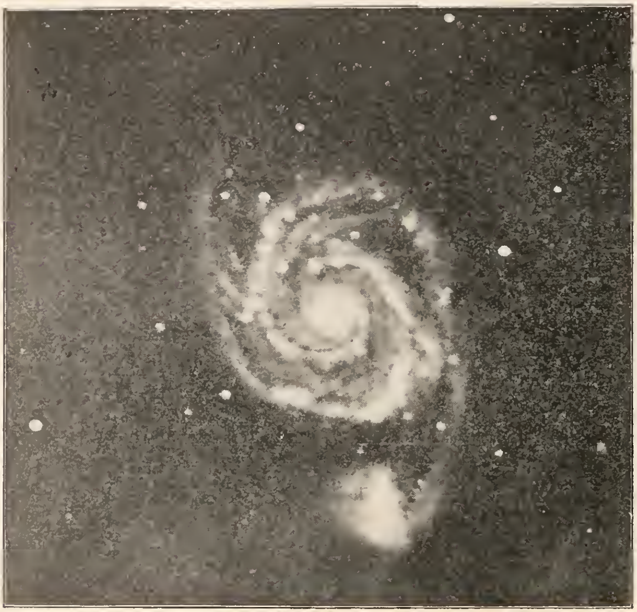

Fig. 10. The Great Spiral Nebula M. 51, as Photographed with the Crossley Reflector at the Lick Observatory.

Another striking feature of numerous nebulæ is their varied and fantastic forms, of which we give a number of examples. The 'Triphid nebula' is a noted one in this respect.

The great nebula of Andromeda is second only to that of Orion. It also is plainly visible to the naked eye and can be more readily recognized as a nebula than can the other. It has frequently been mistaken for a comet. Seen through a telescope of high power, its aspect is singular, as if a concealed light were seen shining through horn or semi-transparent glass. It is somewhat elliptical in form, as will be seen from a photograph by Sir William Roberts, F.R.S., which we reproduce (page 19).

Another nebula which, though not conspicuous to the naked eye, has attracted much attention from astronomers, is known, from the figure of one of its branches as the Omega nebula. Sir John Herschel, who first described this object in detail, says of it: "The figure is nearly that of the Greek capital Omega, somewhat distorted and very unequally bright." From one base of the letter extends out to the east a long branch with a hook at the end, which, in most of the drawings, is more conspicuous than the portion included in the Omega. The

FIG. 11. THE GREAT SPIRAL NEBULA M. 33, PHOTOGRAPHED WITH THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY.

drawings, however, vary so much that the question has been raised whether changes have not taken place in the object. As in other cases, this question is one which it is not yet possible to decide. The appearance of such objects varies so much with the aperture of the telescope and the conditions of vision that it is not easy to decide whether the apparent change may not be due to these causes. It is curious that in a recent photograph the Omega element of it, if I may use the term, is far less conspicuous than in the older drawings, and is, in fact, scarcely recognizable.

Among the most curious of the nebulæ are the annular ones, which, as the term implies, have the form of a ring. It should be remarked that in such cases the interior of the ring is not generally entirely black, but is filled with nebulous light. We may, therefore, define these objects as nebulæ which are brighter round their circumference than in the center. The most striking of the annular nebulæ is that of Lyra. It may easily be found from being situated about half-way be-

FIG. 12. THE TRIPHID NEBULA, PHOTOGRAPHED AT THE LICK OBSERVATORY.

tween the stars Beta and Gamma. Although it is visible in a medium telescope, it requires a powerful one to bring out its peculiar features in a striking way. Recently it has been photographed by Keeler with the Crossley reflector of the Lick Observatory, who found that the best general impression was made with an exposure of only ten minutes.

The ring, as shown by Keeler's photographs, has a quite complicated structure. It seems to be made up of several narrower bright rings, interlacing somewhat irregularly, the spaces between them being filled with fainter nebulosity. One of these rings forms the outer boundary of the preceding end of the main ring. Sweeping around to the north end of the minor axis, it becomes very bright, perhaps by superposition on the broader main ring of the nebula at this place. It crosses this ring obliquely, forming the brightest part of the whole

FIG. 13. THE TRIPHID NEBULA AND ITS SURROUNDINGS, AS PHOTOGRAPHED BY BARNARD.

nebula, and then forms the inner boundary of the main ellipse toward its following end. The remaining part of the ring is not so easily traced, as several other rings interlace on the south end of the ellipse.

The central star of this nebula has excited some interest. Its light seems to have a special actinic power, as the star is more conspicuous on the photographs than to the eye.

There are several other annular nebulæ which are fainter than than of Lyra. The one best visible in our latitudes is known as H IV. 13, or 4,565 of Dreyer's catalogue. It is situated in the constellation Cygnus which adjoins Lyra. Both Herschel and Lord Rosse have made drawings of it. It was photographed by Keeler with the

Fig. 14. Nebulous Mass in Cygnus, including H. V. 14 and H. 2093. Photographed at the Lick Observatory.

Crossley reflector on the nights of August 9 and 10, 1899, with exposures of one and two hours, respectively. Keeler states that the nebula, as shown by these photographs, "is an elliptical, nearly circular ring, not quite regular in outline, pretty sharply defined at the outer edge." The outside dimensions are:

Major axis	42″.5
Minor axis	40 .5
Position angle of major axis	32°

The nebula has a nucleus with a star exactly in the center. This is very conspicuous on a photograph, but barely if at all visible with a 36-inch reflector.

Another curious class of nebulæ are designated as *planetary,* on account of their form. These consist of minute, round disks of light, having somewhat the appearance of a planet. The appellation was suggested by this appearance. These objects are for the most part faint and difficult.

It is impossible to estimate the number of nebulæ in the heavens. New ones have been from time to time discovered, located and described by many observers during the last thirty years. Among these Lewis Swift is worthy of special mention. On photographing the sky near the galactic pole with the Crossley reflector, Keeler found no less than seven of these objects in a space of about one-half a square degree. He therefore estimates the whole number in the heavens capable of being photographed at several hundred thousand. It may be assumed that only a moderate fraction of these are visible to the eye, even aided by the largest telescopes.

Among the most singular of these objects are large diffused nebulæ, sometimes extending through a region of several degrees. A number of these were discovered by Herschel. Barnard, W. H. Pickering and others have photographed these for us. One of the most remarkable of them winds around in the constellation Orion in such a way that at first sight one might be disposed to inquire whether the impression on the photographic plate might not have been the result of some defect in the apparatus or some reflection of the light of the neighboring stars, which is so apt to occur in these delicate photographic operations. But its existence happens to be completely confirmed by independent testimony. It was first detected by W. H. Pickering and afterwards independently by Barnard.

A curious fact connected with the distribution of nebulæ over the sky is that it is in a certain sense the reverse of that of the stars. The latter are, as we shall hereafter show in detail, vastly more numerous in the regions near the Milky Way and fewer in number near the poles of that belt. But the reverse is the case with the nebulæ proper. They are least numerous in the Milky Way and increase in number as we go from it in either direction. Precisely what this signifies one would not at the present time be able to say. Perhaps the most obvious suggestion would be that in these two opposite nebulous regions the nebulæ have not yet condensed into stars. This, however, would be a purely speculative explanation.

On the other hand, star-clusters are more numerous in the galactic region. This, however, is little more than saying that in the regions where the stars are so much more numerous than elsewhere many of them naturally tend to collect in clusters. It is, however, a curious fact that, so far as yet been noticed, the large, diffused nebulæ which we have mentioned are more numerous in or near the Milky Way. If this tendency is established it will mark a curious distinction between them and the smaller nebulæ.

The most interesting question connected with these objects is that of their physical constitution. When, about 1866, the spectroscope was applied to astronomical investigation by Huggins and Secchi, these two observers found independently that the light of the great nebula of Orion formed a spectrum of bright lines, thus showing the object to be gaseous. This was soon found to be true of the nebulæ generally. There is, however, a very curious exception in the case of the great nebula of Andromedæ. This object gives a more or less continuous spectrum. Why this is it is difficult to say.

Beyond the general fact that the light of a nebula does not come from solid matter, but from matter of a gaseous or other attenuated form, we have no certain knowledge of the physical constitution of these bodies. Certain features of their constitution can, however, be established with a fair approach to accuracy. Not only the spectroscopic evidence of bright lines, but the aspect of the objects themselves, show that they are transparent through and through. This is remarkable when taken in connection with their inconceivable size. Leaving out the large diffused nebulæ which we have mentioned, these objects are frequently several minutes in diameter. Of their distance we know nothing, except that they are probably situated in the distant stellar regions. Their parallax can be but a small fraction of a second. We shall probably err greatly in excess if we assume that it varies between one-hundredth and one-tenth of a second. To assign this parallax is the same thing as saying that at the distance of the nebulæ the dimensions of the earth's orbit would show a diameter which might range between one-fiftieth and one-fifth of a second, while that of Neptune would be more or less than one second. Great numbers of these objects are, therefore, thousands of times the dimensions of the earth's orbit, and probably most of them are thousands of times the dimensions of the whole solar system. That they should be completely transparent through such enormous dimensions shows their extreme tenuity. Were our solar system placed in the midst of one of them, it is probable that we should not be able to find any evidence of its existence.

A form of matter so different from any that can be found or produced on the surface of the earth can hardly be explained by our ordinary views of matter. A theory has, however, been propounded by Sir Norman Lockyer, so ingenious as to be worthy at least of mention. It is that these objects are vast collections of meteorites in rapid motion relatively to each other, which come into constant collision. Their velocity is such that at each collision heat and light are produced. In the language of our progenitors, who in the absence of matches used flint and steel, they 'strike fire' against each other. The idea of such a process originated with Prof. P. G. Tait, in an attempt to explain the tail of a comet, but it was elaborated and developed by Mr. Lockyer in his work on the 'Meteoritic Theory.'

The objections to this theory seem insuperable. A velocity so great, at such a distance from the center of the nebulæ, would be incompatible with the extreme tenuity of these objects. Every time that two meteors came into collision they would lose velocity, and, therefore, if the mass was sufficient to hold them from flying through space, would rapidly fall toward a common center. The amount of light produced by the collision of two such objects is only a minute fraction of the energy lost. The meteors which fall on the earth are mostly of iron, and, were the theory true, numerous lines of iron should be most conspicuous in the spectrum. But the fact is that in the great number of these objects there is but a single bright line, which does not seem to correspond to the line of any known substance. The supposed matter which produces it has, therefore, been called *nebulum*.

RAPID BATTLESHIP BUILDING.

BY WALDON FAWCETT.

A VARIETY of influences, aside from the occasional exigencies of actual war conditions, have, during the past few years, combined to force upon naval architects and shipbuilders a conviction of the need for more expeditious work in the construction of war vessels, and especially of battleships. As the modern fighting vessel has grown in weight and complexity of design, the interval necessitated for its construction has very naturally been lengthened. That this condition of affairs would sooner or later induce a sentiment of dissatisfaction was the more certain from the fact that throughout the world many government officers have to do with the construction and operation of naval flotilla who are inadequately informed regarding technical details.

The feeling of impatience on account of the time occupied in building a battleship has, of course, disclosed itself first of all to the shipbuilder, and the practical men of the industry have already set themselves to remedy the conditions in so far as it is possible. How much has been accomplished in a comparatively brief space of time is eloquently attested by the records for time economy in battleship construction which have been made during the past two years, particularly in British and American yards.

Although the shipbuilder has been able to accomplish much by the introduction of improved tools and machinery, with the attendant speedier methods of handling material, he is becoming more and more an advocate of the simplification of the battleship. His contentions are receiving the indorsement of many naval constructors of ability and experience, who are impressed by the advisability of reducing the cost of single ships, on the theory of the old adage against placing all the eggs in one basket. Protests have been directed particularly against the complication and multiplying diversity of function sought by mechanical contrivances, but of late there have been on the part of naval architects many expressions of opinion to the effect that the auxiliaries are not the only features of a battleship which might be modified with profit.

As was stated above, it is the shipbuilder who has first been brought to a realization of the fact that he must keep pace with modern progress by constant reductions of the time necessary to turn out a complete armor-clad. Thus the William Cramp & Sons Ship and Engine Building Company, of Philadelphia, has recently secured a contract from the

Russian government for the construction of a battleship and a cruiser, largely from the fact that they were able to guarantee delivery within thirty-three months, whereas the French builders who made tenders for the contract could not promise the completion of the vessels much under five years.

Some of the most remarkable records in the reduction of the time between the laying of a keel and the launching of a vessel have been made in British shipyards. Notable in this respect was the battleship 'Bulwark,' which was launched at the Davenport dockyard on October 18, 1899. This vessel was laid down on March 20, 1899, and had thus been under construction less than seven months. During that time

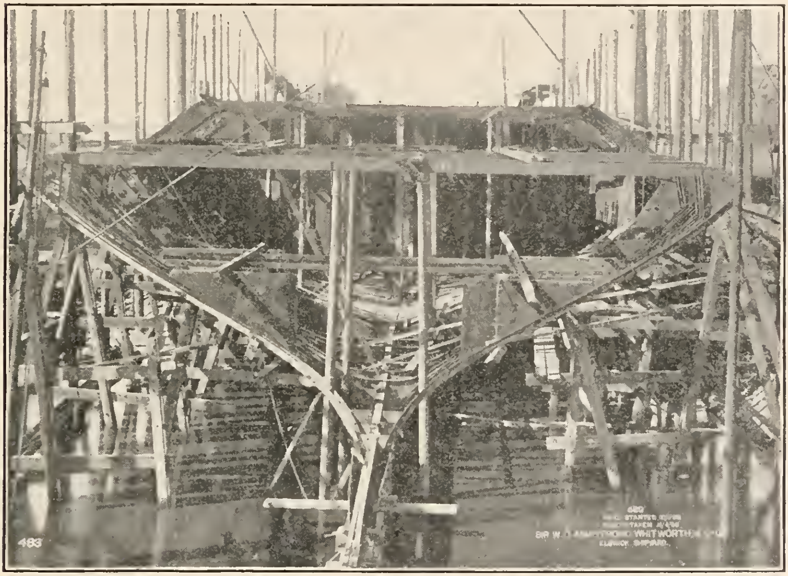

FIG. 1. THE BATTLESHIP 'HATSUSE' THREE MONTHS AFTER THE KEEL HAD BEEN LAID.

5,450 tons of material had been built into her, and there is nothing to controvert the assertions of the dockyard staff that the work created records in both the time she had been under construction and the weight attained for the period. In order to convey a better idea of the work accomplished it may be noted in passing that the 'Bulwark' is 400 feet in length between perpendiculars, 75 feet beam, 27 feet draught and 15,000 tons displacement.

The British builders have for some time past made rapidity of construction a subject of study, and their more recent achievements have been attained as the culmination of a series of performances only slightly less creditable. Thus, but nine months and nine days intervened between the dates of laying the keel and launching the battleship 'Canopas', a vessel of 12,590 tons displacement, and even then the work was delayed by a strike. The cruiser 'Diadem', a sheathed vessel of 11,000 tons displacement and 16,500 horse-power, was built by the Fairfield Shipbuilding and Engineering Company, Limited, of Govan, Scotland, in 214 working days, and moreover, the vessel was fitted, before launching, with all her armor casements.

The battleship 'Majestic' of the British navy was launched complete and ready to go into commission, and this vessel went into the water just twenty-two months from the date of the laying of the keel. An even two years was required for the completion of the 'Magnificent,'

FIG. 2. THE BATTLESHIP 'HATSUSE' AFTER ABOUT FOUR AND A HALF MONTHS, SHOWING THE PROTECTIVE DECK.

another battleship of the same class. A record almost equal to that of the 'Bulwark' was that of the battleship 'Prince George', the displacement of which is 14,900 tons. This vessel was built and launched in eleven months. For purposes of comparison, the fact may be cited that Laird Brothers, of Birkenhead, built the torpedo-boat destroyer 'Sparrow Hawk', a vessel which attained a speed in the neighborhood of thirty knots on trial, in the space of one hundred days.

Taking into consideration, however, all influencing conditions, the records made since the beginning of 1899 indicate a distinct advance on the part of the builders. The Thames Iron Works, Shipbuilding and Engineering Company, of Blackwall, made an excellent showing with the British battleship 'Venerable', which was christened early in November, 1899. This vessel was laid down in the first week of January, 1899, and her construction proceeded at such a rate that it was possible to place her in the water in exactly ten months from the day on which her first keel plate was laid. In this case the builders were impelled not so much by a desire to establish a record, as to provide a slip for the commencement of work on another naval contract.

It is a singular coincidence that the most favorable records established thus far in the annals of naval ship-building should have been made by three sister vessels, the trio being among the largest battle-

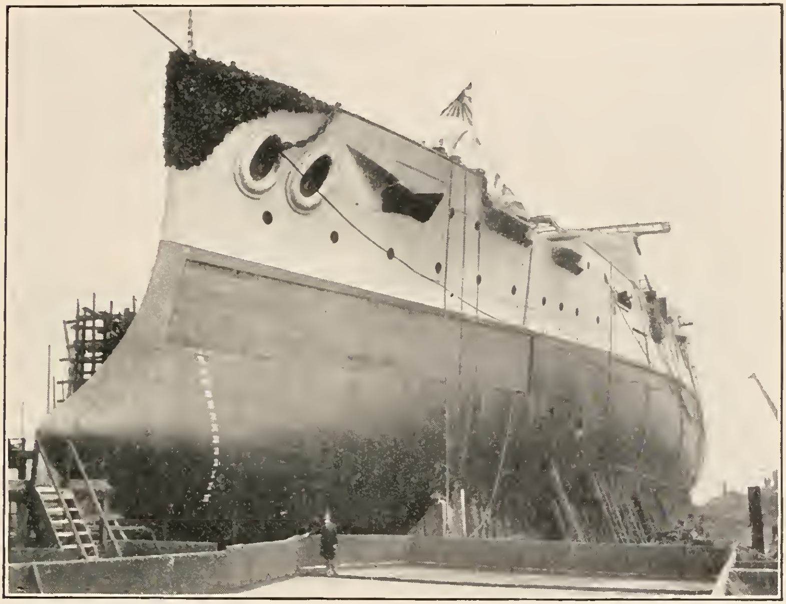

FIG. 3. THE BATTLESHIP 'HATSUSE' READY FOR LAUNCHING.

ships in the world. The performances of the 'Bulwark' and 'Venerable' have already been noted. That of the 'London' is scarcely less creditable. This vessel was built at the Portsmouth dockyard and was laid down on December 8, 1898. She was thus under construction a little more than nine months, and during that time over five thousand tons of material were built into her.

That all the energies of the builders of the United Kingdom are not exerted in behalf of their own nation is attested by the showing made by the Thames Iron Works, Shipbuilding and Engineering Company in the case of the battleship 'Shikishima', completed during the early part of 1899 for the Japanese government. The first plate of this vessel was laid down on May 1, 1897, and although the engineers' strike resulted in a delay of more than six months in the delivery of armor, armament and engines, the trials of the vessel were completed to the satisfaction of all parties concerned, and the 'Shikishima' was turned over to her owners in less than twenty-nine months from the date above given for the commencement of the work. In its way this achievement also constitutes a record which has had no parallel, and certainly the fact that despite detrimental circumstances a vessel of 15,000 tons displacement and 19 knots speed can be built, equipped, armored, engined and

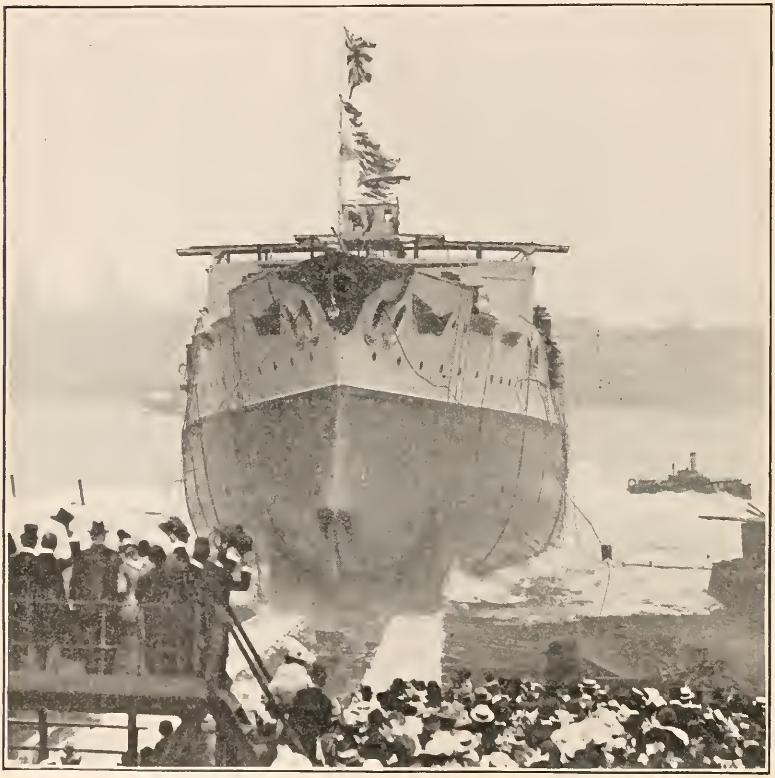

FIG. 4. THE LAUNCHING OF THE BATTLESHIP 'HATSUSE,' JUNE 27, 1899.

tested under actual service conditions, all in little more than two years' time, speaks well for modern engineering methods.

The loss of the Russian contracts previously referred to—and other circumstances—have seemingly made some impression on French shipbuilders, and a shortening of the time consumed in some of the principal yards has already been made. For instance, it is announced that should nothing unforeseen intervene, the first-class battleship 'Suffren', which was launched at Brest on July 25, 1899, will be completed by July, 1901. Should this promise be fulfilled the time consumed in the construction of the vessel will be little more than thirty-one months, which is considerably less than for any French battleship previously constructed. It must also be remembered that the 'Suffren' is the largest battleship yet designed for the French navy, her displacement being 12,728 tons. In some respects, the 'Suffren' outranks the British vessel, as but six months and twenty days elapsed between the laying down of the keel and the launching.

Neither Germany nor the United States can show records to compare with those of the British builders, despite the expeditious delivery of merchant vessels which has been made by firms in both countries. The United States has now several plants capable of building and launching a battleship in an interval very nearly as brief as the best of those above recorded, but American builders have been so retarded ever since bringing their plants to the present stage of efficiency by difficulty in securing prompt delivery of armor and other material that the possibility of making records has been precluded, and, indeed, it is not strange if under the circumstances there has been small ambition to make the endeavor.

The photographs herewith reproduced as illustrative of the building of a battleship represent the 'Hatsuse', which was launched during the summer of 1899 at the Elswick shipyard of Sir W. G. Armstrong, Whitworth & Co., of Newcastle-on-Tyne, England, the builders of the cruisers 'Albany' and 'New Orleans', the only foreign-built war vessels of any considerable size in the American navy. The 'Hatsuse' is a battleship of the largest size, and represents in every respect the most modern practice. She is 400 feet in length, 76½ feet beam, 27 feet draught of water and 15,000 tons displacement. Her engines are capable of developing 14,500 indicated horse-power.

The first photograph was taken about three months after the keel had been laid. It shows the framing of the extreme end of the vessel, with three tires of beams in view.

The second picture in the series, taken about six weeks later, looking aft from about amidships, shows the after barbette about half constructed, while the protective deck is practically completed. The third view represents the vessel ready for launching, and the fourth and last depicts the launch on June 27, 1899. In conclusion, it may be noted that the 'Hatsuse', the launching weight of which was fully 8,000 tons, went down the ways several minutes before the appointed time.

ADDRESS OF THE PRESIDENT BEFORE THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BY SIR WILLIAM TURNER, F. R. S.

II.

FUNCTION OF CELLS.

IT has already been stated that, when new cells arise within pre-existing cells, division of the nucleus is associated with cleavage of the cell plasm, so that it participates in the process of new cell-formation. Undoubtedly, however, its rôle is not limited to this function. It also plays an important part in secretion, nutrition and the special functions discharged by the cells in the tissues and organs of which they form morphological elements.

Between 1838 and 1842 observations were made which showed that cells were constituent parts of secreting glands and mucous membranes (Schwann, Henle). In 1842 John Goodsir communicated to the Royal Society of Edinburgh a memoir on secreting structures, in which he established the principle that cells are the ultimate secreting agents; he recognized in the cells of the liver, kidney and other organs the characteristic secretion of each gland. The secretion was, he said, situated between the nucleus and the cell wall. At first he thought that, as the nucleus was the reproductive organ of the cell, the secretion was formed in the interior of the cell by the agency of the cell wall; but three years later he regarded it as a product of the nucleus. The study of the process of spermatogenesis by his brother, Harry Goodsir, in which the head of the spermatozoon was found to correspond with the nucleus of the cell in which the spermatozoon arose, gave support to the view that the nucleus played an important part in the genesis of the characteristic product of the gland cell.

The physiological activity of the cell plasm and its complex chemical constitution soon after began to be recognized. Some years before Max Schultze had published his memoirs on the characters of protoplasm, Brücke had shown that the well-known changes in tint in the skin of the chameleon were due to pigment granules situated in cells in the skin which were sometimes diffused throughout the cells, at others concentrated in the center. Similar observations on the skin of the frog were made in 1854 by von Wittich and Harless. The movements were regarded as due to contraction of the cell wall on its contents. In a most interesting paper on the pigmentary system in the frog, published in 1858, Lord Lister demonstrated that the pigment granules moved in the cell plasma, by forces resident within the cell itself, acting under the influence of an external stimulant, and not by a contractility of the wall. Under some conditions the pigment was attracted to the center of the cell, when the skin became pale; under other conditions the pigment was diffused throughout the body and the branches of the cell, and gave to the skin a dark color. It was also experimentally shown that a potent influence over these movements was exercised by the nervous system.

The study of the cells of glands engaged in secretion, even when the secretion is colorless, and the comparison of their appearance when secretion is going on with that seen when the cells are at rest, have shown that the cell plasm is much more granular and opaque, and contains larger particles during activity than when the cell is passive; the body of the cell swells out from an increase in the contents of its plasm, and chemical changes accompany the act of secretion. Ample evidence, therefore, is at hand to support the position taken by John Goodsir, nearly sixty years ago, that secretions are formed within the cells, and lie in that part of the cell which we now say consists of the cell plasm; that each secreting cell is endowed with its own peculiar property, according to the organ in which it is situated, so that bile is formed by the cells in the liver, milk by those in the mamma, and so on.

Intimately associated with the process of secretion is that of nutrition. As the cell plasm lies at the periphery of a cell, and as it is, alike both in secretion and nutrition, brought into closest relation with the surrounding medium, from which the pabulum is derived, it is necessarily associated with nutritive activity. Its position enables it to absorb nutritive material directly from without, and in the process of growth it increases in amount by interstitial changes and additions throughout its substance, and not by mere accretions on its surface.

Hitherto I have spoken of a cell as a unit, independent of its neighbors as regards its nutrition and the other functions which it has to discharge. The question has, however, been discussed, whether in a tissue composed of cells closely packed together cell plasm may not give origin to processes or threads which are in contact or continuous with corresponding processes of adjoining cells, and that cells may therefore, to some extent, lose their individuality in the colony of which they are members. Appearances were recognized between 1863 and 1870 by Schrön and others in the deeper cells of the epidermis and of some mucous membranes which gave sanction to this view, and it seems possible, through contact or continuity of threads connecting a cell with its neighbors, that cells may exercise a direct influence on each other.

Nägeli, the botanist, as the foundation of a mechanico-physiological theory of descent, considered that in plants a network of cell plasm, named by him idio-plasm, extended throughout the whole of the plant, forming its specific molecular constitution, and that growth and activity were regulated by its conditions of tension and movements (1884).

The study of the structure of plants, with special reference to the presence of an intercellular network, has for some years been pursued by Walter Gardiner (1882-97), who has demonstrated threads of cell plasm protruding through the walls of vegetable cells and continuous with similar threads from adjoining cells. Structurally, therefore, a plant may be conceived to be built up of a nucleated cytoplasmic network, each nucleus with the branching cell plasm surrounding it being a center of activity. On this view a cell would retain to some extent its individuality, though, as Gardiner contends, the connecting threads would be the medium for the conduction of impulses and of food from a cell to those which lie around it. For the plant cell, therefore, as has long been accepted in the animal cell, the wall is reduced to a secondary position, and the active constituent is the nucleated cell plasm. It is not unlikely that the absence of a controlling nervous system in plants requires the plasm of adjoining cells to be brought into more immediate contact and continuity than is the case with the generality of animal cells, so as to provide a mechanism for harmonizing the nutritive and other functional processes in the different areas in the body of the plant. In this particular, it is of interest to note that the epithelial tissues in animals, where somewhat similar connecting arrangements occur, are only indirectly associated with the nervous and vascular systems, so that, as in plants, the cells may require, for nutritive and other purposes, to act and react directly on each other.

NERVE CELLS.

Of recent years great attention has been paid to the intimate structure of nerve cells, and to the appearance which they present when in the exercise of their functional activity. A nerve cell is not a secreting cell—that is, it does not derive from the blood or surrounding fluid a pabulum which it elaborates into a visible, palpable secretion characteristic of the organ of which the cell is a constituent element, to be in due course discharged into a duct which conveys the secretion out of the gland. Nerve cells, through the metabolic changes which take place in them, in connection with their nutrition, are associated with the production of the form of energy specially exhibited by animals which possess a nervous system, termed nerve energy. It has long been known that every nerve cell has a body in which a relatively large nucleus is situated. A most important discovery was the recognition that the body of every nerve cell had one or more processes growing out from it. More recently it has been proved, chiefly through the researches of Schultze, His, Golgi and Ramon y Cajal, that at least one of the processes, the axon of the nerve cell, is continued into the axial cylinder of a nerve fiber, and that in the multipolar nerve cell the other processes, or dendrites, branch and ramify for some distance away from the body. A nerve fiber is, therefore, an essential part of the cell with which it is continuous, and the cell, its processes, the nerve fiber and the collaterals which arise from the nerve fiber collectively form a neuron or structural nerve unit (Waldeyer). The nucleated body of the nerve cell is the physiological center of the unit.

The cell plasm occupies both the body of the nerve cell and its processes. The intimate structure of the plasm has, by improved methods of observation introduced during the last eight years by Nissl, and conducted on similar lines by other investigators, become more definitely understood. It has been ascertained that it possesses two distinct characters which imply different structures. One of these stains deeply on the addition of certain dyes, and is named chromophile or chromatic substance; the other, which does not possess a similar property, is the achromatic network. The chromophile is found in the cell body and the dendritic processes, but not in the axon. It occurs in the form of granular particles, which may be scattered throughout the plasm, or aggregated into little heaps which are elongated or fusiform in shape and appear as distinct colored particles or masses. The achromatic network is found in the cell body and the dendrites, and is continued also in the axon, where it forms the axial cylinder of the nerve fiber. It consists apparently of delicate threads or fibrillæ, in the meshes of which a homogeneous material, such as is found in cell plasm generally, is contained. In the nerve cells, as in other cells, the plasm is without doubt concerned in the process of cell nutrition. The achromatic fibrillæ exercise an important influence on the axon or nerve fiber with which they are continuous, and probably they conduct the nerve impulses which manifest themselves in the form of nerve energy. The dendritic processes of a multipolar nerve cell ramify in close relation with similar processes branching from other cells in the same group. The collaterals and the free end of the axon fiber process branch and ramify in association with the body of a nerve cell or of its dendrites. We cannot say that these parts are directly continuous with each other to form an intercellular network, but they are apparently in apposition, and through contact exercise influence one on the other in the transmission of nerve impulses.

There is evidence to show that in the nerve cell the nucleus, as well as the cell plasm, is an effective agent in nutrition. When the cell is functionally active, both the cell body and the nucleus increase in size (Vas, G. Mann, Lugaro); on the other hand, when nerve cells are fatigued through excessive use, the nucleus decreases in size and shrivels; the cell plasm also shrinks, and its colored or chromophile constituent becomes diminished in quantity, as if it had been consumed during the prolonged use of the cell (Hodge, Mann, Lugaro). It is interesting also to note that in hibernating animals in the winter season, when their functional activity is reduced to a minimum, the chromophile in the plasm of the nerve cells is much smaller in amount than when the animal is leading an active life in the spring and summer (G. Levi).

When a nerve cell has attained its normal size it does not seem to be capable of reproducing new cells in its substance by a process of karyokinesis, such as takes place when young cells arise in the egg and in the tissues generally. It would appear that nerve cells are so highly specialized in their association with the evolution of nerve energy, that they have ceased to have the power of reproducing their kind, and the metabolic changes, both in cell plasm and nucleus, are needed to enable them to discharge their very peculiar function. Hence it follows that when a portion of the brain or other nerve-center is destroyed, the injury is not repaired by the production of fresh specimens of their characteristic cells, as would be the case in injuries to bones and tendons.

In our endeavors to differentiate the functions of the nucleus from that of the cell plasm, we should not regard the former as concerned only in the production of young cells, and the latter as the exclusive agent in growth, nutrition and, where gland cells are concerned, in the formation of their characteristic products. As regards cell reproduction also, though the process of division begins in the nucleus in its chromosome constituents, the achromatic figure in the cell plasm undoubtedly plays a part, and the cell plasm itself ultimately undergoes cleavage.

A few years ago the tendency amongst biologists was to ignore or attach but little importance to the physiological use of the nucleus in the nucleated cell, and to regard the protoplasm as the essential and active constituent of living matter; so much so, indeed, was this the case that independent organisms regarded as distinct species were described as consisting of protoplasm destitute of a nucleus; also, that scraps of protoplasm separated from larger nucleated masses could, when isolated, exhibit vital phenomena. There is reason to believe that a fragment of protoplasm, when isolated from the nucleus of a cell, though retaining its contractility, and capable of nourishing itself for a short time, cannot increase in amount, act as a secreting structure, or reproduce its kind: it soon loses its activity, withers and dies. In order that these qualities of living matter should be retained, a nucleus is by most observers regarded as necessary (Nussbaum, Gruber, Haberlandt, Korschelt), and for the complete manifestation of vital activity both nucleus and cell plasm are required.

BACTERIA.

The observations of Cohn, made about thirty years ago, and those of De Bary shortly afterwards, brought into notice a group of organisms to which the name 'bacterium' or 'microbe' is given. They were seen to vary in shape; some were rounded specks called cocci, others were straight rods called bacilli, others were curved or spiral rods, vibrios or spirillæ. All were characterized by their extreme minuteness, and required for their examination the highest powers of the best microscopes. Many bacteria measure in their least diameter not more than $\frac{1}{2500}$ of an inch, $\frac{1}{10}$ the diameter of a human white blood corpuscle. Through the researches of Pasteur, Lord Lister, Koch and other observers, bacteria have been shown to play an important part in nature. They exercise a very remarkable power over organic substances, especially those which are complex in chemical constitution, and can resolve them into simpler combinations. Owing to this property, some bacteria are of great economic value, and without their agency many of our industries could not be pursued; others again, and these are the most talked of, exercise a malign influence in the production of the most deadly diseases which afflict man and the domestic animals.

Great attention has been given to the structure of bacteria and to their mode of propagation. When examined in the living state and magnified about 2,000 times, a bacterium appears as a homogeneous particle, with a sharp definite outline, though a membranous envelope or wall, distinct from the body of the bacterium, cannot at first be recognized; but when treated with reagents a membranous envelope appears, the presence of which, without doubt, gives precision of form to the bacterium. The substance within the membrane contains granules which can be dyed with coloring agents. Owing to their extreme minuteness it is difficult to pronounce an opinion on the nature of the chromatine granules and the substance in which they lie. Some observers regard them as nuclear material, invested by only a thin layer of protoplasm, on which view a bacterium would be a nucleated cell. Others consider the bacterium as formed of protoplasm containing granules capable of being colored, which are a part of the protoplasm itself, and not a nuclear substance. On the latter view, bacteria would consist of cell plasm enclosed in a membrane and destitute of a nucleus. Whatever be the nature of the granule-containing material, each bacterium is regarded as a cell, the minutest and simplest living particle capable of an independent existence that has yet been discovered.

Bacteria cells, like cells generally, can reproduce their kind. They multiply by simple fission, probably with an ingrowth of the cell wall, but without the karyokinetic phenomena observed in nucleated cells. Each cell gives rise to two daughter cells, which may for a time remain attached to each other and form a cluster or a chain, or they may separate and become independent isolated cells. The multiplication, under favorable conditions of light, air, temperature, moisture and food, goes on with extraordinary rapidity, so that in a few hours many thousand new individuals may arise from a parent bacterium.

Connected with the life-history of a bacterium cell is the formation in its substance, in many species and under certain conditions, of a highly refractile shiny particle called a spore. At first sight a spore seems as if it were the nucleus of the bacterium cell, but it is not always present when multiplication by cleavage is taking place, and when present it does not appear to take part in the fission. On the other hand, a spore, from the character of its envelope, possesses great power of resistance, so that dried bacteria, when placed in conditions favorable to germination, can through their spores germinate and resume an active existence. Spore formation seems, therefore, to be a provision for continuing the life of the bacterium under conditions which, if spores had not formed, would have been the cause of its death.

The time has gone by to search for the origin of living organisms by a spontaneous aggregation of molecules in vegetable or other infusions, or from a layer of formless primordial slime diffused over the bed of the ocean. Living matter during our epoch has been, and continues to be, derived from pre-existing living matter, even when it possesses the simplicity of structure of a bacterium, and the morphological unit is the cell.

DEVELOPMENT OF THE EGG.

As the future of the entire organism lies in the fertilized egg cell, we may now briefly review the arrangements, consequent on the process of segmentation, which lead to the formation, let us say in the egg of a bird, of the embryo or young chick.

In the latter part of the last century, C. F. Wolff observed that the beginning of the embryo was associated with the formation of layers, and in 1817 Pander demonstrated that in the hen's egg at first one layer, called mucous, appeared; then a second or serous layer, to be followed by a third, intermediate or vascular layer. In 1828 von Baer amplified our knowledge in his famous treatise, which from its grasp of the subject created a new epoch in the science of embryology. It was not, however, until the discovery by Schwann of cells as constant factors in the structure of animals and in their relation to development that the true nature of these layers was determined. We now know that each layer consists of cells, and that all the tissues and organs of the body are derived from them. Numerous observers have devoted themselves for many years to the study of each layer, with the view of determining the part which it takes in the formation of the constituent parts of the body, more especially in the higher animals, and the important conclusion has been arrived at that each kind of tissue invariably arises from one of these layers and from no other.

The layer of cells which contributes, both as regards the number and variety of the tissues derived from it, most largely to the formation of the body is the middle layer, or mesoblast. From it the skeleton, the muscles and other locomotor organs, the true skin, the vascular system, including the blood, and other structures which I need not detail, take their rise. From the inner layer of cells the principal derivatives are the epithelial linings of the alimentary canal and of the air passages. The outer layer of cells gives origin to the epidermis or scarf skin, and to the nervous system. It is interesting to note that from the same layer of the embryo arise parts so different in importance as the cuticle—a mere protecting structure, which is constantly being shed when the skin is subjected to the friction of a towel or the clothes—and the nervous system, including the brain, the most highly differentiated system in the animal body. How completely the cells from which they are derived had diverged from each other in the course of their differentiation in structure and properties is shown by the fact that the cells of the epidermis are continually engaged in reproducing new cells to replace those which are shed, whilst the cells of the nervous system have apparently lost the power of reproducing their kind.

In the early stage of the development of the egg, the cells in a given layer resemble each other in form, and, as far as can be judged from their appearance, are alike in structure and properties. As the development proceeds, the cells begin to show differences in character, and in the course of time the tissues which arise in each layer differentiate from each other and can be readily recognized by the observer. To use the language of von Baer, a generalized structure has become specialized, and each of the special tissues produced exhibits its own structure and properties. These changes are coincident with a rapid multiplication of the cells by cleavage, and thus increase in size of the embryo accompanies specialization of structure. As the process continues, the embryo gradually assumes the shape characteristic of the species to which its parents belonged, until at length it is fit to be born and to assume a separate existence.

The conversion of cells, at first uniform in character, into tissues of a diverse kind, is due to forces inherent in the cells in each layer. The cell plasm plays an active, though not an exclusive part in the specialization; for as the nucleus influences nutrition and secretion, it acts as a factor in the differentiation of the tissues. When tissues so diverse in character as muscular fiber, cartilage, fibrous tissues and bone arise from the cells of the middle or mesoblast layer, it is obvious that, in addition to the morphological differentiation affecting form and structure, a chemical differentiation affecting composition also occurs, as the result of which a physiological differentiation takes place. The tissues and organs become fitted to transform the energy derived from the food into muscular energy, nerve energy and other forms of vital activity. Corresponding differentiations also modify the cells of the outer and inner layers. Hence the study of the development of the generalized cell layers in the young embryo enables us to realize how all the complex constituent parts of the body in the higher animals and in man are evolved by the process of differentiation from a simple nucleated cell—the fertilized ovum. A knowledge of the cell and of its life-history is, therefore, the foundation stone on which biological science in all its departments is based.

If we are to understand by an organ in the biological sense a complex body capable of carrying on a natural process, a nucleated cell is an organ in its simplest form. In a unicellular animal or plant, such an organ exists in its most primitive stage. The higher plants and animals again are built up of multitudes of these organs, each of which, whilst having its independent life, is associated with the others, so that the whole may act in unison for a common purpose. As in one of your great factories each spindle is engaged in twisting and winding its own thread, it is at the same time intimately associated with the hundreds of other spindles in its immediate proximity, in the manufacture of the yarn, from which the web of cloth is ultimately to be woven.

It has taken more than fifty years of hard and continuous work to bring our knowledge of the structure and development of the tissues and organs of plants and animals up to the level of the present day. Amidst the host of names of investigators, both at home and abroad, who have contributed to its progress, it may seem invidious to particularize individuals. There are, however, a few that I cannot forbear to mention, whose claim to be named on such an occasion as this will be generally conceded.

Botanists will, I think, acknowledge Wilhelm Hofmeister as a master in morphology and embryology; Julius von Sachs as the most important investigator in vegetable physiology during the last quarter of a century, and Strasburger as a leader in the study of the phenomena of nuclear division.

The researches of the veteran professor of anatomy in Würzburg, Albert von Kölliker, have covered the entire field of animal histology. His first paper, published fifty-nine years ago, was followed by a succession of memoirs and books on human and comparative histology and embryology, and culminated in his great treatise on the structure of the brain, published in 1896. Notwithstanding the weight of more than eighty years, he continues to prosecute histological research, and has published the results of his latest, though let us hope not his last, work during the present year.

Amongst our countrymen, and belonging to the generation which has almost passed away, was William Bowman. His investigations between 1840 and 1850 on the mucous membranes, muscular fiber and the structure of the kidney, together with his researches on the organs of sense, were characterized by a power of observation and of interpreting difficult and complicated appearances which has made his memoirs on these subjects landmarks in the history of histological inquiry.

Of the younger generation of biologists, Francis Maitland Balfour, whose early death is deeply deplored as a loss to British science, was one of the most distinguished. His powers of observation and philosophic perception gave him a high place as an original inquirer, and the charm of his personality—for charm is not the exclusive possession of the fairer sex—endeared him to his friends.

GENERAL MORPHOLOGY.

Along with the study of the origin and structure of the tissues of organized bodies, much attention has been given during the century to the parts or organs in plants and animals, with the view of determining where and how they take their rise, the order of their formation, the changes which they pass through in the early stages of development and their relative positions in the organism to which they belong. Investigations on these lines are spoken of as morphological, and are to be distinguished from the study of their physiological or functional relations, though both are necessary for the full comprehension of the living organism.

The first to recognize that morphological relations might exist between the organs of a plant, dissimilar as regards their function, was the poet, Goethe, whose observations, guided by his imaginative faculty, led him to declare that the calyx, corolla and other parts of a flower, the scales of a bulb, etc., were metamorphosed leaves, a principle generally accepted by botanists, and, indeed, extended to other parts of a plant, which are referred to certain common morphological forms, although they exercise different functions. Goethe also applied the same principle in the study of the skeletons of vertebrate animals, and he formed the opinion that the spinal column and the skull were essentially alike in construction, and consisted of vertebræ, an idea which was also independently conceived and advocated by Oken.

The anatomist who in our country most strenuously applied himself to the morphological study of the skeleton was Richard Owen, whose knowledge of animal structure, based upon his own dissections, was unrivaled in range and variety. He elaborated the conception of an ideal, archetype vertebrate form which had no existence in nature, and to which, subject to modifications in various directions, he considered all vertebrate skeletons might be referred. Owen's observations were conducted to a large extent on the skeletons of adult animals, of the knowledge of which he was a master. As in the course of development modifications in shape and in the relative position of parts not unfrequently occur, and their original character and place of origin become obscured, it is difficult, from the study only of adults, to arrive at a correct interpretation of their morphological significance. When the changes which take place in the skull during its development, as worked out by Reichert and Rathke, became known and their value had become appreciated, many of the conclusions arrived at by Owen were challenged and ceased to be accepted. It is, however, due to that eminent anatomist to state from my personal knowledge of the condition of anatomical science in this country fifty years ago, that an enormous impulse was given to the study of comparative morphology by his writings, and by the criticisms to which they were subjected.

There can be no doubt that generalized arrangements do exist in the early embryo which, up to a certain stage, are common to animals that in their adult condition present diverse characters, and out of which the forms special to different groups are evolved. As an illustration of this principle, I may refer to the stages of development of the great arteries in the bodies of vertebrate animals. Originally, as the observations of Rathke have taught us, the main arteries are represented by pairs of symmetrically arranged vascular arches, some of which enlarge and constitute the permanent arteries in the adult, whilst others disappear. The increase in size of some of these arches, and the atrophy of others, are so constant for different groups that they constitute anatomical features as distinctive as the modifications in the skeleton itself. Thus in mammals the fourth vascular arch on the left side persists, and forms the arch of the aorta; in birds the corresponding part of the aorta is an enlargement of the fourth right arch, and in reptiles both arches persist to form the great artery. That this original symmetry exists also in man we know from the fact that now and again his body, instead of corresponding with the mammalian type, has an aortic arch like that which is natural to the bird, and in rarer cases even to the reptile. A type form common to the vertebrata does, therefore, in such cases exist, capable of evolution in more than one direction.

The reputation of Thomas Henry Huxley as a philosophic comparative anatomist rests largely on his early perception of, and insistence on, the necessity of testing morphological conclusions by a reference to the development of parts and organs, and by applying this principle in his own investigations. The principle is now so generally accepted by both botanists and anatomists that morphological definitions are regarded as depending essentially on the successive phases of the development of the parts under consideration.

The morphological characters exhibited by a plant or animal tend to be hereditarily transmitted from parents to offspring, and the species is perpetuated. In each species the evolution of an individual, through the developmental changes in the egg, follows the same lines in all the individuals of the same species, which possess, therefore, in common, the features called specific characters. The transmission of these characters is due, according to the theory of Weismann, to certain properties possessed by the chromosome constituents of the segmentation nucleus in the fertilized ovum, named by him the germ plasm, which is continued from one generation to another, and impresses its specific character on the egg and on the plant or animal developed from it.

As has already been stated, the special tissues which build up the bodies of the more complex organisms are evolved out of cells which are at first simple in form and appearance. During the evolution of the individual, cells become modified or differentiated in structure and function, and so long as the differentiation follows certain prescribed lines the morphological characters of the species are preserved. We can readily conceive that, as the process of specialization is going on, modifications or variations in groups of cells and the tissues derived from them, notwithstanding the influence of heredity, may in an individual diverge so far from that which is characteristic of the species as to assume the arrangements found in another species, or even in another order. Anatomists had, indeed, long recognized that variations from the customary arrangement of parts occasionally appeared, and they described such deviations from the current descriptions as irregularities.

DARWINIAN THEORY.

The signification of the variations which arise in plants and animals had not been apprehended until a flood of light was thrown on the entire subject by the genius of Charles Darwin, who formulated the wide-reaching theory that variations could be transmitted by heredity to younger generations. In this manner he conceived new characters would arise, accumulate and be perpetuated, which would in the course of time assume specific importance. New species might thus be evolved out of organisms originally distinct from them, and their specific characters would in turn be transmitted to their descendants. By a continuance of this process new species would multiply in many directions, until at length, from one or more originally simple forms, the earth would become peopled by the infinite varieties of plant and animal organisms which have in past ages inhabited, or do at present inhabit our globe. The Darwinian theory may, therefore, be defined as heredity modified and influenced by variability. It assumes that there is an heredity quality in the egg, which, if we take the common fowl for an example, shall continue to produce similar fowls. Under conditions, of which we are ignorant, which occasion molecular changes in the cells and tissues of the developing egg, variations might arise in the first instance probably slight, but becoming intensified in successive generations, until at length the descendants would have lost the characters of the fowl and have become another species. No precise estimate has been arrived at, and, indeed, one does not see how it is possible to obtain it, of the length of years which might be required to convert a variation, capable of being transmitted, into a new and definite specific character.

The circumstances which, according to the Darwinian theory, determined the perpetuation by hereditary transmission of a variety and its assumption of a specific character depended, it was argued, on whether it possessed such properties as enabled the plant or animal in which it appeared to adapt itself more readily to its environment, *i. e.*, to the surrounding conditions. If it were to be of use, the organism in so far became better adapted to hold its own in the struggle for existence with its fellows and with the forces of nature operating on it. Through the accumulation of useful characters the specific variety was perpetuated by natural selection so long as the conditions were favorable for its existence, and it survived as being the best fitted to live. In the study of the transmission of variations which may arise in the course of development, it should not be too exclusively thought that only those variations are likely to be preserved which can be of service during the life of the individual, or in the perpetuation of the species, and possibly available for the evolution of new species. It should also be kept in mind that morphological characters can be transmitted by hereditary descent, which, though doubtless of service in some bygone ancestor, are in the new conditions of life of the species of no physiological value. Our knowledge of the structural and functional modifications to be found in the human body, in connection with abnormalities and with tendencies or predisposition to diseases of various kinds, teaches us that characters which are of no use, and indeed detrimental to the individual, may be hereditarily transmitted from parents to offspring through a succession of generations.

Since the conception of the possibility of the evolution of new species from pre-existing forms took possession of the minds of naturalists, attempts have been made to trace out the line on which it has proceeded. The first to give a systematic account of what he conceived to be the order of succession in the evolution of animals was Ernst Haeckel, of Jena, in a well-known treatise. Memoirs on special departments of the subject, too numerous to particularize, have subsequently appeared. The problem has been attacked along two different lines: the one by embryologists, of whom may be named Kowalewsky, Gegenbaur, Dohrn, Ray Lankester, Balfour and Gaskell, who, with many others, have conducted careful and methodical inquiries into the stages of development of numerous forms belonging to the two great divisions of the animal kingdom. Invertebrates, as well as vertebrates, have been carefully compared with each other in the bearing of their development and structure on their affinities and descent, and the possible sequence in the evolution of the Vertebrata from the Invertebrata has been discussed. The other method pursued by palæontologists, of whom Huxley, Marsh, Cope, Osborn and Traquair are prominent authorities, has been the study of the extinct forms preserved in the rocks and the comparison of their structure with each other and with that of existing organisms. In the attempts to trace the line of descent the imagination has not unfrequently been called into play in constructing various conflicting hypotheses. Though from the nature of things the order of descent is, and without doubt will continue to be, ever a matter of speculation and not of demonstration, the study of the subject has been a valuable intellectual exercise and a powerful stimulant to research.

We know not as regards time when the fiat went forth, 'Let there be Life, and there was Life.' All we can say is that it must have been in the far-distant past, at a period so remote from the present that the mind fails to grasp the duration of the interval. Prior to its genesis our earth consisted of barren rock and desolate ocean. When matter became endowed with Life, with the capacity of self-maintenance and of resisting external disintegrating forces, the face of nature began to undergo a momentous change. Living organisms multiplied, the land became covered with vegetation and multitudinous varieties of plants, from the humble fungus and moss to the stately palm and oak, beautified its surface and fitted it to sustain higher kinds of living beings. Animal forms appeared, in the first instance simple in structure, to be followed by others more complex, until the mammalian type was produced. The ocean also became peopled with plant and animal organisms, from the microscopic diatom to the huge leviathan. Plants and animals acted and reacted on each other, on the atmosphere which surrounded them and on the earth on which they dwelt, the surface of which became modified in character and aspect. At last Man came into existence. His nerve-energy, in addition to regulating the processes in his economy which he possesses in common with animals, was endowed with higher powers. When translated into psychical activity it has enabled him throughout the ages to progress from the condition of a rude savage to an advanced stage of civilization; to produce works in literature, art and the moral sciences which have exerted, and must continue to exert, a lasting influence on the development of his higher Being; to make discoveries in physical science; to acquire a knowledge of the structure of the earth, of the ocean in its changing aspects, of the atmosphere and the stellar universe, of the chemical composition and physical properties of matter in its various forms, and to analyze, comprehend and subdue the forces of nature.

By the application of these discoveries to his own purposes Man has, to a large extent, overcome time and space; he has studded the ocean with steamships, girdled the earth with the electric wire, tunneled the lofty Alps, spanned the Forth with a bridge of steel, invented machines and founded industries of all kinds for the promotion of his material welfare, elaborated systems of government fitted for the management of great communities, formulated economic principles, obtained an insight into the laws of health, the causes of infective diseases and the means of controlling and preventing them.

When we reflect that many of the most important discoveries in abstract science and in its applications have been made during the present century, and, indeed, since the British Association held its first meeting in the ancient capital of your county sixty-nine years ago, we may look forward with confidence to the future. Every advance in science provides a fresh platform from which a new start can be made. The human intellect is still in process of evolution. The power of application and of concentration of thought for the elucidation of scientific problems is by no means exhausted. In science is no hereditary aristocracy. The army of workers is recruited from all classes. The natural ambition of even the private in the ranks to maintain and increase the reputation of the branch of knowledge which he cultivates affords an ample guarantee that the march of science is ever onwards, and justifies us in proclaiming for the next century, as in the one fast ebbing to a close, that Great is Science, and it will prevail.

THE POPULATION OF THE UNITED STATES DURING THE NEXT TEN CENTURIES.

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IS it possible to predict with any degree of certainty the population of a country like the United States for a hundred years to come?

Doubtless the average intelligent person would say *à priori* that the growth of population is not a matter which can be made the subject of exact computation; that this growth is the result of many factors; and that those factors are subject to such great fluctuations that an estimate of the population a hundred years hence can be, in the nature of the case, only a rough guess.

It is true that the growth of population depends on a number of factors. It is also true that these factors vary in accordance with laws which are at present not known. Nevertheless it does not by any means follow that because the law of these variations is unknown we cannot represent the variations themselves by a mathematical equation. The problem of representing mathematically the law connecting a series of observations for which theory furnishes no physical explanation is one of the most common tasks to which the mathematician is called. And it does not in the least diminish the value of such a mathematical formula, for the purposes of prediction, that it is based upon no knowledge of the real causes of the phenomena which it connects together.

To illustrate: The black spots on the sun have been objects of the greatest interest to astronomers ever since Galileo pointed the first feeble telescope at his glowing disc. These spots, as observed from the earth, seem to pass across the disc from east to west as the sun rotates on its axis.

Among the problems with which the possessors of the first telescopes busied themselves were the observation of these spots for determining the period of the sun's rotation. The observation is a very simple one and consists merely in noting the time which elapses between successive returns of a spot to the central meridian of the disc. The earlier observers were astonished to find that the different spots gave different results for the rotation period, but it was only within the last thirty years that the researches of Carrington brought out the fact that these differences follow a regular law showing that at the solar equator the time of rotation is less than on either side of it.

The explanation which is generally accepted to account for this peculiar state of affairs is that the spots drift in the gaseous body of the sun and that this drift is most rapid near the equator and diminishes towards the poles. But this after all only pushes the explanation a little further back, and no satisfactory theory of this drifting of the spots has ever been reached. Doubtless the phenomenon is due to a large number of causes, acting together, whose resultant effect is shown in the motion of the spots as we see them.

However that may be, and although we are still unable to give any physical explanation of the phenomenon, a formula has been devised which fits the observations fairly well and which enables the astronomer to predict the motion of the spots with an accuracy comparable to the observations themselves. This formula is a complicated one, when written in its mathematical form, and involves a trigonometric function of the latitude of the spot raised to a fractional power.

Now no one pretends that this intricate formula expresses any real law of nature. But it does express the mathematical relation which connects together the observations, and by means of it the motions of the spots at different latitudes on the sun may be predicted with all desirable accuracy.

The problem of deriving an equation which shall represent the growth of the population of the United States during the past one hundred and ten years and which may be used to predict its growth through future decades, is exactly such a case as that of the sun's spots just mentioned. The observations in this case consist of eleven determinations of the population as given in the census returns from 1790 to 1890.

In studying these observations of population, taken at regular intervals of ten years, it occurred to me some years ago to examine them with some care in order to discover whether they were related to each other in any orderly way, and if so whether they could be represented by an equation of reasonable simplicity. It is evident that if an equation can be found which will fit the growth of population during the hundred years which intervened between 1790 and 1890 it would form the most probable basis for predicting the population of the future.

Somewhat to my surprise I discovered a comparatively simple equation which represented the census enumerations very closely and which, notwithstanding the fluctuations in the various factors which affect the growth of population, followed the general course of this growth with remarkable fidelity, as will be seen by the following table, which shows the population as given by the Census Bureau and as determined by the empirical formula. The discrepancies between the observed population and that computed from the formula are also given for the sake of an easy comparison. In each case the population is given to the nearest thousand, a figure far within the limit of error of the census count.

Year.	Observed Population.	Computed Population.	Discrepancy.
1790	3,929,000	4,012,000	83,000
1800	5,308,000	5,267,000	41,000
1810	7,240,000	7,059,000	181,000
1820	9,634,000	9,569,000	65,000
1830	12,866,000	12,985,000	119,000
1840	17,069,000	17,484,000	415,000
1850	23,192,000	23,250,000	58,000
1860	31,443,000	30,468,000	975,000
1870	38,558,000	39,312,000	754,000
1880	50,156,000	49,975,000	181,000
1890	62,622,000	62,634,000	12,000

The smallness of the discrepancies and the consequent close agreement of the formula with the observations show that the growth of the population has been a regular and orderly one. There are, however, two residuals which have abnormally large values. The census of 1860 shows a population of 975,000 larger than the computed value, while that of 1870 falls 754,000 below that of the computed value.

The explanation of these discrepancies is not far to seek. The devastating effect of the war would show itself in the census of 1870 and succeeding years. The effect would be to give 1870 a smaller observed value than would be expected. This is precisely what we find to be the case, the census of that year falling 754,000 short of the computed value. An abnormally small value in 1870 would, of course, have its effect on the population of succeeding decades and would also give an apparent difference of opposite sign to the observed population in 1860.

There is, however, good reason to believe that the population in 1870 as determined by the census was much smaller than the actual population at that time. Mr. Robert Porter, in Census Bulletin No. 12, October 30, 1890, makes the statement that the census of 1870 was grossly deficient in the Southern States and that a correct and honest enumeration would have shown at that time a much larger population than that actually returned by the Census Bureau. There are, of course, no means of ascertaining exactly the extent of these omissions, but there is no question that the population as computed by the formula for 1870 is far nearer the truth than the value given by the census for that year.

However this may be, it is evident that the formula represents the general law of growth which held between 1790 and 1890 with an accuracy almost comparable with that of the census determinations themselves. The question of immediate interest, however, is not whether the growth of population during the last century can be represented by a mathematical formula, but it is that which stands at the beginning of this paper, viz., can the population of the United States an hundred years hence be predicted within reasonable limits of error?

During the past century the factors which govern the growth of population have fluctuated enormously; there have been wars and epidemics; there have been decades in which large numbers of emigrants landed upon our shores and there have been other decades in which emigrants were few; there have been years of plenty and years of want; booms and panics, good times and hard times have had their share in the century which has passed. Yet notwithstanding all these varying conditions, the growth of the population has been a regular and orderly one, so much so that it can be represented by a comparatively simple mathematical equation. Can this equation be trusted to predict the population in the decades which are to come?

How closely the formula will represent the population of the future will depend, of course, upon the continuance of the same general conditions which have held in the past. This does not mean that exactly the same factors are to operate, but that on the whole the change of one factor will be balanced by a change in another, so that in the main the character of the growth manifested during the past century will be continued. A decided change in the birth-rate or a widespread famine would bring out large discrepancies. But on the whole it may be expected that the experience of the last hundred years involves so many varying conditions that the general law of growth which satisfies that period will continue to approximate the development of the population for a considerable time to come.

This does not mean that any particular census enumeration of the future will be represented closely, but simply that in the main the computed values will follow the general growth of the population. The law of probabilities will lead one to expect at times considerable variations. The preliminary announcements from the Census Office, as given in the daily papers, indicate a result for 1900 of about 75,700,000 people, a value considerably below the computed one. This would mean that at this epoch the formula was not representing the actual growth, but does not at all indicate that it will cease to represent the general growth of the succeeding centuries. In any event this method furnishes the most trustworthy estimate which can be made for the future, since it gives the result which is mathematically most probable and which is based on all the data of the past. Carrying forward, therefore, the computation we obtain the following values for the most probable population of the future:

Year.	Computed Population.
1900	77,472,000
1910	94,673,000

1920	114,416,000
1930	136,887,000
1940	162,268,000
1950	190,740,000
1960	222,067,000
1970	257,688,000
1980	296,814,000
1990	339,193,000
2000	385,860,000
2100	1,112,867,000
2500	11,856,302,000
2900	40,852,273,000

The law governing the increase of population, as generally stated, is, that when not disturbed by extraneous causes such as emigration, wars and famines, the increase of population goes on at a constantly diminishing rate. By this is meant that the percentage of increase from decade to decade diminishes. It will be noticed that the figures just given involve such a decrease in the percentage of growth. A simple differentiation of the formula gives as the percentage of increase of the population per decade 32 per cent. in 1790, 24 per cent. in 1880, 13 per cent. in 1990, while in one thousand years it will have sunk to a little less than three per cent. But according to the formula this percentage of increase will become zero, or the population become stationary, only after the lapse of an indefinite period.

The figures just quoted are, to say the least, suggestive. Forming, as they do, the most probable estimate we can make for the population of the future, they suggest possibilities of the highest social and economic interest. Within fifty years the population of the United States (exclusive of Alaska, of Indians on reservations and of the inhabitants of the recently acquired islands) will approximate 190 millions, and by the year 2000 this number will have swelled to 385 millions of people; while should the same law of growth continue for a thousand years the number will reach the enormous total of 41 billions.

How great a change in the conditions of living this growth of population would imply is, perhaps, impossible for us to realize. Great Britain, at present one of the most densely populated countries of the globe, contains about 300 inhabitants to the square mile. Should the present law of growth continue until 2900 the United States would contain over 11,000 persons to each square mile of surface.

With the growth of population our civilization is becoming more and more complex and the drafts upon the stored energy of the earth more enormous. As a consequence of all this, it would seem that life in the future must be subject to a constantly increasing stress, which will bring to the attention of individuals and of nations economic questions which at our time seem very remote.

THE DISTRIBUTION OF TAXES.*

BY EDWARD ATKINSON.

IN nearly all the discussions upon the subject of taxation which have come to my notice, it is assumed that certain specific taxes fall upon and are borne wholly by one class; other taxes fall upon and are borne by a second class; and so on throughout the list. For instance, in the discussion regarding a protective tariff it is held by the advocates of protection that in some cases the imposition of a duty reduces the price of the imported article in the foreign country from which it comes. It is, therefore, held that such a tax may be put upon the foreign producer and is not paid by the domestic consumer. It is held that other duties on other imported articles are added to the cost of importation, then as far as possible added to the price, and are thus distributed in ratio to their consumption. Unless such should be the result of imposing duties on foreign imports, namely, that they may either be borne in the first instance by the foreign producer, or may be distributed on the domestic consumer, there could be no continuous import of any foreign product. Even if it could be proved that some duties are paid by foreign producers, such reduction in price would limit his power of purchase of our domestic goods taken in exchange.

It is also held that excise taxes on liquors and tobacco must be charged to the cost of production, must be recovered from the sales and are, therefore, distributed in ratio to consumption. It is held by the advocates of what is called the single tax that a tax on rent or rental values will be paid out of the rents accruing to the landlord, and that this tax cannot be distributed by him, but that it simply diminishes his income. It is held that a tax on incomes is paid by those who enjoy the income, diminishing their resources. Finally, it is held that a tax on inheritances and successions is taken out of the property and that it cannot be distributed.

All these theories, presented in different forms, are and have been subjects of discussion. They have been debated ever since the subject of taxation became in any measure a matter of scientific inquiry. The conclusions reached by different persons or schools of political economy so-called, are as much at variance now as they have ever been.

I have reached the conclusion that all taxes, wherever placed, however imposed, and through whatever agency collected by the govern-

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ment, either national, State, city or town, are distributed, falling ultimately upon all consumers in proportion to the quantity and value of the product of the country consumed by each person.

What is the cost of each person to the community? Is it not what each person consumes of the materials needed for shelter, food and clothing? What does any one get in or out of life, in a material sense, be he rich or poor, except what we call board and clothing? Incomes in money are distributed. When paid for service that money becomes the means by which the person who has performed the service procures shelter, food and clothing.

If these points are well taken, then it seems to me that the only problem is how much time will elapse before the tax will fall upon the consumers of all products in ratio to consumption; an incidental question being the relative cost of collecting the taxes in one way or another.

I have been led to this conclusion that all taxes are slowly but surely diffused throughout the community—some directly, others indirectly—by reasoning upon the subject without measuring the tax in terms of money—money being only the medium by which the real tax is measured and brought to the use of the government. Does not the same distinction apply to taxes that applies to wages? We are accustomed to speak of money wages and real wages, meaning by real wages the things that money will buy. May we not in the same way speak of money taxes and real taxes, meaning by real taxes the material substances withdrawn from the community for the support of the employees of the government? Does not the real tax consist of the material products needed by and consumed for the subsistence of the officers of the government and of all persons who are in the government service?

The annual product is substantially the source of these material substances. A small part of one year's product is carried over to start the next year's product, a small part of that year being carried forward on which to begin work in the next. Production is a continuous process, but it is governed practically by each series of four seasons. Now, if the real tax is that part of the annual product withdrawn from general consumption to serve the special consumption of the persons who are in the government service, or are pensioned by the government, then by so much as the annual product measured in quantities is lessened in order to meet that demand, will the quantity remaining for distribution among those who directly take part in productive work be diminished.

In the expenditure of the money derived from taxation the government secures materials for constructing buildings, for their furnishings and fittings; for constructing coast defenses; for building naval vessels;

for supplying food, shelter and clothing to all government employees and dependents. With respect to armaments, military and naval, all the materials for the construction of vessels, forts, arms and equipments must be taken from the common stock which is derived from the annual product. The rations and clothing of soldiers, sailors and pensioners must be provided in the same way.

It follows that by so much as these government forces, military and naval, are increased will the proportion of products withdrawn from productive consumption be augmented. If these military expenditures go beyond the absolute requirements for defense, leading to the establishment of a large standing army and a great navy, every one must bear his proportion of that burden, because what is taken from the common stock for these destructive purposes is nothing but the material for shelter, food and clothing which would otherwise be constructively or productively expended. By so much as the burden of militarism is augmented must poverty be increased.

I do not mean to give the idea that many of the functions of government are not necessary and are not productive in a true sense. The functions of the civil government are as necessary to the conduct of productive industry and the government employees in this service are as much needed as are the services of any other body of men who are not directly occupied in the mechanical and manual work of production or distribution. The officials of a just government supply mental energy, the fourth and paramount factor in all production. Hence, the constructive work of governments must be carefully kept distinct from the destructive work of militarism. All that is taken from the annual product either to pay debt incurred in war, or the interest thereon, or for the support of armies or navies, is destructive and not constructive in its immediate application to any given year. By so much as food, shelter and clothing are taken from the annual product for military or destructive purposes, by so much is the quantity lessened which would otherwise be consumed for reproductive purposes. Whether or not such destructive consumption may be justified or otherwise is not a question at issue in this discussion; I merely present the facts and intend to show what militarism costs.

We now come to the relative burden of taxation. If by way of taxation so large a part of the annual product is taken for destructive purposes as to leave less than a sufficient supply for necessity and comfort, then the time has come for revision and removal of taxes lest degeneration should ensue. The case of Italy may be cited. It is stated by Italian economists that from twenty-five to thirty per cent. of the annual product of Italy is expended in support of the government, mainly for the destructive purposes of militarism; the consequences being that great bodies of people cannot get enough to eat—there is not enough to go round. Of course, the richer classes can buy what they need, therefore the ultimate and destructive burden of militarism falls upon the poor and the incapable. I think it cannot fail to be admitted that by so much as products are taken by the government for consumption outside the civil service, mainly for military purposes, in the form of food, fuel, metal, timber and the like, by so much is there less of these materials to be expended for subsistence and for the construction of dwelling houses, factories, workshops and the mechanism of productive industry. If such productive consumption is retarded by an excessive tax on inheritances or on incomes, then the accumulation of capital is retarded, and by so much must the rate of interest or profit be higher than it would otherwise have been. The distribution may be very remote, but it is very certain, unless one is prepared to admit the absurd cry of over-production and to defend a waste of substance by way of taxation in order to get rid of it.

All these material substances which are applied in the end to the supply of shelter, food and clothing are the joint product of land, labor, capital and mental energy. They are derived directly or indirectly from the field, the forest, the mine or the sea. There can be no large production conducted exclusively by labor; tools are necessary. Tools are capital, whether used by hand or worked by power. On the other hand, there can be no production exclusively derived from capital; tools and mechanism without human power or direction are inert. Land is the basis of all production, yet raw land is practically inert. Land is but a tool or instrument of production and has been so ever since the nomadic life gave place to civilized life. Again, there can be no great product, of either land, labor or capital, of either manual or mechanical work, without the directing or coordinating power of mental energy, bringing all these material forces to a constantly augmenting product in ratio to the number of persons occupied in their conduct.

If, then, the entire product of land, labor, capital and mental energy in a given period, consisting of four seasons or one year, is represented by the symbol A, that part of the product which is converted to the uses of government by taxation may be represented by the symbol B; then A minus B equals X, the unknown quantity. If X, the unknown quantity, is the share of the annual product of material substances used for shelter, food and clothing, then the whole burden of taxation, wherever imposed and however collected, with all the expenses of collection, be they greater or less, must fall in the end upon all consumers in proportion to their consumption by diminishing the quantity or value of X.

It follows that if the demand of governments takes so large a portion of the product that what is left is insufficient to meet the necessity and comfort of those who are not in the government service, then, as a matter of course, the people with the larger incomes will buy all they need with the necessary consequence that the final burden falls on those least able to bear it.

All systems of taxation have adjusted themselves more or less logically to these conditions.

It has been found in practice among all civilized nations that any large amount of taxation must be derived from a few articles of very general use; as, for instance, our national taxes on liquors and tobacco have for twenty years preceding the Spanish war annually averaged two dollars and a half ($2.50) per head, that rate sufficing to meet the normal expenses of the government during the same period. That is to say, taxes on liquors and tobacco, domestic and foreign, have annually yielded a revenue in money sufficient for twenty years prior to the Spanish war for the support of the civil service, and the army and the navy before these forces were augmented beyond the requirement of national defense. The taxes necessary to meet pensions and interest have been derived from other sources. In other words, under normal conditions, had we paid the national debt, as we might have many years ago without feeling the burden in any considerable measure, and had our pensions been limited to true cases, the people of this country would only have been called upon to forego a part of their consumption of liquors and tobacco in order to support the national government. At the present time, under the augmented taxes on liquors and tobacco, the revenue from these sources is between three dollars and a half ($3.50) and four dollars ($4) per head.

Great Britain, France and Germany derive a large part of their revenues from the same sources, namely, from these and other articles which are consumed in largest measure by the millions rather than by the millionaires. These taxes are collected at the least cost for collection and they meet a true canon of taxation, taking from consumers a part of a product which consumers can spare without impairing their productive energy.

Again, we may find the almost necessary resort of the British Government in India to a salt tax, because it is only through the tax on salt that the masses of the people can be reached, the next great resource of East Indian revenue being what is practically a single tax on land, assessed directly without regard to the relative product year by year. These taxes on salt and land admittedly reduce a large part of the population of India to such condition of extreme poverty that when a bad year comes famine devastates the land. The hoards of wealth in India are enormous, but they cannot be reached. The problem of taxation in India is not a question of will but of power to collect.

The octroi tax imposed upon the traffic of the city with the country, now in force in France, Italy and some other countries, rendered necessary by the magnitude of the burden of taxation, is one of the most obnoxious of all methods of distributing military burdens.

Finally, the relative burden of taxation cannot be estimated nation by nation by mere computation in symbols or money. The taxation by the measure of money of the United States for national purposes before the war with Spain was five dollars per head, tending to lessen. In Great Britain and Germany taxes for the same purposes were about ten dollars per head; in France about fifteen dollars. But this is no measure of the true burden of taxation. The annual product of this country measured by quantities is vastly greater than that of any European country. It may be approximately estimated twenty-five per cent. greater than that of the people of Great Britain and Ireland, thirty to forty per cent. greater than that of France, double that of Germany, and much more than double that of Italy. Hence, the real taxation of these European countries under their military establishments is vastly more than the mere symbols in money make it appear.

It follows that if all taxes in money stand for that part of the annual product required by Government, and that by so much as the product is diminished will the share falling to labor and capital be lessened, the only way to prevent taxation becoming a cause of pauperism or poverty is to limit the taxes to the necessary conduct of civil government and to national defense, avoiding aggression and forbidding armaments for any purpose except defense.

MUNICIPAL GOVERNMENT NOW AND A HUNDRED YEARS AGO.

BY CLINTON ROGERS WOODRUFF.

A HUNDRED years has wrought marvelous changes. The maps of Asia, Europe and America, of the world, have been changed. The United States of America has fought four wars and demonstrated her prowess on sea and land, at home and abroad. The country has grown from a handful of States strung along the Atlantic seaboard to a great and powerful nation, extending from sea to sea, conquering and subduing in its growth a mighty continent—the mightiest in its latent possibilities on the face of the globe. Commerce and industry and transportation have grown with equal, if not greater, strides, and the time is not far distant, if it has not already arrived, when America will dominate the world along these lines.

Our development thus far has been extensive; during the coming century it will be intensive. A few more decades and the partition of the globe among the world powers will be practically completed; then we shall be compelled to cultivate with closer attention and greater zeal and more care our resources. Intensive culture will succeed extensive cultivation. The great mechanical inventions of the nineteenth century have directly aided the extensive movement—the steam railway, the steamship, the telegraph, the cable, the telephone; the inventions of the next century will as directly aid the intensive movement—they will be designed to make the most of what we have.

Our political problems have also been problems of extension. First, the government and division of the Northwest Territory; then the acquisition and organization of the Louisiana Territory; of Florida; of Texas; of the Southwest Territory; of the Oregon country and California; then the settlement of the great question as to whether the country should be divided, and its reconstruction on the principle that it was one and indivisible; and latterly, Hawaii, Porto Rico and the Philippines. The political problems of the twentieth century will deal with questions of internal development and improvement. The government control, ownership and operation of the great natural monopolies, civil service and constitutional reforms will occupy the time and attention of our statesmen.

Our municipal growth and development during the past hundred years has likewise been along the lines of extension. Our cities have grown in numbers, population and territory. The figures are so familiar and have been so frequently exploited as to obviate the necessity of repetition. The papers are and have been full of Metropolitan Boston, Greater New York, Greater Chicago, Greater Jersey City, Greater Newark—Philadelphia has been Greater Philadelphia since 1854, when the Consolidation Act made the City and County of Philadelphia co-terminous. Indeed, municipal expansion seems to be quite as much the vogue, quite as much the logical sequence of events, quite as much the outgrowth of an inherent Anglo-Saxon instinct, as national expansion.

This development has not been confined to population and territory, but has extended to municipal functions as well. In 1800, if an American city provided for paving the streets and cleansing them of the grosser and fouler impurities; for a few night watchmen and a handful of constables; for cleaning and repairing the sewers and docks; and for lighting the streets with miserable oil-lamps, its 'Fathers' thought that they were performing their whole duty to the inhabitants.

According to a recent authority (Parsons, in 'Municipal Monopolies', 1898), the various courts of this country have decided that the following are now proper public purposes and proper objects of municipal control and ownership: "Roads, bridges, sidewalks, sewers, ferries, markets, scales, wharves, canals, parks, baths, schools, libraries, museums, hospitals, lodging houses, poorhouses, jails, cemeteries, prevention of fire, supply of water, gas, electricity, heat, power, transportation, telegraph and telephone service, clocks, skating-rinks, musical entertainments, exhibitions of fireworks, tobacco warehouses, employment offices."

We have made but a beginning, however, according to the testimony of another recent writer (Dr. Milo R. Maltbie, in 'Municipal Functions', page 784), who says:

"Whither is all this tending? Whatever a few years since may have been the answer suggested by conservatism, there is to-day but one, and that so obvious as scarcely to be questioned. The extension of municipal functions in the direction in which the city is to act as the servant of the individual has barely begun; and its scope, certain to be indefinitely increased in a comparatively near future, is to be measured only by the resources of developing invention and enterprise, so rapidly developing of late that their early realization will be such as to be unthinkable now. The individual will have cheap facilities for transport and communication. The product of his labor will be multiplied in advantage to him by the coöperation for which cities alone give a chance. He will not be left to the hard paths which chance may afford for education of his mind and his senses, but have this facilitated by every device of civilization. It is, therefore, natural, inevitable, indeed, that there should be provided for him first, water, the prime essential of life and health; next, the first of its conveniences —artificial light; later, those universal incidents of its growth—highway facilities (including power supply, as well as a clear path); and, finally, education and recreation."

The tremendous advances of municipal government during the present century can be best and most graphically demonstrated by a comparison of the respective budgets of a single city for the years 1800 and 1899. Let us take Philadelphia as an example. According to Allinson & Penrose, in their work on the 'Government of Philadelphia' (pages 115-116), the budget for the former year as contained in the ordinance of February 20, 1800, was as follows

To meet the deficiency of the tax of 1799	$1,315.44
Interest on water loan	4,200.00
Interest on debts due the banks	1,200.00
Purchase of paving stones and repair of old pavements	1,600.00
Repairs to unpaved streets, &c., paving intersections	2,400.00
For cleansing city	11,250.00
Cleansing and repairing sewers and docks	1,850.00
Lighting and watching the city	18,000.00
Repairs of pumps and wells	2,500.00
Regulating streets	400.00
Center Square improvements	1,650.00
Salaries of City Commissioners and clerk	2,800.00
Expenses of City Commissioners and clerk	100.00
Salaries to Mayor, Recorder, High Constable, clerks and messengers of Councils	3,000.00
Pay of constables for patrolling streets on the Sabbath day	156.00
Incidental expenses of Councils	600.00
Residuary fund for preventing and removing nuisances	4,478.56
Reimbursement from tax fund to corporate fund, 1799	165.92
Other advances by citizens	360.00
Salaries of clerks of markets	1,200.00
Menial service in markets	560.00
Repairs, &c	700.00
Meeting contract engagements for maintenance of two steam engines	8,000.00
Total	$68,485.92

The expenditures for 1899 (exclusive of the amounts appropriated for the maintenance of the county offices) were:

Mayor's Office	$587,770.00
Bureau of Charities	500,308.00
Bureau of Correction	203,295.00
Department of Public Safety—	
Director's Office	18,721.25
Bureau of Health	251,838.08
Bureau of Building Inspectors	46,636.75
Bureau of City Property	777,751.73
Electrical Bureau	1,118,017.78

Bureau of Boiler Inspection	$15,650.00
Bureau of Fire	979,501.20
Bureau of Police	2,732,483.31
Department of Public Works—	
Director's Office	27,963.49
Bureau of City Ice Boats	22,900.00
Bureau of Highways	3,343,789.92
Bureau of Street Cleaning	903,033.00
Bureau of Lighting	287,690.00
Bureau of Surveys	5,014,008.36
Bureau of Water	2,519,425.00
Board of Port Wardens	20,208.40
Board of Revision	147,255.00
Department of City Commissioners	921,054.50
Department of City Comptroller	60,249.52
Department of Law	155,490.00
Department of City Treasurer	4,416,867.43
Department of Clerks of Councils	140,237.95
Fairmount Park Commission	596,104.69
Reed Street Prison	87,172.25
Holmesburg Prison	84,307.43
Public Building Commission	1,011,194.43
Department of Receiver of Taxes	163,205.93
Department of Sinking Fund Commissioners	1,450.00
Department of Education	5,068,253.94
Nautical School of Pennsylvania	20,000.00
Department of Gas	5,921.54
Total	$30,958,382.88

In the year 1897, $3,399,672.43 were appropriated to the Bureau of Gas; but in that year the city (through its Councils and the Mayor) leased the gas works to a private corporation, so that now the city has to maintain a department for inspection only.

The population in 1800 was 70,287, the budget $68,485.92; the per capita expense, therefore, 97 cents. The population in 1899 was approximately 1,115,000; the budget $30,958,382.88; the per capita expense, $27.76. This great increase is due mainly to the fact that the city does more for the citizen than it did one hundred years ago, and is constantly doing more, and partly to the fact that a much larger territory is covered.

In 1897 Philadelphia had 433 public schools, with 3,465 teachers; in 1800 there were none. In 1899 there were 2,191 policemen, commanded by 6 captains, 34 lieutenants, 196 sergeants, with 23 patrol wagons, and requiring an appropriation of $2,732,483.31; in 1800 there was a handful of constables, paid out of an appropriation of $18,000 'for lighting and watching the city', and another of $156 for 'patrolling streets on the Sabbath day'. In 1899 there were 46 fire engines, 32 combination wagons and chemical engines, 15 chemical engines, 13 hooks and ladders, 15 hose carts, manned by 736 firemen, including 1 chief, 8 assistant chiefs and 57 foremen, and the appropriation for the whole bureau amounted to $979,501.20; in 1800 the city was dependent on volunteer fire companies of limited usefulness. In 1899 the sum of $1,118,017.78 was appropriated for electric lighting and $279,930.00 for gasoline lighting, and 19,417 gas lamps were lighted by the gas company; in 1800, $18,000 sufficed for 'watching and lighting' the city.

It is when we come to consider the activities of a bureau like the Electrical Bureau of Philadelphia, however, that we find the most amazing developments. I was about to say changes and advances, but there was nothing corresponding to it a century ago. Chief Walker, of the Electrical Bureau, in a recent report to the Director of Public Safety, summed up the situation in these words:

"Among the many bureaus in the department over which you so ably exercise the directorship, there is none, perhaps, whose duties are so varied and which embraces a system so diversified in its branches and which is required to be so persistently active, as the Electrical Bureau. Correspondents from other cities frequently ask what duties are concentrated in, and what knowledge is necessary to an effectual supervision of the affairs of the Electrical Bureau. An enumeration of the various duties assigned includes, among others, the *Police Telegraph,* the artery through which the orders and wishes of the officials of the executive branches of the municipality are transmitted, and the medium of communication for all municipal affairs requiring immediate attention; the *Fire Signal System,* over whose wires the signals are sent from localities threatened with the dangers of a conflagration; the *Fire Alarm System,* by means of which the signals received over the Fire Signal System are transmitted to those skilled and trained in the handling of the magnificent apparatus provided for the suppression of fire; the *Fire Signal and Telephone System,* a very efficient auxiliary to the Bureau of Fire, by means of which verbal communication is possible between the Chief of the Bureau and his aids, and which at the same time serves as an additional means of transmitting alarms to the Bureau of Fire; the *Police Signal and Telephone System,* by means of which the officials of the Bureau of Police are in almost constant touch with the patrolmen while on their respective beats, and which has proved its value many times over; the *Trunk Line,* between the local and long distance telephone exchanges entering the City Hall, which are of necessity under control of this office, centering at a switchboard in the operating room, where the necessary connections are made by employees of this bureau; the *Telephone Service* between the police stations and their sub-stations, by means of which the officers in charge of the district are in constant communication with their subordinates. The armories of the National Guards and the officers of the various hospitals are in direct communication with and the services connecting them are supervised and maintained by this bureau.

What might be termed the general municipal telephone system, embracing the system of inter-communication in City Hall and connections with all officers that are not yet installed therein, and all other municipal telephone connections are centered in and controlled by this bureau.

All electric lights authorized by Councils are located and their erection supervised by this bureau. Tests of electric lights so authorized and erected are made by us, and if not up to contract standard, deductions are made from the contracting companies' bills.

By ordinance of Councils, we are required to locate each and every pole for telegraph, telephone, electric light, trolley, or whatever electrical purpose, to issue a license for the same, for which, with the exception of the trolley poles, a fee payable at the City Treasury is charged. No poles or wires can be erected within the city limits without a permit issued from this bureau, describing its location, if a pole, and its direction, if a wire.

All conduits for municipal electrical purposes authorized by Councils are laid by this bureau, as are cables necessary for the connection of the various municipal electrical services. All scientific electrical tests of cables are also made by this bureau.

As a member of the Board of Highway Supervisors, the Chief of the Bureau is required to pass upon the location and position of all electrical constructions under and over the highways, and to approve of the materials used and the methods employed in its installation and maintenance. All minor details of electrical construction necessary to the needs of a municipality are formulated and carried forward to successful completion."

Surely a wonderful work; unheard of, yes—I venture to say, unthought of, in the mind of the most imaginative thinker a century ago!

Search we never so carefully, we can find nothing in the budget or reports of 1800, or for those of many years later, which in anywise approaches or approximates this work—for the simplest of reasons—that electricity had not as yet been harnessed to bring the distant near and to eliminate space. Fancy the constable of 1800 communicating every hour with his headquarters without leaving his beat; or having an alarm of fire sounded simultaneously in every section of the city, no matter how remote! Imagine the look of incredulity which would descend upon a citizen who was told that he could be placed in communication with a city official in less than a minute and without leaving his office!

Our municipalities have grown and have developed along extensive lines to an unexpected degree, and the same factors that have been at work in our national development in the same direction have been at work in our municipal development, and the same observation will apply—the next century's development in our cities will be along intensive lines. Already, we see the tide setting in this direction. Take, for instance, the growing demand for charter reform. During the expansive period of a city, everything is sacrificed to size and numbers; the form and methods of government are considered as of secondary importance. When this period is passed there comes a time when the necessity for a conscious adjustment of the form of government to the new conditions and environment becomes paramount; then follows the demand for a new charter; and charter amendments and charter conventions become the order of the day.

Recognizing that we had reached this stage of our development, the National Municipal League, at its Louisville meeting, held in 1897, adopted the following resolution:

"*Resolved*, That the Executive Committee appoint a committee of ten to report on the feasibility of a municipal program, which will embody the essential principles that must underlie successful municipal government, and which shall also set forth a working plan or system, consistent with American industrial and political conditions, for putting such principles into practical operation; and such committee, if it finds such municipal program to be feasible, is instructed to report the same, with the reasons therefor, to the League for consideration."

The committee thus authorized presented its preliminary report at the Indianapolis Conference for Good City Government in 1898, and its final report to the Columbus Conference in 1899. While it is fully aware that its "recommendations do not constitute the last word on the subject, nevertheless the fact that a body of men of widely divergent training, of strong personal convictions, and who approached the matter in hand from essentially different points of view, could and did come to unanimous agreement that a 'Municipal Program' was feasible and practicable, and by fair and full comparison of opinion were able to embody the result of their agreement in definite propositions, is a hopeful augury." This committee realized that "good government is not to be achieved at a stroke, nor do we exaggerate the importance of the form of governmental organization as a factor contributory to this end. Civic advance in general, and municipal efficiency in particular, are the result of a combination of forces, of which higher standards of public opinion and lofty civic ideals are the most important."

Another sign of the times is the formation of organizations like the League of American Municipalities, the State Leagues of Municipalities, the American Society of Municipal Improvements, the National Association of Municipal Electricians, the various societies of fire and police and other municipal officials. These indicate that those who are actually and directly responsible for the administration of municipal government are awakening to their responsibilities, to the need of conference to advance the interests committed to their care. The time was, and that not very far distant, when the principal rivalry between cities was confined to population figures and extent of territory. Now a healthful and auspicious competition based on efficiency is springing up, and such societies and organizations as those to which I have referred foster and encourage this tendency.

We have only to examine the program of conventions such as that held under the auspices of these societies to be convinced of the earnestness and sincerity of purpose of their sponsors. Hard practical questions of municipal administration are to the front. The men come together to exchange views and ideas as to how to conduct certain lines of municipal business—not to listen to useless, though perhaps graceful, oratory and senseless bombast and adulation. Some may decry conventions; but certainly not such as serve so useful a purpose as those conducted under the associations already mentioned. They are a sign of the times—a most auspicious sign of the times. Do you read anywhere a century ago that the mayors or aldermen or constables of that time came together to confer about municipal affairs? We may not hear of them a century hence, because they may have performed their function and gone the way of other good and useful means to an end; but at this time they indicate the change taking place in our development; the change in emphasis.

I do not propose to indulge in prophecy. I am not so gifted with foresight as to be able to peer into the future and read its message. I can only express a personal opinion as to the possible result of present tendencies, based upon a study of present and past developments. I have already indicated what I believe will be the greatest change, that from extensive to intensive growth and development, and with this will come a great amelioration of many of the present-day evils.

The instinct for territorial expansion gratified, the various world powers and their possessions will tend more and more to assume a condition of permanent equilibrium. Great armaments and vast armies will become less and less necessary. Economic causes plus political necessity plus moral growth will gradually result in the substitution of mediation, arbitration and conciliation for warfare and bloodshed. Already the beginning of this substitution is at hand. We have the Argentine-Italian treaty providing for the submission of practically every difficulty to arbitration; similar treaties under consideration; and the Delagoa Bay arbitration has just been completed.

The accomplishment of these ends will result in a transfer of political energy and ability. Constructive statesmanship, liberated from considerations of expansion and colonization, will be free to devote itself to the great questions of internal improvement. Our municipalities will correspondingly benefit and will have at their command that genius and that ability which seem to be a chief characteristic of the Anglo-Saxon race, but which hitherto have been absorbed by national and international activities.

Civil service reform, which lies at the very foundation of efficient government, will become an accomplished fact from the very necessity of things. A century ago there was no need for it, because the number of offices was so small and the interests involved practically so limited. A century hence the number of offices will be so great and the interests so vast, that it will be an impossibility to administer them upon any other basis. Public opinion on fundamental political questions changes slowly; but already we see evidences that there is a growing resentment to the use of public office to pay political debts. The business instinct of the people is slowly but surely asserting itself to the same end. There is a growing appreciation of the fact that an electrical bureau or an engineering bureau or a survey bureau cannot be successfully and efficiently conducted on a spoils basis.

No one doubts or denies that municipal reform is to-day a great and pressing problem, constantly attracting more and more attention and bidding fair, in the course of advancing years, to become a dominating one. When we have accomplished what we are now striving for—civil service reform, the elimination of State and national politics from the consideration of municipal affairs, the conduct of the latter upon enlightened principles, the extension of educational facilities, municipal reform will choose other objects for its end; otherwise, America would not be true to its Anglo-Saxon heritage. One reform achieved, then the Anglo-Saxon presses forward to another. He would not be true to his instinct if he did not. We may not, and I for one believe we shall not, be discussing civil service reform, ballot reform, municipal ownership, a century hence; nor will a National Municipal League perhaps be needed to preach the doctrine of an aroused civic consciousness. These will be accomplished facts, if we may judge of the future by the past and present—but none of these things will come to pass unless every one who now feels the obligations of his political duties is true to the best that is within him. The secret of the greatness of America and England in the civilization of the world is that there has always been a sufficient number of men to respond when a Nelson said, 'England expects every man to do his duty.' Whenever that day passes, then the greatness of the Anglo-Saxon race shall have departed.

CHINA.*

By WILLIAM BARCLAY PARSONS.

EVER since the days when Marco Polo brought back to Europe the seeming fairy tales of the wonderland of the Far East, the country to which we have applied the name of China has been a field more and more attractive for commercial conquest.

At the close of the nineteenth century, when the ever-rising tide of industrial development has succeeded in sweeping over Europe, America, the better portion of Africa, of Western Asia and India, it is the Chinese Wall alone that resists its waves. The movement, however, is irresistible, and not even the exclusiveness of the Chinese and their extreme disinclination to change their ways will be a sufficient protection against it; the recent so-called 'Boxer' outbreak will probably prove to be the death knell to Chinese resistance. Whatever may be the outcome of this outbreak, in so far as it affects the government, or the political integrity of the country, it can be predicated in safety that the commercial and industrial life of China will be revolutionized, and the beginning of the twentieth century will be found to mark the dawning of a new era.

The present moment when we are about to pass from the old into the new state of things is a fitting time to survey the field of industrial enterprise by examining into what has been done and to ascertain the sort of foundation that has been prepared, on which the Chinese people, aided at first by foreigners, will eventually of themselves erect their own industrial structure.

In the consideration of this very interesting land there seems to be a surprise at every turn, and one of the most peculiar is that we are met at the outset by the curious circumstance that it is a country without a name. The Chinese themselves have no fixed designation for their country, using as a general thing either the 'Middle Kingdom,' or the 'Celestial Kingdom,' or the 'Great Pure Kingdom.' The interpretation of the first is that the people consider China to be the center of the world, all the other countries surrounding and being tributary to it; although the term probably originated when what is now the Province of Ho-nan was the central kingdom of several other kingdoms which went to make up a united country. The name 'Celestial Kingdom' is a piece of self-flattery, the Chinese Emperor being called in like manner

*This article will form part of a book entitled "An American Engineer in China," to be published shortly by Messrs. McClure, Phillips & Co.

the 'Son of Heaven;' while the last name, that of the 'Great Pure Kingdom,' follows the designation of the present ruling house, which styles itself the 'Pure Dynasty,' in contradistinction to the preceeding dynasty which it overthrew, and which was called the Ming or 'Bright Dynasty.' The foreigner's appellation of China is of uncertain origin, but it is supposed to mean the land of Chin or Tsin, a family that ruled about 250 B. C., and even this name is used indiscriminately as covering two areas very different in size. When we use the word China it may mean the Chinese Empire proper, the empire of the eighteen provinces; or it may mean the eighteen provinces and the dependencies of Manchuria, Mongolia and Tibet, whose bond of attachment to the empire, in strength, is in the above order. The eighteen provinces comprise in area about 1,500,000 square miles, or an area about equal to that portion of the United States lying east of Colorado. The shape of the empire proper is substantially rectangular, extending from the latitude of 42° north, which is about that of New York, to 18° north, or the latitude of Vera Cruz. When the dependencies are included under the title of China the northern boundary is carried to the forty-eighth parallel, or say the latitude of New Foundland, and the whole has an area of over 4,000,000 square miles, a greater surface than that of Europe, or of the United States and Alaska combined. This great area is reputed to support a population of upwards of 400,000,000; figures, however, which I will later point out to be, in my belief, a gross exaggeration, but the balance, even after the most conservative reductions, will still easily be the greatest single contiguous conglomeration of people under one ruler. Racially speaking, they are a conglomeration. Who the Chinese were originally is not known. It is generally believed that they came from Western or Central Asia, and, conquering the scattering nomadic tribes inhabiting what is now China, seized their country.

In the dependencies and Chinese proper we find distinctly different peoples, with their individual customs; while scattered about the empire proper are settlements of strange tribes, whose origin is absolutely unknown but who are believed to be relics of the aboriginal inhabitants.

Lack of intercommunication has allowed the language of the Chinese to become locally varied, and to such an extent, that although the written characters are the same, the spoken dialect of the North and South are so different as to be mutually unintelligible. There are said to be in the empire proper eight dialects, each again being many times subdivided by local colloquialisms. Of these dialects the most important is the so-called Mandarin or Pekingese, the dialect of the North and the official language of the country, for it is the one which all government officials are required to learn and use. It therefore holds the position in respect to other dialects that the French formerly held in Europe as the Court tongue, or language of diplomacy and officialism.

Historically, China enjoys the distinction of being the oldest continuing nation in the world. Fairly authentic records trace back the course of events to about 3,000 years B. C., so that it rightly claims an existence of at least 5,000 years. Previous to this period there is a vast amount of legendary matter in which probability and fiction have not yet been separated.

China's own historians, with characteristic conceit, make out their country's history to be contemporaneous with time. Owing to her seclusion and isolation from the affairs of other nations, China's history possesses a local rather than a world's interest, and for the most part is a record of the rise and fall of the several tribes or peoples going to make up the nation, each such change establishing a new dynasty. However, there are certain epochs of general interest and certain salient points in the nation's development and growth that should be understood and kept in mind if any study of China or of things Chinese is undertaken.

Accepted Chinese chronology begins with the reign of Fuh-hi in the year 2852 B. C. As to the significance of that date it is interesting to note that it is four hundred years before the rise of the Egyptian monarchy, five hundred years before that of Babylon and precedes the reputed time of Abraham by a period almost as long as the whole record of English history, from the conquest to the present time.

In the Chau Dynasty, which lasted from B. C. 1122 to B. C. 249, we find the great period in Chinese literature, an era comparable with that of Elizabeth in our records. In 550 B. C. Confucius was born, whose philosophical reasonings, owing to the long time he antedated the spread of Christianity and Mohammedanism, have affected the thought of more human beings than the writings or sayings of any other man, with the possible exception of Buddha.

Although Confucius is the central figure of the epoch, there are at least two other men substantially contemporaneous with him, and who are but only a little less prominent, Liao-tze, who preceded him fifty years, and Mencius, who followed him one hundred years. The former was a religious philosopher, on whose writings there has been founded the doctrine of Taoism. This philosophy is based on Reason (Tao) and Virtue (Teh), and is of interest in that it leans towards an eternal monotheism. According to his theory the visible forms of the highest Teh can only proceed from Tao, and Tao, he says, is impalpable, indefinite. Taoism, therefore, contemplates the indefinite, the eternal and a preexistent something which Liao-tze likens to the 'Mother of all things,' or what we call a creator.

In Chinese literature there are the nine classics, the five greater and the four lesser books. The former are Yih-King, the Book of Changes; Shu-King, Historical Documents; Shi-King, the Book of Odes; Li-Ki, the Book of Rites, and Chun-Tsin, a continuation of the Shu-King. Of the above, the second, third and fourth, although long antedating Confucius, were edited by him, while the fifth is from his pen. The four lesser classics are Ta-Hioh, Great Learning; Chung-Yung, the Just Medium; the Analects of Confucius; and the writings of Mencius. The last is the great production of Mencius, while the first three are a digest of the moralizings of Confucius as gathered by his disciples.

On these nine books are founded Chinese philosophy, morals, thought, religion, education, ethics and even etiquette. The spirit of the matter in the classics is essentially lofty, moral and good.

In China, learning transcends all else in importance, and as Confucius is considered as the fountain head of literature and learning, so he has become to be regarded as Europeans in the Middle Ages regarded saints, and temples to his honor are found in all large cities. The most important is the beautiful example of Chinese architecture in Peking, where the Emperor annually worships before his tablet. In spite of this apparent adoration, Confucius is not regarded by the Chinese as a god, but is clearly understood by them to have been a man, a philosopher and the embodiment of wisdom, and is revered as such. He was not the founder of a religion, nor was he a religious writer, although his sentiments have become woven in the complicated fabric of Chinese faith. The name by which foreigners know him is a latinized corruption of Kung-tze, the Master Kung, the last being his family name, as Mencius is a similar corruption of Mang-tze, the Master Mang.

Following the Chau dynasty comes that of Tsin, which was noted for supplying the foreign appellation of the country and for the great works, both good and bad, of its name-giving Emperor. It was he who united the various peoples of Eastern Asia under one sway; laid the foundation for at least internal commerce by beginning the construction of the Chinese system of canals, started the construction of the Great Wall and succeeded in raising his country to a point of material greatness not before reached. Then, with a view to make all records begin with him, he ordered burned all books and writings of every description, including those of Confucius and the other philosophers. Fortunately, in spite of an energetic attempt, this sacrilegious act was not completely consummated.

From this period to the Tang dynasty in 618 A. D. the history of this country is a succession of different reigning houses, internal wars, rebellions, more or less successful, and during which the capital was frequently moved, part of the time being located at Nan-king on the Yang-tze, which many of the Chinese of to-day regard as the proper site. The great single event of this long stretch of years, and practically the only one of foreign interest, was the introduction of Buddhism at the close of the first century A. D.

The Emperor Ming-ti sent an embassy to the West to bring back the teachings of the foreign god, rumors of whose fame had already reached the Pacific shore. It has since been supposed by some that this meant tidings of Christ; but the basis for such an inference is doubtful. At any rate the embassy found its way to India and returned thence with the doctrines of Buddhism, which at once became the established religion of the country, spreading over the whole of China and eventually Japan. It makes an interesting speculation to consider what the effect on the world would have been if the embassy had taken a more northern route, bringing it to Palestine instead of to India.

The Tang dynasty A. D. 618 to 908 marks perhaps the zenith of Chinese development, when, there is no doubt, its civilization and cultivation outshone those of Europe at the same period. Literature flourished; trade was nurtured, the banking system developed, laws were codified and the limits of the empire were extended even to Persia and the Caspian Sea. The art of printing was discovered, certainly in block form and probably by movable type. The fame of China reached India and Europe, whence embassies were despatched bearing salutations and presents. Monks of the Nestorian order were received by the Emperor Tai-tsung, who gave permission for them to erect churches, and thus was Christianity first publicly acknowledged in China. Although the efforts of the Nestorian monks continued for many years from perhaps as early as 500 A. D. to 845, yet they were without permanent results, as they left no monuments behind them, and the practice of Christianity was suspended for some centuries.

In 1213 A. D. the Chinese for the first time passed under a foreign rule, when Genghis Khan, the great Mongol, crossed the wall and began to lay waste the country. When he had captured Peking and established a Mongol dynasty, he turned his attention to further conquests, and in 1219 led a force westward. With it he overran Northern India, Asia Minor, and even entered Europe in Southern Russia. He then withdrew to Peking, having established the largest empire in the world's history. Under his degenerate successors this vast power dwindled, the only permanent result being found in Europe; for the presence of the Turks on that continent is due to the invasion of Genghis, as he drove them before him out of their own Asiatic country.

The last purely Chinese dynasty was the Ming (Bright) which occupied the throne from 1368 to its overthrow by the Manchus in 1644. The capital of this house was originally at Nan-king, but was moved by the great Emperor Yung-loh to Pekin in 1403, where he constructed the famous Ming Tombs forty miles northwest of the city, where he and his successors of Ming lie buried in solitary grandeur. He also established the laws under which China is governed to-day, and under him the seeds of Christianity were permanently planted in China in 1582 by the Jesuit missionary Matteo Ricci. About two hundred and fifty years before a temporary foothold had been gained by the same order. The first effort lasted, however, for but seventy-five years, and then, like the Nestorian movement, quietly died without practical results. It was also during this dynasty that the first foreign settlement was made on Chinese soil, in the Portuguese port of Macao in 1557.

In the seventeenth century the northern tribes set up a rebellion. Gaining adherents to their cause they captured Peking in 1644, swept away Chinese rule and established a Manchu dynasty, to which they gave the name of 'Ta Tsing' or the 'Great Pure.' The principal effects of this change were to establish the northern races in control of the government and to stamp upon the whole people their most striking outward distinguishing mark in the queue, which was a distinctly Manchu custom, the Chinese having cut their hair like Western people. On their establishment the Manchu rulers ordered all people to wear the queue as a token of subjugation which the Chinese natives still do, although the Tibetans and Mongols continue to cut their hair as of old. Manchus and Chinese can be readily recognized by their names. Thus one of Manchu descent has but a double name, like Tung-lu, while a Chinese has three characters as, Li Hung-chang.

The government of China is an absolute imperialism, with powers vested in an Emperor, whose position is well indicated by his most used title, the 'Son of Heaven.' He is assisted by two councils under whom are the seven boards of: Civil Service, Revenue, Rites, War, Punishment, Works and Navy, who severally attend to the administration of affairs in their respective departments. Then there is the Tsung-Li-Yamên, or foreign office; a bureau composed of twelve ministers, with and through whom all relations with other nations and foreigners generally are conducted.

The communication between the Imperial authority and the people is through the local governments of the provinces. These provinces in their organization closely resemble an American State, varying in size from Che-kiang, the smallest, within an area of 35,000 square miles, to Sz-chuen, the largest, embracing 170,000 square miles. These are respectively comparable with the States of Indiana (36,350 square miles) and California (156,000 square miles). Each province is ruled by a governor appointed by the throne, and he exercises his authority through a chain of officialism. The province is divided into circuits, each circuit being controlled by an intendant of circuit or taotai. In addition to the regular taotais, there are special ones appointed to look after the large treaty ports, like Shanghai. Such taotais have immense powers and the positions are much sought after. The circuits or 'Fu' are usually again subdivided into two or more 'Chau' or prefectures under a prefect, and each perfecture into Hsiens or districts, under a magistrate. Cities where such officials dwell are usually indicated by adding 'Fu,' 'Chau' or 'Hsien' to their names. The Hsien magistrates are the men who come in direct contact with the people. The Governor in turn reports to an officer properly styled a Governor-General, but whose title foreign nations have translated as Viceroy, each of whom usually controls two provinces. These Viceroys form the real government of the country. Their powers are absolute. It is to them, armed with judgment of life and death, that the people look for justice and protection, and to them, also, the throne itself looks for support. Each Viceroy maintains his own army, in some instance a portion of which has been foreign drilled, which army he has a right to decide whether he will use for national purposes or not.

Of the existing college of Viceroys, there are three who have brought themselves by their acts, abilities and force of character to the forefront, and who are known as the three great Viceroys. These men are Li Hung-chang, formerly Viceroy of Pe-chi-li, but now of Canton, ruling the provinces of Kwang-tung and Kwang-si, and so usually referred to as the Viceroy of the two Kwang; Chang Chi-tung, the Viceroy of Wu-chang, in like manner called the Viceroy of the two Hu, as his dominion covers the provinces of Hu-peh and Hu-nan, and Liu Kun-yi, the Viceroy of Nan-king, ruling the provinces of Kiang-su and Ngan-whui.

Li Hung-chang, whose reputation is international, needs no introduction. The other two, while, perhaps not so well known, are in China of scarcely less importance, especially as they have a personal hold on their people that is not equaled by any other official. They are not rich, which is almost the same as saying that they are honest, and, although they are decidedly pro-foreign in their views, nevertheless they are at the same time imbued with a strong and earnest desire to ameliorate the condition of their charges and, therefore, are honored and respected by their people. To accomplish this end they do not hesitate to avail themselves of occidental ideas or means if therein they see a possibility of benefit.

When the Empress Dowager in 1898 executed her *coup d'etat* and notified the Viceroys of what she had done, Chang Chi-tung and Liu Kun-yi were the only ones who had courage to express their disapproval. In consequence there is little doubt that she would have removed or beheaded them if she had dared to brave the outcry of the people of the four provinces, which would certainly have followed. In any reorganization of China these three men will play an important part in which the influence of Chang Chi-tung and Liu Kun-yi will certainly be of weight as they enjoy the esteem and confidence of both foreigner and native.

In the appointing of all officials there is one rule that is curiously indicative of Chinese reasoning and methods. No official is allowed to serve in a district in which he was born. The reason for this is that, being a stranger, without local prejudice or interest, it is believed that he will administer justice quite impartially. Unfortunately, human nature being the same in China as elsewhere, the official, on account of his lack of local prejudice, administers justice in such a manner as will best promote his own interests and secure his advancement.

Topographically considered, China lies on the eastern flank of the great Central Asian plateau and, therefore, its main drainage lines lie east and west. There are three great valleys: that of the Yellow, in the north; Yang-tze in the center; and the Si (or West), in the south. The Yellow River, or Hoang-ho, or as it is frequently called, on account of its erratic and devastating floods, 'China's Sorrow,' is a stream very much resembling the Mississippi, carrying a great amount of alluvium, which it deposits at various places, forming bars and shoals. In order to protect the shores from inundations, the Chinese for many years have been building dykes with the result of gradually raising the bottom of the river through the deposition of alluvium. There are now many places where the bottom of the stream is actually higher than the normal banks. Under such circumstances the breaking of a dyke means untold destruction, with possible permanent change of bed. The location of its mouth shows the character of this great river. Eighty years ago it flowed into the Yellow Sea, south of the Shang-tung Peninsula. To-day it enters the Gulf of Pe-chi-li two hundred and fifty miles in a direct line northwest of its previous location, or about six hundred miles, when measured around the coast line. The Yang-tze, on the other hand, rightly merits its name of 'China's Glory.' This noble stream, whose length is about 3,500 miles, of which 1,100 miles are navigable by steam vessels, divides the country, approximately equally north and south. Its drainage area covers more than one-half of the empire, the richest and most valuable portion. This stream, like the Hoang-ho, carries a large amount of alluvial matter, but it is much more orderly and well regulated. Practically at its mouth, the gateway to Central China, although actually on a small tributary called the Wang-Poo, is Shanghai. The West River, or Si-Kiang, drains the southern and southwestern section of the empire, flowing into the sea at Canton, where with the Pei (North) and Pearl rivers it forms the broad estuary known as the Canton River.

In agricultural possibilities and mineral wealth China is particularly fortunate. On account of its great dimensions north and south it enjoys all varieties of climate from the tropical to the temperate, and in consequence possesses the ability to raise almost any crop. The great bottom lands of the Yang-tze, Hoang and other rivers, which are subject to annual overflow, are thus by nature enriched and automatically fertilized as are the bottom lands along the Mississippi and other alluvium-bearing streams. In addition to the ordinary advantages of soil and variety of climate to which such a large expanse is naturally entitled, China enjoys one special favor in the singular deposit known as Loess.

The country lying north from the Yang-tze to the Gulf of Pe-chi-li, part of which area has been made by the alluvial deposits of the Yang-tze and Yellow rivers, is known as the Great Plain. Of this territory there is a considerable section in the provinces of Shen-si, Shan-si and Shan-tung, which is known as the Loess formation. This particular soil is yellow in appearance, resembling alluvial material, but on examination is found to consist of a network of minute capillary tubes. The best theory for its deposit is that it is the fine dust of dried vegetable matter carried down by the winds from the northwest plains and dropped where found. The fine tubes are accounted for by believing them to be the spaces occupied by the roots of grasses, as the latter have been continually raising themselves to keep on the consequently rising surface. The Loess soil is of great and unknown thickness, of extraordinary fertility and with great capacity for withstanding droughts, as the tubes by their capillary action serve to bring up moisture from the ground water below. This part of the Great Plain has been supplying crops for many centuries without fertilizing and supports the densest part of the Chinese population.

In minerals, China is particularly rich. Of the precious metals, gold and silver are known to exist, and probably in paying quantities, while of the less valuable metals, copper, lead, antimony and others have been found, and but await the introduction of proper transportation methods to be developed. Petroleum occurs in Sz-chuen, the extreme western province lying next to Tibet. But China's greatest mineral wealth lies in iron and coal. The great fields of the latter are in Pe-chi-li, Shen-si, Shan-si, Sz-chuen, Kiang-si and Hu-nan, where all varieties from soft bituminous to very hard anthracites are found. Of the former there are coals, both coking and non-coking, fit for steel-making or steam uses, while of the latter there are those adapted for domestic use, with sufficient volatile matter to ignite easily, and others sufficiently hard to bear the burden in a blast furnace and sufficiently low in phosphorus, sulphur and volatile substances to render them available for the manufacture of Bessemer pig, as is done in Pennsylvania. Chinese houses are usually without chimneys, and, therefore, the native is compelled to use for domestic purposes an anthracite, or, as he calls it, a non-smoking coal, which he burns in an open fireplace, the products of combustion escaping through the doors, unglazed windows or the many leaks which are usually found in Chinese roofs.

In opposing the introduction of occidental reforms, methods and commercial relations, China has invited, if not actually obliged, the forming of bases by other nations from which to push their trade. Chinese soil is now heid, through some excuse and under various conditions, by Portugal, Great Britain, France, Germany, Russia and Japan. In addition to this Italy has made an unsuccessful attempt to secure a foothold at San Mun Bay.

The Portugese possession is Macao, situated on the western side of the mouth of the Canton River, a charming settlement covering the city and a few square miles of territory separated from the main land by a narrow neck. It is a delightful little piece of southern European refinement in an Oriental setting, and perhaps the only point on the coast to which the word charming can be rightly applied. It was the first foreign settlement in China, being ceded to Portugal in 1557 in return for services in putting down pirates. On account of the shallowness of the harbor, the importance of Macao as a trading point or military base is very small.

The British possessions are Hong Kong, Kow-loon and Wei-hai-wei. As a result of the Opium War of 1841, the island of Hong Kong, whose greatest dimension is but nine miles, and wholly mountainous, located at the eastern side of the Canton estuary, directly opposite to Macao, but distant therefrom about forty miles, was given over by China as a part of the indemnity. In 1860 there was added the shore of the main land, called Kow-loon, across the roadstead whose width is rather more than a mile, in order to complete the harbor. On this island the English have established a colony, built the city of Victoria, and through the magnificent land-locked harbor, have developed a trading point, whose commerce ranks with that of the world's greatest ports. There are no customs dues, no restricting conditions—all nations and nationalities have an equal footing, so that Hong Kong has become the great *entrepôt* or warehouse for nearly the whole of the Orient, and absolutely so for Southern China, whose gateway it controls. A year's record shows that over 11,000 vessels enter and clear, not including upwards of 70,000 junks. Thus have the English converted an apparently useless island into a most valuable possession for themselves and a great stepping-stone for the world's commerce.

The next country to establish a foothold on Chinese soil was France, who acquired from Annam, by war and treaty, between the years 1860 and 1874, part of the province of Tong-king. In 1882 further trouble arising between France and Annam, the latter appealed to her protector, China, and war ensued. The result was the permanent occupation of the whole of Tong-king and the placing of the French frontier next to that of China.

At the conclusion of the Japanese war, the island of Formosa was permanently ceded by China and an arrangement made for the temporary occupation of Port Arthur. Then Russia interfered, insisted on the withdrawal of the Japanese troops from the North, and, as her price for aiding China, secured a lease for twenty-five years of the Liao-tung Peninsula, covering eight hundred square miles, including the harbors of Port Arthur and Talien-wan, and so, practically obtained the control of Chinese Manchuria.

In 1897 two German missionaries having been killed, the German Emperor demanded as compensation a share of Chinese soil, which was granted through a 'lease' of Kiao-Chau Bay for ninety-nine years.

The following abbreviated quotations indicate the tenor of these curious arrangements:

"I. His Majesty the Emperor of China, being desirous of preserving the existing good relations with His Majesty the Emperor of Germany and promoting an increase of German power and influence in the Far East, sanctions the acquirement under lease by Germany of the land extending for one hundred li at high tide.

"Germany may engage in works for the public benefit, such as waterworks, within the territory covered by the lease, without reference to China. Should China wish to march troops or establish garrisons therein she can only do so after negotiating with and obtaining the express permission of Germany.

"II. His Majesty the Emperor of Germany being desirous, like the rulers of certain other countries, of establishing a naval and coaling station and constructing dockyards on the coast of China, the Emperor of China agrees to lease to him for the purpose all the land on the southern and northern sides of Kiao-Chu Bay for a term of ninety-nine years. Germany is to be at liberty to erect forts on this land for the defense of her possessions therein.

"III. During the continuance of the lease China shall have no voice in the government or administration of the leased territory. It will be governed and administered during the whole term of ninety-nine years solely by Germany, so that the possibility of friction between the two powers may be reduced to the smallest magnitude.

"If at any time the Chinese should form schemes for the development of Shan-tung, for the execution of which it is necessary to obtain foreign capital, the Chinese government, or whatever Chinese may be interested in such schemes, shall, in the first instance, apply to German capitalists. Application shall also be made to German manufacturers for the necessary machinery and materials before the manufacturers of any other power are approached. Should German capitalists or manufacturers decline to take up the business, the Chinese shall then be at liberty to obtain money and materials from other nations."

While the area actually covered by the lease is small, the shore line being but one hundred li (thirty-three miles), nevertheless the Germans have thrown a sphere claim over the whole province of Shan-tung, an area as large as New England, based on the special commercial concession, as above quoted.

The strongholds of Kiao-Chau and Port Arthur, for the Germans and Russians immediately set about fortifying them, so threatened the balance of power in the North, that the British government in 1898, demanding something to offset them, secured the harbor of Wei-hai-wei, directly opposite Port Arthur and with it marking the entrance to the Gulf of Pe-chi-li. This territory is to be held as long as the Russians hold Port Arthur. At the same time Great Britain extended the limits of the Kow-loon possession by two hundred square miles, so as to absolutely protect the harbor of Hong Kong, and secured from the Chinese government a promise that no territory in the Yang-tze Valley should be alienated to any other power, thus obtaining a so-called sphere of influence over the richest half of the empire. France, not wishing to see her commercial rivals outdo her, demanded, as her share of the plunder, the harbor and port of Kiang-chau-wau near her province of Tong-king and secured a lease of the same for ninety-nine years. Thus has the Chinese government given away its patrimony.

In addition to the above possessions of territory actually held under the domination of their respective governments, there are at the various treaty ports the so-called foreign concessions, which have been given by the Chinese government to the temporary care of the people of other nationalities, permitting them to establish a police force, courts of justice, fire protective service, to collect taxes for local use, and otherwise to maintain local governments according to foreign regulations and practically without interference by the Chinese government. Such concessions remain, in name, at least, Chinese territory. The largest and most important of them is Shanghai, where grants were made some years ago to the English, American and French. The first two have been combined into the Shanghai municipality, under a system of popular government with annual elections, where the rate-payers are voters and which in all functions closely resembles an independent republic. The theory that all nations are on an equal footing within the limits of the municipality is carried out to such an extreme that not only does the Chinese government maintain a post-office, but so also do all other countries whose citizens operate lines of mail steamers to and from the port. There are thus to be found, in addition to the Chinese post-office, regular establishments of the United States, Great Britain, Germany and Japan, while France has hers in the French concession, at all of which the stamps of the several countries are for sale.

Such in a few words is the political and physical status of that nation and that country on which the attention of the civilized world is focused, and whose development and regeneration will probably be the leading feature of the early years of the new century.

RESCUE WORK IN HISTORY.

By President DAVID STARR JORDAN,

LELAND STANFORD, JR., UNIVERSITY.

AT the November meeting of the Astral Camera Club, Mr. Asa Marvin presiding, Prof. Abram Gridley, the learned master of the Alcalde Union High School, spoke on the unique topic of his proposed 'Rescue Work in History.'

He began with the bold declaration that the two great discoveries, twin triumphs of the human mind, which will make this age memorable, were these, the Banishment of Space and the Annihilation of Time. He proposed to illustrate the results of these discoveries and to show how they could be turned to the advantage of mankind by means of an esoteric foray through the echoing aisles of the past.

"It has been shown by the great Dr. Hickok," said Professor Gridley, "that matter is but a portion of space filled with a modicum of 'force, which is actively engaged in holding itself still.' When this activity becomes passive, matter is no more. Thus as matter has no real existence, space, which is its matrix, is banished also from the category of realities.

"Even more remarkable is the discovery of the famous Dr. Hensoldt that time could be literally 'rolled away as a scroll,' and therefore practically annihilated. This fact is stated in these memorable words: 'We count our time by the rotations of our planet. If you were to go close to the north pole and then travel around it in a westerly direction you could walk back all the lost days of your childhood. And if you are moderately swift-footed you might run around that pole until you caught the earth where it was when Julius Cæsar first landed in Britain or when the pyramids were built."

"Only this year," continued the learned schoolmaster, "has the practical significance of all this been brought to light." Referring to the phenomena of thought-transference, our friend and guide, the venerable sage of Angels, spoke before us these words:

" 'All manner of sensations,' Mr. Dean has told us, 'may be transmitted, and these over any distance or through any time. It is as easy, for example, for me as an adept to speak to Marcus Brutus as for me to speak to the Lama of Thibet, and equally easy for Plato or Ptolemy to speak to me. Through this power I may yet dissuade Brutus from his awful deed or save Cæsar from that ambition through which fall the emperors and the angels. In history nothing is too late and the great tangled fabric of the past is ever open to reconstruction.'

"With all this knowledge gained," said Professor Gridley, "the work of these adepts should not lapse for want of initiates bold enough to act." He proposed that the Astral Club add to its purposes that of serious effort in the direction formerly occupied by space and time. His thought was nothing less than the perfection of the human race through the correction of history. This could be best accomplished by collective personal influence on the lives of great men. The value of such influence all teachers must admit. That it is not too late is now a certain fact, and to work in unison is to do the best work.

Mr. Dean had already devoted many esoteric and soulful hours to this labor, but he had used only the method of telepathy, subtle enough in its action, but not powerful enough for large results. Because it is dependent on etheric vibrations and electric inductions, it is practically ineffective except in settled weather. The turbulent atmosphere of the Middle Ages renders settled communication difficult if one tries to go back far enough for his influence to be worth while. It is also much better to use personal presence than any form of esoteric induction, if the former is possible.

If you wish a thing to be well done, the great Franklin assures us, you must do it yourself, and few of us moderns could speak with higher authority on electrics and etherics than he. The mere extension of a personal aura backward through history, Mr. Dean has privately admitted, fails of the highest results, and nothing short of the best can be satisfactory to the initiates of Alcalde. Still less can we count on projecting such an aura into the future. The forms of men and nations of future centuries are now in Devachan, in the subastral or plasto-nebulose state. A human aura can have little definite influence upon them, especially because, not knowing what influence should be exerted, the sensator would work in utter astral darkness which could yield no tangible result. It is evident that this great work needs the personal presence. How to produce this Dr. Hensoldt's discovery clearly indicates.

If we go around the earth from west to east, as the sun seems to go, we have added one whole day for each revolution. If we go to the high north, the circles grow shorter, and barring certain difficulties in transportation, it is easier to go around. If we ascend to the very pole, which by the aid of the non-friable astral body is not so very difficult to adepts, we find a circle of revolution only a few feet in circumference.

"Let us suppose," continued Professor Gridley, "that we have arrived at the north pole on the first day of August. A single circuit around it to the eastward and we reach the second of August. A dozen circuits and we have August the fourteenth. With the aid of the mechanical skill now so easily acquired it will be easy to prepare an electric turn-table by which these revolutions can be accomplished. This can be set in rotation by the electric force of the Northern Lights. Seated upon its edge and whirled eastward for a dozen minutes, one would find himself, perhaps, in the midst of the twenty-sixth century. Then turning southward to the abodes of men, the adept would be received with the greatest eagerness. To these far-off people, 'the latest progeny of time,' he would appear as a Mahatma wise to overflowing with the lore of bygone centuries. It is even possible that such an invention was already in the hands of the ancient Mahatmas. Of such origin beyond a doubt were the sages or Old Men of the Mountains, who from time to time in the past have appeared in the cities of men, filled with forgotten information and equipped with magic power. Such a one of a surety was Trismegistos, three times greatest, and such was Peter the Hermit and Gautama. In the light of our present knowledge, the appearance of Van Winkle at the town of Falling Waters should be carefully reinvestigated. The explanation currently given is far from conclusive, and the little men of the Catskills were probably of an astral nature and not contemporaneous with the ignorant villagers who scoffed at their existence.

"But far more important than any result from the projection of the personal presence into the future are those derived from its retrojection into the scenes of the past. For this purpose the machinery of the turn-table should be attuned to the greatest possible accuracy. Its movement must be as perfect as that of the finest chronometer. A whirl or two too much or too little might leave the personal presence stranded in an age on which its influence would be wasted. For instance, the attempt to rescue Cæsar from his ambitions or Brutus from his crime would be futile if attempted before Cæsar was born. A single day too late and the whole matter must needs be gone over again from the first, with large chances that the drifting floes of the North may have swept away the turn-table. In such case the painful journey on foot round and round the pole till the desired meridian is reached would be inexpressibly tedious. Even the most eager adept could hardly be blamed if he directed his steps toward his own century and his bodily home. To prevent gross accidents and to secure the best results, therefore, a considerable number of people should cooperate. We should make of the matter a kind of Salvation Army. Seated on the turn-table a hundred adepts could be whirled round and round to the westward, each descending at the time his mission might designate. Miss Jones, for example, would descend in 1776 to gain the confidence of Benedict Arnold and thus save him from his treason. Our friend, Doctor Cribbs, perhaps could descend in the reign of James II., and by a few doses of Swamp Root cure the judge's sad malady and save

England from the strain of the Bloody Assizes. Mr. Marvin could muffle the bell of St. Germain l'Auxerrois and the name of St. Bartholomew would lose its dark suggestion. Miss Lucy Wilkins could leave us to the north of Cologne and in the time of St. Ursula. This good woman could be turned from her useless quest and her sad host of martyred virgins could each become a German Hausfrau. Again, our fair friend from Fidèletown, Miss Violet Dreeme, could find scope for her powers in the rescue of Guinevere. These serve simply as illustrations. We may vary them as we please.

"The preliminary difficulties once surmounted, the auroral turntable once in operation and in the hands of a few hundred adepts, missionaries of the present to the past, the tangled jungles of history would be turned to a field of the Cloth of Gold. By keeping open telepathic connection with the esoteric clubs at home, we can inform the world that is, of the progress of our work, and the changes we make in history could be announced in our schools.

"Grand indeed is our conception," said Professor Gridley, "and it is not far from realization. The initial expense is but a trifle. A few hundred dollars in tense springs, clockwork and dynamos, a table of the finest rosewood and the service of a skilled mechanic, an adept in electricity and skilled in astral impersonation, and it is done.

"More than this," continued Professor Gridley impressively, "all this is already provided. I have here a letter from the editor of the New York Sunday 'Monarch,' an offer of all expenses and a generous salary in return for the first telepathic advices, going back beyond the present century. For each preceding century, the sum will be doubled. I have, indeed, contracted with the great journal for the exclusive account of my interviews with the great Bacon, whose noble but polluted nature it shall be my life work to redeem."

JAMES EDWARD KEELER.

By Prof. W. W. CAMPBELL,

ACTING DIRECTOR OF THE LICK OBSERVATORY.

THE Lick Observatory has lost an ideal director. Astronomy has suffered a loss it can ill afford. Colleagues and friends widespread will miss a companionship which was simply delightful.

James Edward Keeler was born in La Salle, Ill., on September 10, 1857. Ralph Keeler, his first American ancestor, settled in Hartford in 1635. His father, Wm. F. Keeler, was an officer of the original 'Monitor' at the time of its engagement with the 'Merrimac.' His mother (still living) is the daughter of Henry Dutton, former Governor of Connecticut and Dean of the Yale Law School.

In 1869 the family removed from La Salle, Ill., to Mayport, Fla. Here Keeler prepared for college, under the tutelage of his father and his older brother. Here his fondness for astronomical studies was developed. He established 'The Mayport Astronomical Observatory' in 1875-77. It included, at the least, a quadrant, a two-inch telescope, a meridian circle and a clock. Under date of 1875, September 22, his journal records an observed altitude of *Polaris* secured with 'my quadrant.' Other entries read:

"1875, November 14. Sent to Queen last night for lenses for my telescope."

"1875, November 29. Lenses from Queen came to-night; one two-inch achromatic, and two plano-convex lenses for eyepiece."

"1875, December 12. Directed my telescope to the stars, and saw the rings of Saturn for the first time. . . ."

"December 14. Saw the Annular Nebula in Lyra. One satellite of Saturn. . . . All four of the stars in the Trapezium. . . ."

"1876, January 26. Got up at half-past four this morning and applied my telescope to Jupiter for the first time. . . ."

In 1877, at the age of twenty years, he constructed a meridian-circle instrument. The telescope was that of a common spyglass, 1.6-inch aperture and 13.45-inch focus. The axis was turned out of wood. Brass ferrules, driven on the ends of the axis and turned down, formed the pivots. The wooden circle, 13.3 inches in diameter, was graduated to 15′.*

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* Keeler's original sketch of this instrument and his written description of it will be published in the next number of the 'Publications of the Astronomical Society of the Pacific.'

His 'Record of Observations made at the Mayport Observatory' contains beautiful colored sketches of Jupiter, Saturn, Venus, Mars, the Orion Nebula, of double stars and of 'Scenery on the Moon'; and in addition, data of a numerical character. These early drawings are characterized by the refined taste and skill so well known from his later professional work.

Keeler entered Johns Hopkins University late in 1877; and, following major courses in physics and German, he was graduated with the degree of A. B. in 1881. At the end of his freshman year he accompanied Professor Hastings, as a member of Professor Holden's party from the Naval Observatory, to observe the total solar eclipse of July 29, 1878, at Central City, Col. Although his part was the modest one of making a drawing of the corona, his written report on the work is a model scientific paper, and may be read with profit by visual observers of eclipses.

In the spring of 1881 Professor Langley, desiring an assistant in the Allegheny Observatory, requested the Johns Hopkins University to recommend a suitable man for the place. Keeler was named and accepted the appointment, beginning work at Allegheny several weeks before receiving his degree. I was speaking in June of this year (1900) with one of the physicists who had recommended Keeler for the Allegheny position, and the subject of this very appointment came up. "I told Professor Langley," said he, "that one of my strongest reasons for the recommendation is that Keeler doesn't claim to know everything." To the end of his life this charming trait remained unimpaired. It is to Keeler's credit that he largely defrayed his own expenses in college by acting as assistant to some of the lecturers in the experimental courses.

Professor Langley made his noted expedition to the summit of Mt. Whitney, Cal., in June-September, 1881, to determine the value of the 'Solar Constant.' Keeler accompanied the expedition in the capacity of assistant, and carried out his share of the program with skill and efficiency. Returning at once to Allegheny, his work until May, 1883, was closely related to the many problems arising from the Mt. Whitney expedition.

The year 1883-84 was devoted to study and travel abroad. The months of June, July and August, at Heidelberg, were given to the study of light and electricity under Quincke, chemistry under Bunsen, and integral calculus under Fuchs. In the winter semester in Berlin he heard the lectures on physics by Helmholtz and Kayser, on differential equations by Runge and on quarternions by Glan. His main investigation in the physical laboratory was on 'the absorption of radiant heat by carbon dioxide'—a problem suggested no doubt by his Mt. Whitney experiences.

From June, 1884, to April, 1886, Keeler again served as assistant in the Allegheny Observatory, affording most efficient help to Professor Langley in his classical researches on the lunar heat and on the infra-red portion of the solar spectrum.

Early in 1886, on Professor Holden's recommendation, Keeler was appointed assistant to the Lick trustees. He arrived at Mt. Hamilton on April 25, 1886, and immediately proceeded to establish the time service. The telegraph line to San José was perfected, the transit instrument, the clocks and the sending and receiving apparatus at both ends of the line were installed. The signals were sent out on and after January 1, 1887, north to Portland, east to Ogden and south to San Diego and El Paso. In addition to the time service, he assisted the trustees in installing the various instruments.

When the observatory was completed and transferred to the regents of the University of California, on June 1, 1888, Mr. Keeler was appointed astronomer: the original staff consisting of Astronomers Holden, Burnham, Schaeberle, Keeler and Barnard, and Assistant Astronomer Hill.

Professor Keeler was placed in charge of the spectroscopic work of the observatory. The large star spectroscope, constructed mainly from his designs, has no superior for visual observations. Of the many results obtained with this instrument we may mention the observations of Saturn's rings and Uranus, with reference to their atmospheres; of the bright and dark lines in the spectra of γ Cassiopeiæ and β Lyræ; of the color curve of the 36-inch equatorial, and of the spectra of the Orion Nebula and thirteen planetary nebulæ.

His beautiful observations on the velocities in the line of sight of these fourteen nebulæ mark a distinct epoch in visual spectroscopy. His memoir on the subject took its place as a classic at once. The probable error of the final result for each nebula, based on the mean of several observations, is only 3.2 kilometers per second. Attention should be called to one extremely important fact established by these measures, viz., the velocities of the nebulæ in their motion through space are of the same order of magnitude as the velocities of the stars.

The recognition of the fact that a great refracting telescope is also a most powerful spectroscope for special classes of objects, by virtue of the chromatic aberration of the objective, is due to Professor Keeler. Among the first objects observed with the 36-inch equatorial were the planetary nebulæ and their stellar nuclei. The observers were struck with the fact that the focal length for a nebula is 0.4 inch longer than for its stellar nucleus; a discrepancy which Professor Keeler at once explained by recalling that the star's light is yellow, whereas that of the nebula is greenish-blue.

Astronomical readers will remember Keeler's splendid drawings of the planets Saturn, Jupiter and Mars, made with the assistance of the

36-inch telescope during 1888-90. His faithful and artistic drawings of Jupiter have no equal.

He was in charge of the very successful expedition sent by the Lick Observatory to Bartlett Springs, Cal., to observe the total solar eclipse of January 1, 1889.

Professor Keeler resigned from the Lick Observatory staff on June 1, 1891, to succeed Professor Langley as director of the Allegheny Observatory, and professor of astrophysics in the Western University of Pennsylvania. The Allegheny Observatory has perhaps the poorest location of any observatory in this country for spectroscopic work. But in spite of this disadvantage Keeler's investigations continued and promoted the splendid reputation established for the observatory by his predecessor. He comprehended the possibilities and limitations of his situation and his means, and adapted himself to them. His spectroscopic researches were largely confined to the orange, yellow and green regions of the spectrum, since these would be less strongly affected by the smoky sky for which that vicinity is famous.

The Allegheny spectroscope, designed and constructed soon after his acceptance of the position, contained several valuable improvements. The use of three simple prisms in its dispersive train was a departure which has been followed with great advantage in many later instruments. With this instrument he made an extensive investigation of the Orion Nebula and the stars immersed in it, establishing the fact that the nebula and the stars are closely related in physical condition.* His beautiful observations of Saturn's rings, proving that they are a cluster of meteorites—myriads of little moons—have never been surpassed in interest in the entire astronomical field. These observations are so well known to every one interested in astronomy that one sentence suffices. He proved spectrographically, using the Doppler-Fizeau principle, that every point in the ring system is moving with the velocity which a moon would have if situated at that distance from the planet. Professor Keeler's main piece of work at the Allegheny Observatory, on the spectra of the third (Secchi) type stars, remains unpublished, but the measures and reductions are left in an advanced stage.

The regents of the University of California appointed Professor Keeler to the position of Director of the Lick Observatory on March 8, 1898. The ties which bound him and his family to Allegheny were difficult to sever; but the greater opportunities offered by the instruments and the atmospheric conditions at Mt. Hamilton decided him in favor of accepting the appointment. He entered upon his new duties on June 1, 1898.

Without making any rearrangement of the work of the staff, but

* Simultaneous observations of the same object made at another observatory led to the same conclusion.

affording them every possible encouragement to continue along the same lines, Professor Keeler arranged to devote his own observing time to the Crossley reflector. He recognized that the instrument was not in condition to produce satisfactory results. He made one change after another, overcoming one difficulty after another, until, on November 14, he secured an excellent negative of the Pleiades, and on November 16 a superb negative of the Orion Nebula. The enormous power of the reflector in nebular photography was established, and he entered upon the program of photographing all the brighter nebulæ in Herschel's catalogue. More than half the subjects on the program have been completed. The observatory possesses a set of negatives of the principal nebulæ which is priceless and unequaled. These photographs have already led to many discoveries of prime importance; and they furnish a vast amount of material for future investigations of questions bearing especially upon the early stages of sidereal evolution. The photographs record incidentally great numbers of new nebulæ—as many as thirty-one on a single plate covering less than one square degree of the sky. A conservative estimate places the number within reach of the Crossley reflector at 120,000, of which only ten or fifteen thousand have thus far been discovered.

It had previously been supposed that the great majority of nebulæ were irregular and without form, and that only a few were spiral. Professor Keeler's photographs have recorded more spiral nebulæ than irregular ones. This discovery bears profoundly on theories of cosmogony, and must be considered as of the first order.

It is time to refer to Professor Keeler's work as director. I but faintly reflect the views of every member of the staff, and indeed of all who have been interested in the work of this observatory, when I say that his administration was completely successful. He cherished and promoted ideal conditions in this ideal place. He made a success of his own work in a splendidly scientific manner, and he saw to it that every one had all possible opportunities to do the same. No member of the staff was asked to sacrifice his individuality in the slightest degree. Nor were demands made for immediate results: no one's plans were torn up by the roots to see if they were growing. The peace of mind of the investigator, so absolutely essential for complete success, was full and undisturbed. Withal, Professor Keeler's administration was so kind and so gentle—and yet so effective—that the reins of government were seldom seen and never felt.

The elements of his successes are simple and plainly in view. His openness and honesty of character, his readiness and quickness to see the other man's point of view, his strong appreciation of the humorous as well as the serious, and above all, his abounding good sense—these traits made his companionship delightful and charming. Scientifically Professor Keeler never groped aimlessly in the dark. He would not attack a problem until he had as fully as possible comprehended its nature and the requirements for success. With the plan of attack completely considered, and the instruments of attack at hand, the execution of his plans involved little loss of time. The Crossley reflector affords a case in point. Assisted by a fellow in astronomy and by the instrument-maker, he devoted five months to preparing the reflector for turning out the magnificent results which at once followed.

Professor Keeler's published papers have a finish and a ripeness which are rarely seen. His love of the beautiful and his artistic skill are evident in all his work.

To speak of the people who had afforded him encouragement at different times in his life was one of his pleasures. His father's friend, Mr. Chas. H. Rockwell, of Tarrytown, was constant in urging the development of so promising a career. He did not forget Professor Hastings' continual kindness and interest during his college days. He frequently spoke of the great value of Mr. William Thaw's interest and encouragement, both to himself and to the Allegheny Observatory; an interest which was continued after Mr. Thaw's death by other members of his family.

The honorary degree of Sc. D. was conferred upon Professor Keeler in 1893 by the University of California. He received the Rumford Medal from the American Academy of Arts and Sciences in 1898 and the Henry Draper Medal from the National Academy of Sciences in 1899. He was a member of the National Academy of Sciences, an Associate of the American Academy of Arts and Sciences, a Fellow and Foreign Associate of the Royal Astronomical Society, a Fellow of the American Association for the Advancement of Science, a member and officer of the Astronomical and Astrophysical Society of America, an honorary member of the Toronto Astronomical and Physical Society, the president of the Astronomical Society of the Pacific, a member of the Washington Academy of Sciences, and of various other organizations. Professor Keeler was an associate editor of 'Astronomy and Astro-physics' during 1892-94, and editor with Prof. George E. Hale of 'The Astrophysical Journal,' since 1895.

It appears that Professor Keeler had long been a mild sufferer from heart weakness; to run even fifteen steps caused him great physical distress. It is feared that on Mt. Hamilton he worked beyond his strength. His weakness seemed to develop rapidly this summer. He went away from the observatory on July 30, in the best of spirits and with no anxiety, to secure medical treatment and to spend a brief vacation in the northern part of the State. Increasing difficulty in breathing led him to seek skilled treatment in San Francisco on August 10. His dangerous condition was recognized on the 11th, and on the 12th a stroke of apoplexy proved fatal.

Professor Keeler married Miss Cora S. Matthews, at Oakley Plantation, Louisiana, on June 16, 1891. Of her great sorrow and of the grievous loss to the two children it would be futile to speak.

When the dangerous weakness of his heart was discovered by the physicians, Professor Keeler's main regret was that he would have to leave Mt. Hamilton and its opportunities in order to live at a lower altitude. It is known that he had planned his work with the Crossley reflector far into the future. A small spectrograph which he was most anxious to employ on certain interesting spectra was completed on the day of his leaving the observatory.

The absence of one so old in experience and so ripe in judgment will be seriously felt throughout his profession.

DISCUSSION AND CORRESPONDENCE.

SCIENTIFIC AND LITERARY HISTORIANS.

The address of Mr. Thomas Ford Rhodes, president of the American Historical Association, on the subject of history, delivered before the midwinter meeting of that body, and published in the 'Atlantic Monthly' for February, has gone forth to the world with a high degree of authority and impressiveness. Nevertheless, there are some members of the Association—the writer humbly trusts enough to make a large majority—for whom the president does not speak, and who dissent widely from his views.

Mr. Rhodes begins by representing himself as an advocate 'holding a brief for history,' and proceeds to make important concessions to those who refuse it a place in the front rank of subjects of human thought. "It is not the highest form of intellectual endeavor; let us at once agree that it were better that all the histories ever written were burned than for the world to lose Homer and Shakespeare." One more concession yields "to the mathematical and physical sciences precedence in the realm of intellectual endeavor over history." But, having admitted so much, Mr. Rhodes is still of the opinion that the historian's place in the field remains secure. Why he thinks so is not made quite clear. It is true enough that there has never been 'so propitious a time for writing history as in the last forty years'; that 'there has been a general acquisition of the historic sense'; that 'the methods of teaching history have so improved that they may be called scientific'; and that 'the theory of evolution is firmly established.' There is, however, in all this nothing to attract the youth conscious of intellectual strength and brimming with energy and courage to a study which cannot claim to rank among the highest forms of intellectual endeavor. Shall we suppose that the historian's 'place in the field remains secure' only because the giants do not care to wander that way? If so, those who love history better than they love the historians will find little satisfaction in this security.

But, following Mr. Rhodes further, one finds the apparent gist of his contention to be that the new thought throughout the country, which has resulted in better work in almost every direction, has had no such result in historiography; that "with all our advantages" we do not "write better history than was written before 1859, which we may call the line of demarcation between the old and the new," and that Thucydides and Tacitus are still the best models for the historian. The whole address appears to breathe the spirit of a somewhat over-reverent devotion to the Classics, and the hearers may well have imagined that they were listening to an appeal for the study of Greek and Latin. When the Lord of the vineyard comes, there will no doubt be a sufficiently grave indictment against the keepers of the historical portion for the waste they have made of the last eighteen hundred years; but it is hard to believe that they will be found guilty of having failed to improve on the methods of the classical writers.

Has science, then, done nothing for history? Somewhat, even according to Mr. Rhodes himself. In addition to acknowledgments already quoted, he goes on to say: "The publication of the 'Origin of Species,' in 1859, converted it (the theory of evolution) from a poet's dream and philosopher's speculation to a well-demonstrated scientific theory. Evolution, heredity, environment, have become household words, and their application to history has influenced every one who has had to trace the development of a people, the growth of an institution, or the establishment of a cause." Yet it seems that this has not enabled us to equal the excellence of two or three writers who flourished more than two-thirds of the way back to the dawn of European civilization. Let us at least be frank with ourselves, if such be the fact, and not refuse to recognize the disheartening nature of the conclusion.

There are some iconoclasts, however, who will not accept it; and, if they allowed the barbarian that is in them to speak out, in spite of their high respect and deference for Mr. Rhodes, it would probably assert that there is little hope for the elevation of history to the highest rank of intellectual endeavor by champions so imbued with the spirit of the past. He that would show the subject worth the attention of the most gifted, the strongest and the most penetrating minds can be no worshipper before the marble god of the Classics. He must—difficult as the task would seem to Mr. Rhodes—write history better than Thucydides or Tacitus wrote it. But this is, after all, not so difficult if the proper meaning is given to the words. There are several men living who do it. This I fully believe; and I wish to say that the assertion is made in no spirit of defiance to the standards of my generation, but rather in the spirit of respect for these standards as I see them.

There seems, in fact, to lie some subtle poison in the classics whereby their devotees become intoxicated. Their admiration for the ancient languages and literatures, for the civilizations in which their chosen work lies, appears to grow until they lose faith in the present and depreciate it correspondingly. Modern education, which is aimed to fit, rather than to unfit men for the life they must live, to adjust them to their environment rather than to put them out of harmony therewith, would not be wholly unjustified in entering its *caveat* for all who undertake the study of Greek and Latin.

"If indeed there haunt
About the moulder'd lodges of the Past
So sweet a voice and vague, fatal to men,
Well needs it we should cram our ears with wool
And so pace by."

These expressions are not prompted by any sympathy with materialism. I am well aware that humanity fed upon such meat will never be great. But must we look back over two thousand years to find ideals—even in the matter of history writing? It will be a sad day, if it ever come, when the teaching of Greek and Latin shall fail in our universities and men shall cease to study them; but it is certainly unnecessary that the classical measuring rod shall be laid to all the dimensions of modern thought. Shall we not be free? Shall there never be a literary mortmain to lift the dead hand of the classics and leave us at liberty to render service where it is due?

Wherein lies the hitherto unequaled excellence of Thucydides and Tacitus? Not in their superior 'accuracy, love of truth and impartiality'; for 'Gibbon and Gardiner among the moderns possess equally the same qualities.' Mr. Rhodes would doubtless deprecate any suggestion of placing his own name in this honorable company, but I believe it would occur at once to those who are familiar with his works. Certainly it is not difficult for the unprejudiced reader to see in him a conscientious and brave fidelity to the truth that can be found in a higher degree in no historian, ancient or modern.

Nor does the advantage of the classical historians lie "in the collection of materials, in criticism and detailed analysis, in the study of cause and effect, in applying the principle of growth, of evolution," in all of which 'we certainly surpass the ancients.' This with characteristic fairness Mr. Rhodes admits, but it is still his conviction that we have not risen to the classical standard of historiography.

Where, then, is the advantage in favor of Thucydides and Tacitus? The answer of their advocate is that they "are superior to the historians who have written in our century, because, by long reflection and studious method, they have better digested their materials and compressed their narrative. Unity in narration has been adhered to more rigidly. They stick closer to their subject. They are not allured into the fascinating by-paths of narration, which are so tempting to men who have accumulated a mass of facts, incidents and opinions."

Lest this discussion should resolve itself into an unprofitable difference about words, it may be worth while to consider just at this point the meaning of 'better history,' as Mr. Rhodes uses the term. He can hardly mean better from the scientific standpoint; for he admits that our historical science is superior to the ancient. If, therefore, we put that into the history we write, we shall make it better in so far at least. No doubt he means better from the standpoint of historiographic art.

Here lies, I take it, the *crux* of the controversy. Here begins the divergence between the scientific and the literary historians. They differ as to the relative values of the elements they represent, and this difference rests upon another still more fundamental as to the relative values of ancient and modern thought. This will serve to explain the objections I have already made to the attitude of Mr. Rhodes. I would not deny the justice nor the propriety of judging any historical work from the artistic standpoint. It would not be going too far to say that no history which fails when brought to such a test can be called good. But there is no art that can neglect its fundamental science. Other things being equal, that is the best history—even from the artistic point of view—which gives the clearest explanation of the unfolding of national life; and in this respect modern historiography is beyond all comparison superior to ancient. It is, therefore, not conclusive of the preeminent excellence of Thucydides and Tacitus to show the admirable proportion and conciseness of their narratives. If the historians of the present century show some loss in this respect, they do more than make it up by gain in others. It is not enough that the ancient writers of history told so well what they saw and understood; there was so much that they did not see and understand. If historical literature is to be distinguished from other forms and have canons peculiar to itself at all, its expository completeness must be considered in estimating it as good or bad.

It must be confessed, however, that the indictment of Mr. Rhodes against modern historians for prolixity is well-deserved. It could be sustained not only against the historians, but against nearly all book-makers of our time, and is far graver than his degree of emphasis would indicate. Life is short, and there is continually more to be crowded into it. The literature of almost every field of progressive thought is outgrowing the capacity of its workers, who are striving in truly reckless fashion to add thereto each what he can. Conciseness and proportion are, if not the most priceless jewels of all literature, at least their most useful and attractive setting. Blessed is he, and a benefactor of his race, who can deliver his message in few words, and for the rest keep silent.

One other point made by Mr. Rhodes deserves attention, namely, the advantage of writing contemporaneous history. Three difficulties lie in the way of it: First, that of getting the perspective; second, that of so far removing one's prejudices as to see the truth; third, that of telling the truth as seen, in spite of popular prejudice. If they can be overcome, the history of any epoch can be written best by those belonging to it. Mr. Rhodes has himself shown how this can be done. But I do not think that he has established the superiority of Thucydides and Tacitus over modern historians. Their work may excel in conciseness and proportion, but that of the moderns has a more than compensatory advantage in deeper insight and clearer exposition. Partisans of either may fail to see that the shield is silver on one side and gold on the other; or, seeing this, they may fail to agree as to which is the golden side. "Let every man be fully persuaded in his own mind."

George P. Garrison.
University of Texas.

THE RETARDATION OF SCIENCE.

We hear a good deal about the advancement of science. There are huge associations which make it the object of their existence; there are universities, colleges, societies, museums, institutes and laboratories which reckon this as at least one of their aims; and the individual scientific workers, even those who look upon science as

"The milch-cow of the field,
Their only care to calculate how much
butter she will yield"—

Even they, we say, profess to regard science as 'the goddess great,' and base their claim to honor on the service they have rendered to her. And, at this turning year of time, as we indulge in self-complaisant retrospect, we boast that, as a result of all this, science really has advanced. Contradictions, inconsistencies, harkings back: these we frankly admit; but the shattered theories line an onward path, and the discovered errors are lamps on the way of truth. We do well to rejoice; but we shall not do ill to look also at the other side of the shield. Might we not be advancing more rapidly, surely and easily? Are there not opposing forces which combine to effect the retardation of science?

Space need not be occupied by insisting on the inertia of governments, composed of ministerialists rather than statesmen on the lethargy and ignorance of the mass of people; on the curse of Babel, or on any such obvious hindrances to progress. But every scientific student knows that many of the difficulties in his way have no necessity in the nature of things, and that many of them are raised by scientific men themselves. We expect to meet with difficulties when we read a foreign language, but we resent having to ferret out an author's meaning when he publishes in our own tongue. This is what one has to do too often, for a vast number, if not the majority, of scientific men write abominably. It is all very well for the chemist in a factory, or the electrician to a lighting company, to be careless about the parts of speech; it hurts no one except himself and his employer. But for the student who makes researches in pure science, the case is altered. The object of the former is to earn his daily bread, and the sooner the better; the object—professed, at least—of the latter is to enlighten the world. A man may be a profound investigator, and may penetrate far into the mystery of the unknown, but if he cannot give an intelligible report to his colleagues, his travels in the undiscovered country will be disregarded. Worse than this, his fellow-workers waste valuable time in trying to read his riddles or very likely are led astray by his bungling presentation of veritable facts, and so science is retarded.

We do not propose to arouse the anger of our scientific friends by quoting elegant extracts from their writings to support our contention. We pass over the phraseology, to consider the general plan and the details of the arrangement. There are, it is true, masters in science who are also masters of method. But they have gained their mastery of the latter, as of the former, in the school of experience. This would be all very well were it not that we others have to suffer during their apprenticeship. Their immature essays, with all the faults of a beginner, have to be read and reckoned with, and are just as much part of the self-styled literature of science as are their *magna opera*. This would not be worth a complaint were it inevitable; but that is just what it is not. If only scientific people in general could be got to care a little about these things, and if only their opinion could be organized and brought to bear more directly on the evil-doers, improvement would soon follow. The fact is that we are too content to muddle along, and what is everybody's business is nobody's business. Hence the student fresh from college, or while still a pupil, is set to attack some problem in science, which, with the help of his professor, he solves in a satisfactory manner. Then he must print, and here, too often, the help of the professor seems to be lacking. The student has had next to no training in the composition of scientific articles and none in the preparation of work for the press. He does not know how to find the previous literature, and when found he does not know how to quote it. Having no experience in the use of other men's writings, he does not know what to insert, what to omit, or what faults to avoid. He is, perhaps, a good draughtsman, but his media have been pencil and paint, and he has no idea how to do black-and-white work for the photo-engraver. He begins with a title in the style of the eighteenth century, that takes up three lines and leaves you in the dark as to the contents of his paper. Full of enthusiasm and imbibed knowledge, he either plunges into his subject without explaining what his subject is, or else he introduces it by a lengthy 'history,' mostly copied from the last worker that preceded him. He ends with a nicely-rounded period, but you search in vain for a summary of his results.

One cannot be hard on the poor young fellow, who doubtless will do well enough in time; but one can protest against the nonchalance that permits this state of things. There are two sources from which a remedy may spring, and to each we herewith make appeal. First, let the colleges provide instruction in the technique of authorship, just as they provide it in the technique of research. This will not help to swell the flood of publication, too great already; rather it will diminish it, by entailing more rigorous preparation on would-be authors. Let the student be taught the conventional rules that govern the formal aspect of his science, just as he is taught the laws of chemical combination or dental formulæ. In zoology and botany, for instance, he should be taught the rules of nomenclature, or at least those generally followed, and taught how to write the names of animals and plants in the accepted manner. He should be made to study the classical memoirs of great masters from the point of view of presentation—of manner rather than of matter. And even then he should not be turned loose on an unwilling public, but should be practised in writing and drawing for the press, in proof-correcting and so forth. The examiners of doctoral theses should consider their style and arrangement no less than their contents, and, if necessary, should insist on formal alterations being made before they give permission to publish.

So much for the universities. The second source of help lies in the editors, whether of independent periodicals or of publishing societies. The editor has, by tacit agreement, great powers. But in the case of publications devoted to pure science, those powers often seem to be very little used. There is a prejudice against interfering with an author's statement of his case; for here the substance is regarded as everything and the form as nothing, and an editor fears lest, in re-shaping the form, he may hack away an essential portion of the substance. This delicacy is likely to be more appreciated by the author in question than by his readers. The editors of purely scientific publications labor, of course, under a peculiar disadvantage in that both the contribution and the publication of matter are voluntary offices with no binding contract; the editor is often only too glad to get 'copy,' and dare not risk offending a contributor. But the experience of many years in the conduct of many classes of publications has led us to the conviction that the authors most likely to be offended by judicious editing are those whose services can best be spared. Many, and especially beginners, often express their gratitude for editorial advice, and in most cases an editor has only to act *suaviter in modo* to be able to proceed *fortiter in re.* Moreover, in the case of the more serious and technical papers, these positions of author and editor are often reversed, since it is not so easy for an author to get his memoir published, especially with the requisite illustrations. Here, then, the editor has the whip hand, and his power is enhanced if he be acting for a learned society of which the author is a member. In brief, editors, as a rule, have the power, and we beg them to use it. Not every author can have a university training, but all (except the few rich and foolish enough to publish for themselves) must submit their manuscripts to the blue pencil of an editor. We want to see that blue pencil used.

But this leads us to another unfortunate influence tending to retard science, and that is the ignorance and incompetence of editors. We speak as one of the fraternity. How can an editor know the conventions of physicists, of zoologists, of botanists, of chemists, of geologists and all the rest? Specialization has proceeded so far that the editor of a general scientific journal nowadays must have, some may think, either enormous learning or vast audacity. But this is not quite a fair view of the case. Most scientific journals of any importance are, like other journals, run by a large staff of specialists in cooperation with one managing editor. Theoretically, at least, this is the case, as may be seen by reference to the covers of the 'American Journal of Science,' the 'American Naturalist,' 'Science,' and many more. If all these associate editors could be got to do editorial work, the supposed difficulty would vanish. Sorrowfully we admit that even editors do not always act rightly, and that 'Editor, edit thyself!' may be a true reproach. But the realization of a defect goes half-way towards curing it.

To put in few words what we have tried to make clear in these notes: Among the causes tending to retard science is carelessness as regards form and expression. The prevalence of this carelessness is largely due to want of training, and this defect can be remedied. We appeal, therefore, to teaching bodies to insist on instruction in the methods of scientific authorship; and we appeal to editors to exercise their powers in all questions of grammar, lucidity, arrangement and the formal conventions of each science.

AN EDITOR.

SCIENTIFIC LITERATURE.

CHRISTMAS ISLAND.

THOSE areas of the earth's surface outside of the Polar regions which retain their original fauna and flora unmodified by the action of man and the organisms which accompany him in his migrations are very few and are rapidly passing away. It is obvious that it is of great importance that we should know something of the conditions, animals and plants which exist under such circumstances, in order that the effects of the influx of human beings into a virgin wilderness may be determined and recorded.

Opportunities for such researches are very rare and in a few years will be non-existent. A settlement has recently been made upon the isolated bit of land known as Christmas Island, which lies some two hundred miles southwest of the western part of Java and is separated from it by sea which reaches a depth of three thousand fathoms. At the initiative and expense of Sir John Murray, known from his connection with the Challenger expedition, Mr. C. W. Andrews, of the British Museum, was granted leave of absence for the purpose of making a thorough biological survey of this island, and the report which is the result of his observations and collections, assisted by a number of expert naturalists in working up the material, has just been issued by the Museum. It is believed to be the most elaborate account of the animal and plant life of an oceanic island ever published.

The island is of volcanic origin and comprises, beside igneous rocks, a variety of tertiary and recent limestones. Most of the life upon it is of the Malaysian type, the prevalent winds being from that quarter. However, there is a recognizable portion of it which is related to that of Ceylon and another to that of Australia, though the latter country is nine hundred miles away. About ten per cent. of the plants and forty-five per cent. of the three hundred and nineteen species of animal organisms are regarded as peculiar to the island. There are thirty-one species of birds, five of mammals and six of reptiles, of which sixteen are known only from this island. These figures, of course, exclude all pelagic forms. Altogether, many interesting facts have been brought out and several puzzling questions raised in the discussion of the data which form the basis of this valuable report.

PALEONTOLOGY.

THE absence of a text-book on paleontology in English which in any adequate measure reflected the philosophic illumination of modern zoology has long been a subject of regret. The only manual worthy of the name which has enjoyed any wide reputation among scientific paleontologists has been that of von Zittel, published originally in German, but since well rendered into French with some additions. Dr. C. R. Eastman, of Harvard University, having in view a translation of von Zittel's 'Grundzüge,' with the permission of the author, submitted the different sections of the work to various American specialists for revision. The original work was lavishly illustrated with excellent, mostly original figures, which have been utilized in the present translation. The task of revision was undertaken by a number of experts as a labor of love, in the desire that the deficiency in our text-book literature, above referred to, might be done away with and that English-speaking students might possess a work of reference in which modern ideas of classification and of the relations and development of organic life on the globe would find a place. This task presented many difficulties, both for the revisers and for the editor, and one can not but regret that the cost of illustration and the difficulties of finding a publisher for a wholly new work stood in the way of preparing a manual which should be avowedly, as well as practically, independent. The excellent work of von Zittel, good as it is, was designed on the lines of the science as it was a quarter of a century ago. The revision, though in several departments fundamental, is naturally more or less uneven, the restrictions of space insisted on by the publishers and other causes hampering the freedom of treatment desirable, while the composite nature of the work, part of which was stereotyped before other portions were received in manuscript, has inevitably resulted in some incongruities. However, in spite of such minor deficiencies, the result has been the most notable advance in the treatment of invertebrate paleontology as a whole since text-books began to be made. This is especially evident in such groups as the Polyzoa, Mollusca, Brachiopods and Trilobites, in which the illustrations and a part of the bibliography are all that remain of the older work. Any work in which the latest views of large divisions of the animal kingdom are summed up by such experts as Wachsmuth, Ulrich, Schuchert, Hyatt and Beecher must appeal strongly to students and long remain an indispensable aid to science, whether all matters of detail meet with final acceptance or not. Wholesale changes, such as are indicated in several of the groups, might very well be unacceptable to the original author of the work thus modified, but, while suspending his opinion on the advisability of some of the novel methods, Dr. von Zittel, in his preface to the present work, has been moved by the true scientific spirit which, while holding fast to that believed to be good, is ever ready to welcome any new light. The untouched riches of American fossiliferous horizons, especially above the Paleozoic, are almost incalculable, and the existence of Dr. Eastman's valuable text-book can not but be a most important factor in the training of those who will hereafter bring to light the riches now awaiting the advent of paleontological explorers.

ZOOLOGY.

There has been somewhat of a dearth of works on natural history during the past few months. Among those which have appeared is 'Nature's Calendar,' by Ernest Ingersoll, a book intended to stimulate the reader's power of observation by inducing him to note down, day by day, what he sees going on in the world of animals and plants about him. There are twelve chapters, one for each month, in which the author writes pleasantly of what is being done by the more familiar beasts and birds, reptiles, fishes and insects, as well as plants, in an ordinary season in the vicinity of New York. The limits, however, have not been very rigidly drawn, and we read of deer, bears and wildcats, animals not commonly found about that city. We are told, as the case may be, how animals and plants are guarded against extremes of heat and cold, at what time the animals make their appearance, when the woodchuck comes from his burrow and the shad and herring ascend the streams; when they mate; at what time the eggs are deposited or the young come forth; at what time the buds burst and the blossoms open, and of many other occurrences. Each chapter is preceded by a full-page plate, after photographs by Clarence Lown, of some landscape in accord with the text, and at the end of each chapter is a 'calendar,' in which the birds naturally appear in the majority, stating what animals are present, the approximate times at which, if they migrate, they come or go, or the dates on which they go into or come out of winter quarters. The compact text occupies less than half the page, the remainder being left for recording the observations of the reader, who thus becomes a joint author and has the pleasure of seeing whether or not he is in agreement with his collaborateur.

The book is written in a pleasing style and while here and there a little loose in its statements, one should not hold the author too strictly to account, since the very object of the book is to induce the reader to make his own observations and draw his own deductions, and the possibility of proving someone wrong is a great stimulus towards this end.

The recent issue of part four, consisting of 283 pages of text and 392 plates, completes Jordan and Evermann's 'Fishes of North and Middle America,' published as Bulletin No. 47 of the U. S. National Museum. The 'Synopsis of the Fishes of North America,' by Jordan and Gilbert, issued in 1882, was a single volume of 1,074 pages, with no plates, containing descriptions of 1,340 species of fishes; the present work is in four volumes, consisting of 3,528 pages, 240 of which are devoted to the index and 392 plates, and over 3,000 species are described. Naturally, a considerable portion of this increase is due to the extension of the area covered, but still a large part is caused by the increased number of species now known to ichthyologists. The work is in no sense of a popular nature and it goes without saying that it is simply indispensable to the student of North American ichthyology: it will doubtless be many years before any revision of it is attempted. It is not our purpose to review the work—to do that would require much knowledge and much time—but to congratulate the authors on the completion of their task.

Six years ago Mr. Robert Ridgway, at the request of Dr. Goode, undertook the preparation of a work that should do for birds what Jordan and Evermann have done for fishes, give a description of all forms inhabiting North America north of the Isthmus of Panama, including as well the West Indies, the Galapagos and the islands of the Caribbean Sea. Although several times interrupted by the illness of Mr. Ridgway, the manuscript of the first volume is now ready for the printer and the second is so far advanced that it will probably be completed by the end of the year. The outlines for the entire series, which will, it is estimated, fill seven octavo volumes of 600 pages each, are drawn up, and several of the other volumes are well under way.

The total number of species and subspecies to be treated is, roundly speaking, 3,000, and the first volume, devoted to the *Fringillidae*, comprises descriptions of over 370 species and subspecies. There are keys to the families, genera and species, and besides a careful technical description and very full synonymy, the range of each species is given; all extra-limital families are included in the keys, but extra-limital genera and species only when their number is small. As much more work has been done in ornithology than in ichthyology, the synonymy will be much more extensive than in Jordan and Evermann's 'Fishes of North and Middle America,' and as particular attention has been given to the verification of references and ascertaining the original spelling of generic and specific names, this part of the work has necessitated an amount of labor that can only be appreciated by those who have been engaged in similar tasks. In addition, the type locality of each species and the present location of each type has been given whenever it could be ascertained.

The work is based on the collections of the U. S. National Museum, but much material has been examined belonging not only to other museums, but to private individuals who have generously placed their specimens at Mr. Ridgway's disposal. The collections of the Biological Survey of the Department of Agriculture have been particularly helpful in the case of Mexican species.

AGRICULTURE.

'The Use of Water in Irrigation' is the title of an extensive bulletin just issued by the U. S. Department of Agriculture, under the authorship of Prof. Elwood Mead, expert in charge of irrigation investigations, and C. T. Johnston, assistant. It embodies the results of extensive investigations conducted last year with the assistance of a number of collaborators in ten States of the arid region and presents an array of data on the use which is being made of water under different systems of management, such as has never before been collected for the irrigated region of this country. It constitutes a part of the irrigation studies which are being carried on under the U. S. Department of Agriculture.

To many readers the lavish prodigality which has characterized the diversion and application of water for irrigating will come as something of a surprise, when the paramount importance of water in developing the arid country is considered. This has been fostered by the fact that "the laws which govern appropriations of water from streams have, in most cases, no relation to the actual practice of irrigation and therefore fail to secure either the systematic distribution or best use of the available supply." Ditches diverted more water than was used; their owners claimed more than they could divert, while decrees gave appropriators titles to more water than the ditches could carry and many times what the highest floods could supply. Little was known as to the quantity of water needed to irrigate an acre of land, and in the absence of such information the ignorance and greed of the speculative appropriator had its opportunity.

In the investigations reported, farmers whose fields were under observation were instructed to use water as they had hitherto been in the habit of doing. The result of the measurements of the water used showed very forcibly the influence of waste in lowering the 'duty of water' and of care and skill in increasing it. They confirm the conviction long held by students of the subject that the amount of water used in practice bears no definite relation to the requirements of the crop, but is subject to the whim of the individual and the supply of water provided by the contract with the canal company. For instance, the average amounts of water used in different part of New Mexico varied from less than three feet to nearly seven feet. This was independent of the rainfall. In many cases the farmers using the least water got quite as good crops as those who used enormous quantities. On some soils which were not well drained there was a very marked injury from excessive irrigation. In the Boise Valley in Idaho it was found by measurement that fully one-half the water now diverted by canals is wasted under present methods. Apart from the losses from extravagant use of water, there are heavy losses, under present management, from evaporation and seepage from the canals. The average of the measurements made show the loss from this source to be fully thirty per cent. Mr. Mead expresses the conviction that throughout the sections where measurements were made last year it will be possible, through improved methods, to double the average duty of water now obtained, so that the quantity now required for one acre will serve to irrigate two.

The importance of this becomes more strikingly apparent when it is remembered that there is a limit to the amount of land which can be reclaimed with the available water supply, generally estimated at about seventy million acres, or approximately one-fifth of the arid region, and that the thousands of miles of canals and laterals thus far constructed have only reclaimed an area approximately as great as the State of New York.

The results reported in this bulletin

not only furnish the basis for improving the existing methods of irrigation and for framing more equitable laws, but they indicate the lines along which investigation should be directed.

THIS year marks the twenty-fifth anniversary of the establishment of agricultural experiment stations in the United States. Beginning with a single station in Connecticut in 1875, the number has steadily grown until to-day we have a system of experiment stations embracing every State and Territory in the Union. The history of this movement and the present status of the stations is the subject of an interesting and attractive volume of over six hundred pages, prepared by Dr. A. C. True, director of the Office of Experiment Stations, and Mr. V. A. Clark, assistant, and published by the United States Department of Agriculture. It is a comprehensive account of the evolution and development of the experiment station enterprise; the organization, lines of work and equipment of the stations; some of the more striking results of practical application which they have attained; and a description of each of the fifty-six stations individually. These latter descriptions are illustrated by one hundred and fifty-three plates, showing the buildings, fields, laboratories, herds, etc., of the different stations. The greatest impulse to the station movement was given by the passage of the Hatch Act, in 1887, providing for the establishment of experiment stations in connection with the land-grant colleges, and appropriating $15,000 a year to each State and Territory for their maintenance. At that time there were some twelve stations, a part of which received regular State appropriations. During 1888 stations sprang into existence rapidly all over the country, and in a surprisingly short time these stations had justified the expectations of their advocates and proved their usefulness to the agriculture of the country.

During the past ten years more than ten million dollars have been expended in their maintenance, seven million of which has come from the Federal Government. Dr. True reviews the manifold benefits which have come from their operations, and points out their value in (1) the introduction of new agricultural methods, crops or industries, and the development of those already existing; (2) the removal of obstacles to agriculture, such as diseases of plants and animals, injurious insects and other natural enemies; (3) the defense of the farmer against fraud in the purchase of fertilizers, feeding stuffs, insecticides and in other ways; (4) aiding in the passage and administration of laws for the benefit of agriculture; and (5) in an educational way. Brief as this summary necessarily is, it brings out very forcibly the wide range of usefulness of the experiment stations to the farming community, touching nearly every phase of agricultural operation, and their very potent influence in arousing widespread interest in the various forms of agricultural education. "The stations are not only giving the farmer much information which will enable him to improve his practice of agriculture, but they are also leading him to a more intelligent conception of the problem with which he has to deal, and of the methods he must pursue to successfully perform his share of the work of the community and hold his rightful place in the commonwealth." One large result of the educational work of the stations has been the general breaking down of the popular conception that agriculture is not capable of improvement through systematic and progressive researches in its behalf conducted on scientific principles. "There is now in this country a much keener appreciation than heretofore of the fact that the problems of agriculture furnish adequate opportunity for the exercise of the most thorough scientific attainments and the highest ability to penetrate the mysteries of nature."

Considered merely as organizations for the advancement and diffusion of knowledge, the stations have attained to an important position. They now include upon their staffs nearly seven hundred persons, who constitute a body of organized scientific workers such as is hardly to be found in any other field of investigation. While they are laboring primarily for the advancement of applied science, they have made a quite large number of important contributions to the sciences, and their investigations are followed with interest by workers in similar lines the world over.

The past history of the stations gives every assurance of increasing strength and efficiency in the future. They have passed through the formative period of their existence, and year by year have secured a better equipment and more thoroughly trained officers. "The people generally have come to regard the stations as permanent institutions, and are convinced of the usefulness of their work. They will, therefore, enter upon the twentieth century with bright prospects for the development of their researches in scientific thoroughness and accuracy and for the securing of larger practical results."

The lastest addition to the list of experiment stations is the Alaska Station, which was established last year, with headquarters at Sitka. Some preliminary work to determine the practicability of conducting station work there was carried on the year previous. The report of the operations of the Alaska Station for 1899 has recently been issued by the United States Department of Agriculture.

It is only recently that Alaska has been regarded as possessing agricultural possibilities. Potatoes and a few other vegetables were grown in a small way by some of the settlers and at a few missions, but for more than a quarter of a century after Alaska became a part of the United States no effort was made to encourage agriculture. It was not until the discovery of gold in Alaska attracted a large number of people there and created a demand for foodstuffs that any interest was manifested in the study of its agricultural capabilities, or in the attempt to establish there at least sufficient agriculture to meet a considerable proportion of the needs of its population. The results of the experiments carried on by the Alaska Station have been a surprise to those who have regarded the country as suited only to the fisheries, the fur trade and mining. Professor Georgeson's report shows that vegetable growing in Alaska is no longer a matter of experiment. "It has been abundantly proved that all the common, hardy vegetables which are grown in the gardens of the States, such as potatoes, cabbage, cauliflower, kale, peas, onions, carrots, parsnips, parsley, lettuce, celery, radishes, turnips, beets and the like, in their numerous varieties, can be grown in Alaska to a high degree of perfection and attain a crispness and delicacy of flavor which is rarely equaled in the best farming regions of the States, because they are there very frequently dwarfed and toughened by drought and heat." He has also shown that in Southeastern Alaska and in Cook Inlet oats, barley, buckwheat and spring wheat will mature with careful culture. Flax has been grown for two years with marked success, indicating that the climate is particularly favorable for flax growing. In addition to the native grasses, which grow luxuriantly, a long list of forage plants have been successfully grown, and Professor Georgeson asserts that it is safe to depend on growing an abundance of feed for live stock every year, which leads him to believe that dairying, beef, mutton and wool production are assured of success. Thus far the experiments have been confined to the southern coast of Alaska, but the present season work will be undertaken in the Yukon district and at other places in the interior.

PHILOSOPHY.

The appearance of a book by the veteran Dr. Hutchinson Sterling, from whose 'Secret of Hegel,' published in 1865, the rise of the neo-rationalist school in Britain and the United States dates, is always welcome. And, even if scientific students lay up old scores against him for his attack on Huxley, and for his more recent, suggestive, though unfair assault on the Darwinians, they must remember that he represents one type of contemporary thinking favored by a large and influential group; they must remember, too, that he was trained as a physician and has competent first-hand knowledge of the scientific standpoint. The present work—'What *Is* Thought,' published by the Blacks in Edinburgh, and imported by the Scribners—although highly metaphysical, in the Hegelian sense, contains not a little interesting material. The early chapters, on 'Substance,' the 'Ontological Proof,' 'Self-consciousness,' and the like, summarize views familiar to philosophical students, and known more or less to scientific men through such books as Prof. Ritchie's 'Darwin and Hegel,' and Prof. Watson's 'Kant and his English Critics.' Fortunately, these chapters occupy but a third of the volume. The three hundred pages devoted to some account of the development from Kant, through Fichte and Schelling, to Hegel, are more important, and present, in some aspects, the best statement of the subject at present available in English. The long chapter on Kant is full of points demanding consideration from thoughtful scientific workers; while the estimate of the relations between Schelling and Hegel must be held of exceptional value. No doubt, the book is hard reading; all Dr. Sterling's works are, for he has never been able to rid himself of the curious Carlylese style that so strongly marked his first, and greatest, effort. Nevertheless, all the old vigor and all the power remain. It may be added that the book appeals very specially to students of the history of European thought in the nineteenth century—a subject which, particularly as concerns the relation between the sciences and philosophy, is very far from being understood as yet.

It is not easy to speak of the English translation from the German version of the Danish original of Höffding's 'History of Philosophy.' Professor Höffding's work is admirable, as all know; the translation—well, the less said of it, the better. We dismiss it with but one comment. The most laughable of the translator's numerous errors happens to be venial, as too many others are not. He tells us that Geulincx died at Pesth. Knowing of the Dutch philosopher's sojourn in Lyons, but being in ignorance of a visit to Pesth, one naturally turned to the original, and found Höffding recording that Geulincx died of the plague (*pest*)! This is fit companion for the similar error (now classical) whereby the Wolffian psychology (*wolffischen Psychologie*) was Englished as *animal* psychology. *Pest* and Pesth obviously bear much the same relation to each other as Wolff and wolf! This may be sublime, it is hardly translation. One may venture to express a hope that the publishers will see to a thorough revision by a competent hand. The work is far too important to be left thus; moreover, we are unaccustomed to associate such a performance with the house of Macmillan. As compared with other histories of philosophy, Höffding's possesses quite peculiar attractions for those whose main interests lie in the direction of science. The space at disposal compels the briefest statement of these points. In the first place, then, Höffding devotes great attention to the formation and import of the Renaissance view of the universe. He bears it specially in mind that this view was evolved as much, if not more, by science than by philosophy. Consequently, Copernicus, Galileo and Newton take their places alongside Descartes, Spinoza and Leibnitz. The importance of this method of treatment can hardly be exaggerated to-day. For one of the main problems at the moment is nothing more than a determination of the extent to which 'modern thought' is still controlled by the cosmic conceptions and categories of the sixteenth, seventeenth and eighteenth centuries. In the same way generous consideration is accorded to thinkers who are passed over with scant ceremony in the ordinary text-books. Bruno, Bacon and Kepler are instances of this. The same appreciation of the immense importance of science for philosophical inquiry marks the perspective in which nineteenth century workers are placed. Kant, who is more influential for science than any other thinker, receives very full discussion—a discussion, too, which however one may dissent from it, as the present writer dissents, bears everywhere the traits of prolonged study and of first-hand acquaintance with the principal primary sources. Similarly, the English school of Positivists, elbowed out in the country of its birth as it has been by a metaphysicising Hegelianism, is restored to its true importance, and the post-Kantian rationalism, that has ousted it, is bidden come down lower. In a work so extensive there are, of course, many points on which one can not agree with the distinguished author. For example, his conception of the relation between Descartes and Spinoza requires revision; he makes too much of Bruno; he has not reasoned the standpoint of Copernicus out to its logical conclusion; Hobbes and Rousseau get more than their due, and Hume less; the peculiar genius of the English school, particularly as represented by Locke, does not seem to have been caught. But, after all, these are defects which appear to the expert and do not seriously mar the book as a whole. For the scientific man, it is the best presentation of the constructive development of philosophical theory from the Renaissance till within the last twenty-five years.

THE PROGRESS OF SCIENCE.

It is frequently said that the days of the discovery of general principles and far-reaching laws are past, and that students of science are now settling down to minor questions and the elaboration of details. The amount of specialized work, unproductive of immediate result in general truths, is naturally increasing, both because of the assiduity of scientific workers and because each general truth brings a number of minor problems. But the acquisition of wide theories is by no means at an end when we are told, as we have been during the last year, that the nebular hypothesis of Laplace is at variance with the facts; that the atoms are made up of smaller bodies whose nature can be known; that inertia and gravitation are not special facts by themselves, but are the results of the electrical charges of bodies. In papers in the *Journal of Geology* and the *Astrophysical Journal*, Prof. T. C. Chamberlin and Dr. F. R. Moulton seek to show that the nature of the earth's atmosphere is not compatible with the traditional idea of the formation of the earth from a hot gaseous ring; that the force of gravity would not cause such a ring to form a sphere; that the matter given off by a rotating spheroid of gas would not go off in the form of rings, and that the present mechanical arrangement of the solar system could not be derived from a spheroidal nebula such as Laplace assumed. It is suggested that the spiral nebulæ may offer conditions analogous to those of our own solar system in its early stages. The hypothesis receives confirmation from the important paper published just before his death by Keeler, and described by Professor Campbell in the obituary notice published above. Keeler's beautiful photographs with the Crossley reflector, several of which are reproduced by Professor Newcomb in the opening article of this issue of the Monthly, indicate that most nebulæ are in fact spiral.

Recent researches in molecular physics threaten to disqualify the time-honored position of the atoms as the smallest known particles of matter and to push the analysis of material substances to a point where the dreams of a primary order of sub-atoms or corpuscles whose varying combinations shall account for the so-called 'elements' seems almost probable. The work of Prof. J. J. Thomson and others on the electrical condition of gases has resulted in the hypothesis that the ions or bodies carrying the electric charges are not greater than one-thousandth the mass of the hydrogen atom; further, that the mass of each ion is the same in the case of all the gases tried, regardless of their atomic weights. The latter statement indicates that atoms of totally different constitution yet consist of corpuscles that are alike at least in mass. Although the experiments and reasoning which have led to these conclusions are beyond the comprehension of any but the specialist, and so cannot be suitably given in this connection, it should be remembered that the conclusions are far from being mere speculations. On the contrary, they are the result of the most careful experimental work, accord well with a number of facts and have already been tentatively applied to the explanation of other phenomena. Thus, Dr. Reginald A. Fessenden has arrived at certain far-reaching hypotheses concerning the possible explanation of inertia and gravitation in terms of electric charges. In a recent issue of *Science* he writes: "We thus find that both inertia and gravitation are electrical effects and due to the fact that the atom consists of corpuscular charges. The constant ratio between quantity of inertia and quantity of gravitation, for a given body, is thus explained. We may state the theory thus: The inertia of matter is due to the electromagnetic inductance of the corpuscular charges, and gravitation is due to the change of density of the ether surrounding the corpuscles, this change of density being a secondary effect arising from the electrostatic stress of the corpuscular charges."

We are able to publish in the present issue of this Journal an article on China, by Mr. William Barclay Parsons, which represents the best knowledge obtainable from recent and accurate observations. The present political crisis has called forth other articles, and books will be forthcoming, giving a certain amount of reliable information in regard to the physical and social aspects of the country. Still, the difference between Eastern and Western civilization becomes apparent the moment any definite question is asked about the natural resources or social conditions of China. Almost any fair question of this nature about our own country would meet with a ready and reasonably complete answer from some one of the government bureaus or from general scientific literature. When it is asked about China we obtain in general only opinions of travelers, missionaries or other foreign residents, opinions based on vague data and guided usually by mediocre scientific training. On what is perhaps the most important questions of all: What is the mental and moral make-up of the Chinese people? How will they act singly or collectively under given conditions? we get even less accurate judgments than we do on the mineral resources, the fauna and flora, etc. It is a pity that the sciences of human nature are not far enough advanced to make it practicable to send a body of anthropologists and psychologists to China to examine and diagnose the mental capacities and proclivities of the race. Even as things are, such a report would be worth something as a supplement to the impressions of those who have written about China. It might be assumed from the general principles of the theory of evolution that races which have for many centuries been subject to a nearly constant environment will be greatly disturbed by new conditions. It is not surprising that the native tribes of America and Australasia should be exterminated. On the other hand, rabbits imported into Australia and negroes imported into America have flourished, and the Japanese have adapted themselves to a new civilization in a marvelous fashion. Common-sense and science are in equal measure unable to foretell what will happen to China and its peoples.

It will be remembered that the late Dr. Alfred Nobel bequeathed nearly all his great fortune, estimated at ten million dollars, for the establishment of five prizes. The exact terms of his will, which have only recently been made public, are as follows:

The capital, converted into safe investments by the executors of my will, shall constitute a fund the interest of which shall be distributed annually as a reward to those who, in the course of the preceding year, shall have rendered the greatest services to humanity. The sum total shall be divided into five equal portions, assigned as follows:

1. To the person having made the most important discovery or invention in the department of physical science.
2. To the person having made the most important discovery or having produced the greatest improvement in chemistry.
3. To the author of the most important discovery in the department of physiology or of medicine.
4. To the author having produced the most notable literary work in the sense of idealism.
5. To the person having done the most, or the best, in the work of establishing the brotherhood of nations, for the suppression or the reduction of standing armies, as well as for the formation and propagation of peace conferences.

The prizes will be awarded as follows: For physical science and chemistry, by the Swedish Academy of Sciences; for works in physiology or medicine, by the Carolin Institute of Stockholm; for literature, by the Academy of Stockholm; finally for the work of peace, by a committee of five members, elected by the Norwegian Stortung. It is my expressed will that nationality shall not be considered, so that the prize may accrue to the most worthy, whether he be a Scandinavian or not.

The organization for executing this will has, after an interval of about three years, been completed, and its nature has been formally announced in an official communication to our government. Nobel's intentions have not been exactly carried out, the chief deviations being that part of the money is used for the establishment of certain Nobel institutes, the objects of which are not exactly defined. On these institutes and on the incidental expenses of awarding the prizes, one-fourth of the income may be expended. Further —and this seems to be in direct violation of the provisions of the will— prizes need be given only once in five years, and the money thus saved may be used to establish special funds 'to encourage otherwise than by prizes the tendencies aimed at by the donor.' It is to be hoped that the administrators will make only judicious use of these provisions, for Nobel's purpose to establish for eminence in science and literature a few rewards as munificent as the world gives in politics, war or business is too wise to be neglected. Any attempt to divert the funds to the encouragement of local institutions or to the education of inferior men should be carefully guarded against. Nobel's will explicitly ordered that the money be awarded in prizes for eminence and without any consideration of nationality.

New York University received early in the year a gift of $100,000 from Miss Helen Gould for the erection of a Hall of Fame. On the colonnades are to be inscribed the names of the most eminent Americans, and thirty of these have recently been selected by the Senate of the University, in accordance with the votes of certain prominent men selected as judges. Ninety-seven of these handed in their votes, and the following eminent Americans received the majority required: George Washington 97, Abraham Lincoln 96, Daniel Webster 96, Benjamin Franklin 94, Ulysses S. Grant 92, John Marshall 91, Thomas Jefferson 90, Ralph Waldo Emerson 87, Robert Fulton 85, Henry W. Longfellow 85, Washington Irving 83, Jonathan Edwards 81, Samuel F. B. Morse 80, David Glasgow Farragut 79, Henry Clay 74, Nathaniel Hawthorne 73, George Peabody 72, Robert E. Lee 69, Peter Cooper 69, Eli Whitney 67, John James Audubon 67, Horace Mann 67, Henry Ward Beecher 66, James Kent 65, Joseph Story 64, John Adams 61, William Ellery Channing 58, Elias Howe 53, Gilbert Stuart 52, Asa Gray 51. It will be noticed that the list contains four inventors—Robert Fulton, S. F. B. Morse, Eli Whitney and Elias Howe—while there are but two scientific men—J. J. Audubon and Asa Gray, unless Benjamin Franklin be included. The judges probably were more interested in birds and flowers than in the history of science in America. Audubon and Gray should certainly be included in a list of eminent scientific men, but not to the exclusion of Benjamin Thompson (Count Rumford), Joseph Henry and others. Twenty further names are to be added in 1902 and thereafter five at intervals of five years.

The papers and discussions before many of the congresses of the Paris Exposition were technical in character, as is demanded by the advanced and specialized state of the sciences, but there also met at Paris during August and September a number of congresses devoted to the mental and social sciences which perhaps presented more aspects of interest to those who are not special students. The only one of these congresses that can be noted here is that devoted to psychology, a science intermediate, in its present state of development, between the exact sciences and those subjects in which individual opinions are more prominent than ascertained facts. About three hundred students of psychology attended the fourth international congress, which met in seven sections, namely: (1) Psychology in its relation to anatomy and physiology; (2) Introspective psychology in its relation to philosophy; (3) Experimental psychology and psychophysics; (4) Pathological psychology and psychiatry; (5) Psychology of hypnotism and related phenomena; (6) Social and criminal psychology, and (7) Comparative psychology and anthropology.

Among the subjects discussed by the Psychological Congress was the establishment at Paris of a 'Psychical Institute' under the auspices of an international society. This Institute proposes to do for 'psychics' what the Pasteur Institute does for biology and pathology. According to M. Janet, its aims are: (1) To collect in a library and museum all books, works, publications, apparatus, etc., relating to psychical science; (2) To place at the disposal of researchers, either as gifts or as loans, according to circumstances, such books and instruments necessary for their studies as the Institute may be able to acquire; (3) To supply assistance to any laboratory or to any investigators, working singly or unitedly, who can show that they require that assistance for a publication or for a research of recognized interest; (4) To encourage study and research with regard to such phenomena as may be considered of sufficient importance; (5) To organize lectures and courses of instruction upon the different branches of psychical science; (6) To organize, as far as means will allow, permanent laboratories and a clinic, where such researches as may be considered desirable will be pursued by certain of the members; (7) To publish the 'Annales de l'Institut Psychique International de Paris,' which will comprise a summary of the work in which members of the Institute have taken part and which may be of a character to contribute to the progress of the science. The Institute aims to cover the whole field of psychology, but it appears from the discussions and from those who are interested in the movement that it will favor those more or less occult phenomena which go under the name 'psychical.' Thus the American members of the committee are Prof. J. Mark Baldwin, Prof. J. H. Gore and Mr. Elmer Gates, which is as if the committee on a pathological institute consisted of one physician, a lawyer interested in homeopathy and a faith curist.

The experiment demonstrating the relation of mosquitoes to malarial fever, undertaken under the auspices of the London School of Tropical Medicine, has apparently been successful. Its somewhat dramatic character and wide advertisement in the daily papers will prove of benefit both in leading people to take precautions to avoid infection by mosquitoes and in leading to increased appreciation of the importance of experiments in medicine. Drs. Sambon and Low, who have been living in a hut in one of the most malarial districts of Italy since last June, drinking the water, exposed to the night air and taking no quinine, have so far been entirely free from malaria. The converse of the experiment has been equally successful. Dr. Patrick Manson's son, who had never suffered from malaria, allowed himself to be bitten in London on three occasions by mosquitoes fed in Rome on patients suffering from malaria. He suffered an attack of fever and the tertian parasites were found in his blood. Americans, and especially readers of this journal, may be interested to learn that the earliest article on the relation of mosquitos to malaria was published in the Popular Science Monthly for September, 1883. Prof. A. F. King, still living in Washington, contributed an article entitled

'Insects and Disease—Malaria and Mosquitoes,' in which, after calling attention to the then recent researches of Dr. Patrick Manson, in China, and others, proving that the mosquito acts as an intermediary host of *Filaria sanguinas hominis*, he proceeds to point out in detail the connection existing between mosquitoes and malaria. Nineteen special arguments are marshaled, several of which deserve consideration at the present time. Among the points urged by Dr. King is the fact that malaria is prevented by mosquito nets, a statement being quoted to the effect that "on surrounding the head with a gauze veil or conopeum the action of malaria is prevented and that thus it is possible to sleep in the most pernicious parts of Italy without hazard of fever." This was, of course, written long before Laveran discovered *Plasmodium malariae*, and before exact experiment was possible, but Dr. King deserves much credit for bringing together so much evidence in favor of a theory the correctness of which could only be demonstrated twenty-seven years later.

THE proper standard for atomic weights has occasioned controversies among chemists for nearly a century, but at last bids fair to be settled, through the practical agreement of an international committee, under the auspices of the German Chemical Society. The original standard, proposed by Berzelius, was the weight of the oxygen atom taken as 100. This gave rise to very large numbers, in the case of numbers with high atomic weights, and gradually the use of hydrogen = 1 came to supersede that of oxygen = 100. So long as it was assumed that the oxygen atom was exactly sixteen times as heavy as the hydrogen atom, this standard was satisfactory. With increasing refinement of analytical work, it began to appear that the atomic weight of oxygen, with reference to hydrogen, was slightly less than sixteen. For some time the exact figure was supposed to be 15.96. This necessitated a recalculation of the atomic weights of all the elements, for they are for the most part determined with reference directly to oxygen or chlorin, and only indirectly with reference to hydrogen. As it was certain that the final word had not been said as to the atomic weight of oxygen, the suggestion was made by a few chemists to use as a standard *oxygen* = 16. The first article published advocating this new standard was by Dr. F. P. Venable, of the University of North Carolina, in 1888. Discussion was particularly aroused in the German Chemical Society by Professor Brauner, of Prague, who was strongly supported by Ostwald and opposed by Meyer and by Seubert. The latter, who is one of the great authorities on atomic weights, has since come to the support of *oxygen* = 16. The recent report of an international committee representing chemical societies of eleven countries (America, Belgium, Germany, England, Holland, Japan, Italy, Austria, Hungary, Sweden, Switzerland), showed forty in favor of *oxygen* = 16, seven opposed, while two wanted both standards. Except one American, none were opposed but Germans, and the German vote was a tie between the two standards. The objections raised against using *oxygen* = 16 as a standard seem to be solely from a didactic standpoint, in having something other than unity as a standard. It was clearly pointed out by Dr. Venable in his second paper that there was no necessary connection between the standard and unity. Some objectors would take oxygen as unity, but this would be impracticable, as it would make such radical changes in the numbers now in use. An additional reason for the newer standard is that a large proportion of those weights most frequently used approach very closely to whole numbers, a point of no slight advantage to the technical chemist. While the small minority of the international committee are making a vigorous protest against the decision of the majority, it seems probable that this decision will be concurred in by most chemists throughout the world.

Foreign men of science have a pleasant custom of celebrating the long service of their colleagues. Giovanni Virginio Schiaparelli was born in 1835, and in June, 1860, he was appointed one of the astronomers of the Observatory of Milan. In June, 1900, thirty-six Italian astronomers joined in a memorial to him which has been handsomely printed in a pamphlet of eighty-eight pages. On November 1 of this year Schiaparelli is to retire to private life, after more than forty years of active service. For thirty-eight years he has been director of the observatory at the Brera palace, which, by his researches, has been raised to a very high rank. His first observations were made with quite small instruments, but his successes with limited means finally brought splendid modern instruments to his observatory. His earliest examinations of planets (1861) were made with a small telescope of only four inches aperture. For many years he employed a telescope of eight inches, but since 1887 he has had at his disposition a refractor of eighteen inches —one of the powerful telescopes of the world.

Schiaparelli is best known to the world at large by his long continued and very successful observations of Mars. It is not too much to say that his work has revolutionized our notions of the physical conditions existing on that planet. It is more than likely that some of his conclusions will have to be revised; and it is certain that some of his less cautious followers have drawn conclusions that the master's observations do not warrant. However this may be, his own work has a high and permanent value. Astronomers rate other researches of Schiaparelli's quite as highly as his studies of the planets. The relation between comets and meteor-showers was most thoroughly worked out by him; we owe to him also thousands of accurate observations of double stars; as well as a great number of important researches on many and various questions of mathematics, physics and astronomy. It is interesting to note, here and there, in the list of the 206 memoirs which he has published, certain papers of an antiquarian and literary turn—on the labors of the ancients before Copernicus; Græco-Indian studies; on the interpretation of certain verses of Dante, etc. The nomenclature of his topographical chart of Mars, among other things, proves the accuracy and elegance of his classical learning.

He has been rewarded for a long and laborious life by the respect and admiration of his colleagues and by the continued interest of the larger public in his discoveries. Academies of science all over the world (with the singular exception of America) have elected him to membership and have awarded their medals and other honorary distinctions, and he has been decorated with orders of knighthood by Italy, Brazil and Russia. Finally, he is a life-senator of the Kingdom of Italy.

These tokens of particular appreciation and his widespread popular reputation are the rewards of a life devoted strictly to science. He has not gone out of his way to seek applause, though it has come to him in full measure. The graceful tribute of his colleagues signalizes his retirement from his official position, but we trust that he may be spared for many years to devote his genius to the science he has so greatly forwarded.

The New York Central and Hudson River Railroad still announces in its time tables that the Empire State Express is the fastest regular train in the world; but this appears to be no longer correct. The Empire State Express traverses the distance from New York to Buffalo, about 440 miles, in eight hours and fifteen minutes, or at a rate of 53.33 miles per hour. The Sud Express on the Orleans and Midi Railway travels from Paris to Bayonne in eight hours and fifty-nine minutes. The distance is in this case 466¼ miles, the speed, including the time taken by six stops, is 54.13 miles per hour. The engine of the New York Central Railroad has, however, a heavier load and is checked by necessary slacking as it passes through crowded streets and past level crossings. The fastest long-distance train in England is 'The Flying Scotsman,' which goes from London to Edinburgh, a distance of 393½ miles, at a rate of 50.77 miles per hour. The United States holds the record for short distances in the run from Camden to Atlantic City, which is made by the Philadelphia and Reading Railroad at a rate of 66.6 miles per hour and by the Pennsylvania Railroad at a rate of 64.3 miles per hour. There is a considerable number of trains run at these rates or nearly as fast, and the rate is sometimes as great as eighty-eight miles an hour for distances of twenty miles. England seems to be now distinctly inferior to France and America in the speed for both long and comparatively short distances, although the road-beds are better, and although they do not have to contend with level crossings and runs through streets. The greater speed of the American trains appears to be due to the superiority of the engines. It is a fact that the speed of railway trains has increased little in recent years—scarcely at all in Great Britain for thirty years. If more rapid transit is required it will probably be found in the use of light trolley cars. There seems to be no technical difficulty in establishing a ten-minute service between Jersey City and Philadelphia, the time being reduced to one hour.

Among recent events of scientific interest we note the following: Prof. H. A. Rowland, of the Johns Hopkins University, has been awarded the grand prize of the Paris Exposition for his spectroscopic gratings, and Prof. A. Michelson, of the University of Chicago, the same honor for his echelon spectroscope. —The Balbi-Valier prize (3,000 francs) of the Venetian Institute of Sciences has been awarded to Professor Grassi, at Rome, for his work on the relation of Mosquitoes to malaria. —The Paris Academy of Moral and Political Sciences has awarded its Audifred prize of the value of 15,000 francs to Dr. Yersin for the discovery of his anti-plague serum. —A movement has begun in London for the erection of a memorial in honor of the late Sir William Flower, which will consist of a bust and a commemorative brass tablet to be placed in the Whale Room of the Natural History Museum—one of the departments in which he was most interested and to which he devoted special care and attention. —A monument in honor of Pelletier and Caventou, the chemists, to whom the discovery of quinine is due, was unveiled at Paris on August 7. An address was made by M. Moissan, president of the committee, who presented the monument to the city of Paris, and by other speakers. —Milne Edwards has by his will bequeathed his library to the Paris Jardin des Plantes, of which he was a director. It is to be sold and the proceeds to be applied toward the endowment of the chair of zoology which he held. He also leaves 20,000 francs to the Geographical Society, of which he was president, for the establishment of a prize and 10,000 francs to the Société des Amis des Sciences. —The collection of jewels arranged by Mr. George F. Kunz and exhibited by Messrs. Tiffany & Co. at the Paris Exposition has been presented to the American Museum of Natural History by Mr. J. Pierpont Morgan. —The New York Board of Estimate and Apportionment has authorized the expenditure of $200,000 for the Botanical Garden and $150,000 for an addition to the American Museum of Natural History. —The Peabody Academy of Science at Salem, Mass., is trying to raise $50,000 for an addition to the museum building. Already over $26,000 has been pledged for the purpose.

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OXYGEN AND THE NATURE OF ACIDS.

[These selections from Priestley's account of the discovery of oxygen and from Lavoisier's first formal presentations of his theory of acids are classical examples of scientific work which will always be worth reading. They have also the historical interest due to the fact that the discoveries they describe served as the turning-point of chemistry to the paths it has since followed. The dates of publication were respectively 1775, 1776 and 1777. We realize the progress of the century when we remember that these experiments are now among the first in an elementary course. These two papers are also representatives of two well-defined types of scientific advance; Priestley's discovery was one of the happy accidents that often reward the investigator, one of the cases where he reaps a hundred fold, while Lavoisier's work was the result of gifted insight and careful consideration of the entire range of phenomena concerned. Lavoisier had, as is shown in this paper, the faculty of giving the right meaning to the data acquired by others. The phlogiston theory is now so much a matter of antiquity that it seems proper to give the modern equivalents of some of Priestley's terms: Air is used by him in the modern sense of gas, dephlogisticated air=oxygen, inflammable air=hydrogen, phlogisticated air=nitrogen, marine acid air=hydrochloric acid gas, fixed air=carbon dioxid, nitrous air=nitric oxid (N O), dephlogisticated nitrous air=nitrous oxid (N_2O), vitriolic acid air=sulphur dioxid, mercurius calcinatus=red oxid of mercury.]

ON DEPHLOGISTICATED AIR.*

BY JOSEPH PRIESTLEY.

THERE are, I believe, very few maxims in philosophy that have laid firmer hold upon the mind than that air, meaning atmospherical air (free from various foreign matters, which were always supposed to be dissolved, and intermixed with it), is a *simple elementary substance,* indestructible and unalterable, at least as much so as water is supposed to be. In the course of my inquiries I was, however, soon satisfied that atmospherical air is not an unalterable thing; for that phlogiston with which it becomes loaded from bodies burning in it, and animals breathing it, and various other chemical processes, so far alters and depraves it, as to render it altogether unfit for inflammation, respiration and other purposes to which it is subservient; and I had discovered that agi-

* From 'Experiments and Observations on Different Kinds of Air.' London, 1775.

tation in water, the process of vegetation, and probably other natural processes, by taking out the superfluous phlogiston, restore it to its original purity. But I own I had no idea of the possibility of going any farther in this way, and thereby procuring air purer than the best common air. I might, indeed, have naturally imagined that such would be the air that should contain less phlogiston than the air of the atmosphere; but I had no idea that such a composition was possible.

It will be seen in my last publication that, from the experiments which I made on the marine acid air, I was led to conclude that common air consisted of some acid (and I naturally inclined to the acid that I was then operating upon) and phlogiston; because the union of this acid vapor and phlogiston made inflammable air, and inflammable air, by agitation in water, ceases to be inflammable and becomes respirable. And though I could never make it quite so good as common air, I thought it very probable that vegetation, in more favorable circumstances than any in which I could apply it, or some other natural process, might render it more pure.

Upon this, which no person can say was an improbable supposition, was founded my conjecture of volcanoes having given birth to the atmosphere of this planet, supplying it with a permanent air, first inflammable, then deprived of its inflammability by agitation in water, and farther purified by vegetation.

Several of the known phenomena of the *nitrous acid* might have led me to think that this was more proper for the constitution of the atmosphere than the marine acid; but my thoughts had got into a different train, and nothing but a series of observations, which I shall now distinctly relate, compelled me to adopt another hypothesis, and brought me, in a way of which I had then no idea, to the solution of the great problem, which my reader will perceive I had had in view ever since my discovery that the atmospherical air is alterable, and, therefore, that it is not an elementary substance, but a *composition*, viz., what this composition is, or *what is the thing that we breathe*, and how it is to be made from its constituent principles.

At the time of my former publication I was not possessed of a *burning lens* of any considerable force; and for want of one I could not possibly make many of the experiments that I had projected, and which, in theory, appeared very promising. I had, indeed, a *mirror* of force sufficient for my purpose. But the nature of this instrument is such that it cannot be applied, with effect, except upon substances that are capable of being suspended or resting on a very slender support. It cannot be directed at all upon any substance in the form of *powder*, nor hardly upon anything that requires to be put into a vessel of quicksilver; which appears to me to be the most accurate method of extracting air from a great variety of substances, as was explained in the introduction to this volume. But having afterwards procured a lens of twelve inches diameter and twenty inches focal distance, I proceeded with great alacrity to examine, by the help of it, what kind of air a great variety of substances, natural and factitious, would yield, putting them into the vessels represented in Fig. *a*, which I filled with quicksilver, and kept inverted in a bason of the same. Mr. Warltire, a good chymist and lecturer in natural philosophy, happening to be at that time in Calne, I explained my views to him, and was furnished by him with many substances, which I could not otherwise have procured.

With this apparatus, after a variety of other experiments, an account of which will be found in its proper place, on the 1st of August, 1774, I endeavored to extract air from *mercurius calcinatus per se;* and I presently found that, by means of this lens, air was expelled from it very readily. Having got about three or four times as much as the bulk of my materials, I admitted water to it, and found that it was not imbibed by it. But what surprized me more than I can well express was that a candle burned in this air with a remarkably vigorous flame, very much like that enlarged flame with which a candle burns in nitrous air exposed to iron or liver of sulphur; but as I had got nothing like this remarkable appearance from any kind of air besides this particular modification of nitrous air, and I knew no nitrous acid was used in the preparation of *mercurius calcinatus*, I was utterly at a loss how to account for it.

In this case, also, though I did not give sufficient attention to the circumstance at that time, the flame of the candle, besides being larger, burned with more splendor and heat than in that species of nitrous air; and a piece of red-hot wood sparkled in it, exactly like paper dipped in a solution of nitre, and it consumed very fast; an experiment which I had never thought of trying with nitrous air.

At the same time that I made the above mentioned experiment, I extracted a quantity of air, with the very same property, from the common *red precipitate,* which being produced by a solution of mercury in spirit of nitre, made me conclude that this peculiar property, being similar to that of the modification of nitrous air above mentioned, depended upon something being communicated to it by the nitrous acid; and since the *mercurius calcinatus* is produced by exposing mercury to a certain degree of heat, where common air has access to it, I likewise concluded that this substance had collected something of *nitre* in that state of heat from the atmosphere.

This, however, appearing to me much more extraordinary than it ought to have done, I entertained some suspicion that the mercurius calcinatus, on which I had made my experiments, being bought at a common apothecary's, might, in fact, be nothing more than red precipitate; though, had I been anything of a practical chymist, I could not have entertained any such suspicion. However, mentioning this suspicion to Mr. Warltire, he furnished me with some that he had kept for a specimen of the preparation, and which, he told me, he could warrant to be genuine. This being treated in the same manner as the former, only by a longer continuance of heat, I extracted much more air from it than from the other.

This experiment might have satisfied any moderate sceptic; but, however, being at Paris in the October following, and knowing that there were several very eminent chymists in that place, I did not omit the opportunity, by means of my friend, Mr. Magellan, to get an ounce of mercurius calcinatus prepared by Mr. Cadet, of the genuineness of which there could not possibly be any suspicion; and at the same time, I frequently mentioned my surprise at the kind of air which I had got from this preparation to Mr. Lavoisier, Mr. le Roy and several other philosophers, who honored me with their notice in that city; and who, I dare say, cannot fail to recollect the circumstance.

At the same time I had no suspicion that the air which I had got from the mercurius calcinatus was even wholesome, so far was I from knowing what it was that I had really found; taking it for granted that it was nothing more than such kind of air as I had brought nitrous air to be by the processes above mentioned: and in this air I have observed that a candle would burn sometimes quite naturally, and sometimes with a beautiful, enlarged flame, and yet remain perfectly noxious.

At the same time that I had got the air above mentioned from mercurius calcinatus and the red precipitate, I had got the same kind from *red lead* or *minium*. In this process that part of the minium on which the focus of the lens had fallen turned yellow. One third of the air in this experiment was readily absorbed by water; but, in the remainder, a candle burned very strongly and with a crackling noise.

That fixed air is contained in red lead I had observed before, for I had expelled it by the heat of a candle, and had found it to be very pure. (Vol. I., p. 192.) I imagine it requires more heat than I then used to expel any of the other kinds of air.

This experiment with *red lead* confirmed me more in my suspicion that the *mercurius calcinatus* must get the property of yielding this kind of air from the atmosphere, the process by which that preparation and this of red lead is made being similar. As I never make the least secret of anything that I observe, I mentioned this experiment also, as well as those with the mercurius calcinatus and the red precipitate, to all my philosophical acquaintances at Paris and elsewhere, having no idea at that time to what these remarkable facts would lead.

Presently, after my return from abroad, I went to work upon the *mercurius calcinatus* which I had procured from Mr. Cadet, and, with a very moderate degree of heat, I got from about one fourth of an ounce of it, an ounce-measure of air, which I observed to be not readily imbibed, either by the substance itself from which it had been expelled (for I suffered them to continue a long time together before I transferred the air to any other place) or by water, in which I suffered this air to stand a considerable time before I made any experiment upon it.

In this air, as I had expected, a candle burned with a vivid flame; but what I observed new at this time (Nov. 19), and which surprized me no less than the fact I had discovered before, was that whereas a few moments' agitation in water will deprive the modified nitrous air of its property of admitting a candle to burn in it; yet, after more than ten times as much agitation as would be sufficient to produce this alteration in the nitrous air, no sensible change was produced in this. A candle still burned in it with a strong flame, and it did not in the least diminish common air, which I have observed that nitrous air, in this state, in some measure does.

But I was much more surprized when, after two days, in which this air had continued in contact with water (by which it was diminished about one twentieth of its bulk) I agitated it violently in water about five minutes and found that a candle still burned in it as well as in common air. The same degree of agitation would have made phlogisticated nitrous air fit for respiration indeed, but it would certainly have extinguished a candle.

These facts fully convinced me that there must be a very material difference between the constitution of the air from mercurius calcinatus and that of phlogisticated nitrous air, notwithstanding their resemblance in some particulars. But though I did not doubt that the air from *mercurius calcinatus* was fit for respiration after being agitated in water, as every kind of air without exception on which I had tried the experiment had been, I still did not suspect that it was respirable in the first instance; so far was I from having any idea of this air being what it really was, much superior in this respect to the air of the atmosphere.

In this ignorance of the real nature of this kind of air, I continued from this time (November) to the 1st of March following; having, in the meantime, been intent upon my experiments on the vitriolic acid air, above recited, and the various modifications of air produced by spirit of nitre, an account of which will follow. But in the course of this month I not only ascertained the nature of this kind of air, though very gradually, but was led by it to the complete discovery of the constitution of the air we breathe.

Till this 1st of March, 1775, I had so little suspicion of the air from mercurius calcinatus, etc., being wholesome that I had not even thought of applying to it the test of nitrous air; but thinking (as my reader must imagine I frequently must have done) on the candle burning in it after long agitation in water, it occurred to me at last to make the experiment: and putting one measure of nitrous air to two measures of this air, I found not only that it was diminished, but that it was diminished quite as much as common air, and that the redness of the mixture was likewise equal to that of a similar mixture of nitrous and common air.

After this I had no doubt but that the air from mercurius calcinatus was fit for respiration, and that it had all the other properties of genuine common air. But I did not take notice of what I might have observed, if I had not been so fully possessed by the notion of there being no air better than common air, that the redness was really deeper, and the diminution something greater than common air would have admitted.

Moreover, this advance in the way of truth, in reality, threw me back into error, making me give up the hypothesis I had first formed, viz., that the mercurius calcinatus had extracted spirit of nitre from the air; for I now concluded that all the constituent parts of the air were equally and in their proper proportion imbibed in the preparation of this substance, and also in the process of making red lead. For at the same time that I made the above mentioned experiment on the air from mercurius calcinatus, I likewise observed that the air which I had extracted from red lead, after the fixed air was washed out of it, was of the same nature, being diminished by nitrous air like common air; but, at the same time, I was puzzled to find that air from the red precipitate was diminished in the same manner, though the process for making this substance is quite different from that of making the two others. But to this circumstance I happened not to give much attention.

I wish my reader be not quite tired with the frequent repetition of the word *surprize*, and others of similar import; but I must go on in that style a little longer. For the next day I was more surprized than ever I had been before with finding that after the above mentioned mixture of nitrous air and the air from mercurius calcinatus had stood all night (in which time the whole diminution must have taken place, and, consequently, had it been common air it must have been made perfectly noxious and entirely unfit for respiration or inflammation) a candle burned in it and even better than in common air.

I cannot at this distance of time recollect what it was that I had in view in making this experiment; but I know I had no expectation of the real issue of it. Having acquired a considerable degree of readiness in making experiments of this kind, a very slight and evanescent motive would be sufficient to induce me to do it. If, however, I had not happened, for some other purpose, to have had a lighted candle before me I should probably never have made the trial, and the whole train of my future experiments relating to this kind of air might have been prevented.

Still, however, having no conception of the real cause of this phenomenon, I considered it as something very extraordinary; but as a property that was peculiar to air that was extracted from these substances and *adventitious;* and I always spoke of the air to my acquaintance as being substantially the same thing with common air. I particularly remember my telling Dr. Price that I was myself perfectly satisfied of its being common air, as it appeared to be so by the test of nitrous air; though, for the satisfaction of others, I wanted a mouse to make the proof quite complete.

On the 8th of this month I procured a mouse and put it into a glass vessel containing two ounce-measures of the air from mercurius calcinatus. Had it been common air a full-grown mouse, as this was, would have lived in it about a quarter of an hour. In this air, however, my mouse lived a full half hour, and though it was taken out seemingly dead, it appeared to have been only exceedingly chilled; for, upon being held to the fire, it presently revived and appeared not to have received any harm from the experiment.

By this I was confirmed in my conclusion that the air extracted from mercurius calcinatus, etc., was *at least as good* as common air; but I did not certainly conclude that it was any *better;* because, though one mouse would live only a quarter of an hour in a given quantity of air, I knew it was not impossible but that another mouse might have lived in it half an hour, so little accuracy is there in this method of ascertaining the goodness of air: and, indeed, I have never had recourse to it for my own satisfaction since the discovery of that most ready, accurate and elegant test that nitrous air furnishes. But in this case I had a view to publishing the most generally-satisfactory account of my experiments that the nature of the thing would admit of.

This experiment with the mouse, when I had reflected upon it some time, gave me so much suspicion that the air into which I had put it was better than common air, that I was induced, the day after, to apply the test of nitrous air to a small part of that very quantity of air which the mouse had breathed so long; so that, had it been common air, I was satisfied it must have been very nearly, if not altogether, as noxious as possible, so as not to be affected by nitrous air; when, to my surprize again, I found that though it had been breathed so long it was still better than common air. For after mixing it with nitrous air, in the usual proportion of two to one, it was diminished in the proportion of $4\frac{1}{2}$ to $3\frac{1}{2}$; that is, the nitrous air had made it two ninths less than before, and this in a very short space of time: whereas I had never found that in the longest time any common air was reduced more than one fifth of its bulk by any proportion of nitrous air, nor more than one fourth by any phlogistic process whatever. Thinking of this extraordinary fact upon my pillow, the next morning I put another measure of nitrous air to the same mixture, and, to my utter astonishment, found that it was farther diminished to almost one half of its original quantity. I then put a third measure to it; but this did not diminish it any farther; but, however, left it one measure less than it was even after the mouse had been taken out of it.

Being now fully satisfied that this air, even after the mouse had breathed it half an hour, was much better than common air, and having a quantity of it still left sufficient for the experiment, viz., an ounce measure and a half, I put the mouse into it; when I observed that it seemed to feel no shock upon being put into it, evident signs of which would have been visible if the air had not been very wholesome; but that it remained perfectly at its ease another full half hour, when I took it out quite lively and vigorous. Measuring the air the next day I found it to be reduced from $1\frac{1}{2}$ to 2-3 of an ounce measure. And after this, if I remember well (for in my register of the day I only find it noted that it was considerably diminished by nitrous air) it was nearly as good as common air. It was evident, indeed, from the mouse having been taken out quite vigorous, that the air could not have been rendered very noxious.

For my farther satisfaction I procured another mouse, and putting it into less than two ounce-measures of air extracted from mercurius calcinatus and air from red precipitate (which, having found them to be of the same quality, I had mixed together) it lived three quarters of an hour. But not having had the precaution to set the vessel in a warm place, I suspect that the mouse died of cold. However, as it had lived three times as long as it could probably have lived in the same quantity of common air and I did not expect much accuracy from this kind of test, I did not think it necessary to make any more experiments with mice.

Being now fully satisfied of the superior goodness of this kind of air, I proceeded to measure that degree of purity with as much accuracy as I could, by the test of nitrous air; and I began with putting one measure of nitrous air to two measures of this air, as if I had been examining common air, and now I observed that the diminution was evidently greater than common air would have suffered by the same treatment. A second measure of nitrous air reduced it to two thirds of its original quantity, and a third measure to one half. Suspecting that the diminution could not proceed much farther, I then added only half a measure of nitrous air, by which it was diminished still more; but not much, and another half measure made it more than half of its original quantity; so that, in this case, two measures of this air took more than two measures of nitrous air and yet remained less than half of what it was. Five measures brought it pretty exactly to its original dimensions.

At the same time air from the *red precipitate* was diminished in the same proportion as that from *mercurius calcinatus*, five measures of nitrous air being received by two measures of this without any increase of dimensions. Now as common air takes about one half of its bulk of nitrous air before it begins to receive any addition to its dimensions from more nitrous air, and this air took more than four half measures before it ceased to be diminished by more nitrous air, and even five half measures made no addition to its original dimensions, I conclude that it was between four and five times as good as common air. It will be seen that I have since procured air better than this, even between five and six times as good as the best common air that I have ever met with.

MEMOIR ON THE EXISTENCE OF AIR IN THE ACID OF NITRE (AND ON THE MEANS OF DECOMPOSING AND RECOMPOSING THIS ACID).*

BY ANTOINE-LAURENT LAVOISIER.

I TOOK a small retort with a long narrow neck, which I bent over a lamp so that the end of the neck could be held under a bell-jar full of water standing in a vessel of water. Into the retort I put two ounces of slightly fuming acid of nitre, the weight of which was to that of distilled water in the proportion of 131,607 to 100,000. I added two ounces one dram of mercury and heated it slightly to hasten the solution.

As the acid was very strong, the effervescence was lively and the decomposition very rapid. I received the air which was liberated in different bell-jars in order to be able to tell the differences which might be found between the air at the beginning and at the end of effervescence, supposing there should be such. When the effervescence had stopped and all the mercury had dissolved, I continued to heat the material in the same apparatus. Soon boiling appeared in place of the effervescence, and while the boiling went on air was produced in almost as great abundance as before. I continued this until all the fluid had passed out, either by distillation or as elastic vapors of air, and nothing was left in my retort save a white salt of mercury, in a pasty form, dry rather than wet, which began to grow yellow on its surface. The quantity of air obtained up to this point was about 190 cubic inches; that is to say, about four quarts. All this air was of a uniform sort and was nowise different from what M. Priestley has called nitrous air.

On continuing the experiment, I noticed that from the mercury salt there arose red fumes like those of the acid of nitre; but this phenomenon did not last long and soon the air in the empty part of the retort

* Read before the Paris Academy of Science on April 20, 1776. Translated for THE POPULAR SCIENCE MONTHLY from the 'Comptes Rendus' for the meeting.

regained its transparence.* Having put to one side the air which had been given off during the period of the red fumes, I found ten to twelve inches of air very different from what had been given off up till then, and apparently differing from ordinary air only in that lights burned slightly better in it. At the same time the mercury salt had turned to a fine red precipitate, and, keeping it at a moderate heat, I obtained at the end of seven hours 224 cubic inches of air much purer than ordinary air, in which a light burned with a much brighter, larger and brilliant or more active flame. This air, from all its characteristics, I could not but recognize as the same that I had extracted from calx of mercury, known as mercury *precipitatum per se;* the same that M. Priestley extracted from a number of substances by treating them with spirits of nitre. In proportion as this air had been freed, the mercury had been reduced, and I found again, within a few grains, the two ounces one dram of mercury which I had dissolved. The slight loss may have been due to a little yellow and red sublimate which clung to the upper part of the retort.

The mercury came out of this experiment as it went in, that is, without change in its quality or to any noticeable extent in its weight. So it is evident that the 426 cubic inches of air which I had obtained could have been produced only by the decomposition of the acid of nitre. I was then right in concluding from these facts that two ounces of acid of nitre are composed, first, of 190 cubic inches of nitrous air; second, of 12 cubic inches of ordinary air; third, of 224 cubic inches of air better than ordinary air; fourth, of phlegm; but as it was proved from M. Priestley's experiments, that the small amount of common air which I had obtained could be nothing save air better than common air, the superior quality of which had been altered by mixture with nitrous air in the transition or passing from one to the other, I can determine the amount of these two airs before their mixture and suppose that the 12 cubic inches of common air which I got were due to a mixture of 30 cubic inches of nitrous air and 14 cubic inches of air better than ordinary air.

After thus determining these quantities, we get as the product of two ounces of acid of nitre:

Nitrous air	226 cubic inches.
Purest air	238 " "
Total	464

[Lavoisier here uses the estimated weight of the gases found to decide the composition by weight of nitric acid.]

*These red fumes are due to portions of nitrous air and of air purer than ordinary, which are freed from the mercury salt and which combine and form the acid of nitre. The force of this explanation will be fully felt only after the entire memoir has been read.

Such then is a way to decompose the acid of nitre and demonstrate the existence in it of a pure air and (if I may be allowed to use this expression) more an air than ordinary air. But the complement of the proof was, after having decomposed the acid, to succeed in re-compounding it out of the same materials, and that is what I have done.

[Lavoisier here inserts some preliminary remarks about the nature of nitrous air, and then describes his experiment as follows:]

I filled with water a tube which was closed at one end and which was marked off along its length by equal divisions of volume. I inserted this tube, thus filled with water, in another vessel, likewise filled with water; I let into it seven and one-third parts of nitrous air and mixed with this at the same time four parts of air purer than ordinary air, which I had measured out in another separate tube.* At the moment of mixture, the eleven and a third parts of air occupied 12 to 13 measures, but, a moment later, the two airs mingled and combined, very red vapors of spirits of fuming nitre were formed, which were at once condensed by the water, and in a few seconds the eleven and a third parts of air were reduced to about a third of a measure; that is to say, to about the thirty-fourth part of their original volume.

The water contained in the tube was sensibly acid at the end of this experiment, or, rather, it was a weak acid of nitre; when I treated it with alkali I got from it by evaporation real nitre. . . . After having shown that one can separate and combine again the principles of the acid of nitre, it remains for me to show that the same can be done with materials not all taken from the acid of nitre. Instead of the purest air, or that drawn from the red precipitate of mercury, one may use the air of the atmosphere; but much more of it will have to be used, and instead of the four parts of pure air which are sufficient to saturate seven and one-third parts of nitrous air, one will have to use nearly sixteen of common air; all the nitrous air is, in this experiment, as in the preceding one, destroyed or rather condensed; but this is not the case with common air; not more than a fifth or a fourth of it is absorbed, and what remains is no longer able to support the flame of a candle or to support respiration in animals. It seems proved by this that the air which we breathe contains only a fourth part of real air; that this real air is in our atmosphere mixed with three or four parts of a harmful air, a sort of choke-damp, which would cause the death of the majority of animals if it were present in a little greater quantity. The injurious effects on the air of vapor of charcoal and of a large number of other emanations prove how near this fluid is to the point beyond which it would be fatal to animals. I hope to soon be in a position to discuss this idea and to place before the Academy the experiments on which it is based.

*I pass over the tentative efforts by which I came to know the exact proportion.

It results from the experiments contained in this memoir that when mercury is dissolved in nitric acid, this metallic substance acquires the pure air contained in the nitric acid and constituting it an acid. On the one hand this metal, when combined with the purest air, is reduced to a calx; on the other the acid deprived of this same air expands and forms nitrous air, and the proof that such are the facts in this experiment is that if after having thus separated the two airs which enter into the composition of the acid of nitre, you combine them anew, you make pure acid of nitre such as you had before, with the single difference that it fumes.

The acid of nitre, drawn from saltpetre by clay, is consequently nothing but nitrous air combined with nearly an equal volume of the purest part of the air and with a fairly large amount of water; nitrous air, on the contrary, is the acid of nitre deprived of air and of water. People will no doubt ask here if the phlogiston of the metal does not play some part in this process. Without daring to decide a question of so great importance, I will reply that since the mercury comes out of this experiment just as it went in, there are no signs that it has lost or gained any phlogiston, unless we claim that the phlogiston which brought about the reduction of the metal passed through the vessels. But that is to admit of a particular sort of phlogiston, different from that of Stahl and his school; it is to return to the theory of fire as a principle, to fire as an element of bodies, a theory much older than Stahl's and very different from it.

I will end this memoir as I began it, by thanking M. Priestley, to whom the greater part of whatever interest it possesses is due; but the love of truth and the progress of knowledge, towards which all our efforts should be directed, oblige me at the same time to correct a mistake which he has made, which it would be dangerous to leave unchallenged. This rightly famous physicist, who had discovered that when he combined the acid of nitre with any earth, he invariably obtained ordinary air or air better than ordinary air, believed that he could thence draw the conclusion that the air of the atmosphere is a compound of acid of nitre and of earth. This bold conception is quite overthrown by the experiments contained in this memoir. It is clear that it is not air that is composed of acid of nitre, as M. Priestley claims; but, on the contrary, it is the acid of nitre that is composed of air; and this single remark gives the key to a large number of experiments contained in Sections III., IV. and V. of M. Priestley's second volume.

GENERAL CONSIDERATIONS ON THE NATURE OF ACIDS *

By ANTOINE-LAURENT LAVOISIER.

WHEN the chemists of olden times had reduced a body to oil, salt, earth and water, they believed that they had reached the limits of chemical analysis, and consequently they gave to salt and to oil the names of 'principles of bodies.'

In proportion as the art made progress, the chemists who succeeded them became aware that substances which had been held to be primary could be decomposed, and they recognized in succession that all the neutral salts, for instance, were formed by the union of two substances, an acid of some sort and a salt, earth or metal.

Hence arose the entire theory of neutral salts which has held the attention of chemists for over a century, and which is to-day so near perfection that we may regard it as the surest and most complete part of chemistry.

Chemical science has been handed down to us in this condition, and it is our business to do with the constituents of the neutral salts what the chemists who went before us did with the neutral salts themselves, to attack the acids and bases and to carry chemical analysis along this line a step beyond its present limits.

I have already imparted to the Academy my first efforts in this field. I have in earlier memoirs demonstrated to you as far as it is possible to demonstrate in physics and chemistry that the purest air, that to which M. Priestley has given the name of 'dephlogisticated air,' enters as a constituent part into the composition of several acids, notably of phosphoric, vitriolic and nitric acids.

More numerous experiments put me in a position to-day to draw general conclusions from these results and to assert that the purest air, the air most suitable for respiration, is the principle which causes acidity; that this principle is common to all acids, and that in addition one or more other principles enter into the composition of each acid, differentiating it and making it one sort of acid rather than another.

In consequence of these facts, which I already regard as very firmly established, I shall henceforth call dephlogisticated air or air most suitable for respiration, when it is in a state of combination or fixity, by the name of 'the acidifying principle,' or, if one prefers the same meaning in a word from the Greek, 'the principle *Oxygine*.' This nomenclature will save periphrases, will make my statements more exact, and will avoid the ambiguities I would be likely to fall into constantly if I used the word 'air.'

* Read before the Paris Academy of Sciences on September 5, 1777. Translated for THE POPULAR SCIENCE MONTHLY from the 'Comptes Rendus' for the meeting.

Without repeating details which I have given elsewhere, I will recall herein a few words, adopting this new language:

1. That the acidifying principle or oxygen, when combined with the substance of fire, heat and light, forms the purest air, that which M. Priestley has called dephlogisticated air; it is true that this first proposition is not strictly proved and perhaps is not susceptible of strict proof; so I have proposed it only as an idea that I regard as very probable, and in that respect it must not be confused with the propositions which are to follow, which are based on rigorous experiments and proofs;

2. That this same acidifying principle or oxygen, combined with carbon or substances containing carbon, forms the acid of chalk (carbonic acid) or fixed air;

3. That with sulphur it forms vitriolic acid;

4. That with nitrous air it forms nitric acid;

5. That with Kunckel's phosphorus it forms phosphoric acid;

6. That with metallic substances in general it forms metallic calces, with the exception of the cases of which I shall speak in this or a following memoir.

Such is very nearly our present general knowledge of the combinations of oxygen with the different substances in nature, and it is not hard to see that there remains a vast field to explore; that there is a part of chemistry absolutely new and until now unknown, which will be completely investigated only when we shall have succeeded in determining the degree of affinity of this principle with all the substances with which it can combine, and in discovering the different sorts of compounds which result.

All chemists know that the simpler the substances are with which you are working, the nearer you come to reducing substances to their elementary molecules, the more difficult become the means of decomposing and recomposing the substances; we may suppose, therefore, that the analysis and synthesis of acids must present much greater difficulties than does the analysis of the neutral salts into the composition of which they enter. I hope, however, to be able in what follows to show that there is no acid, unless, perhaps, it be that of sea salt, which we cannot analyze and put together again and from which we cannot at will abstract the acidifying principle.

This kind of work demands a great variety of means, and the procedures necessary to success in effecting combination vary according to the different substances with which one is working. In some cases we must have recourse to combustion, either in atmospheric air or pure air. Such is the case with sulphur, phosphorus and carbon; these substances during combustion absorb the acidifying principle or oxygen, and by the addition of this principle become vitriolic, phosphoric and carbonic acid or fixed air.

In the case of other substances mere exposure to the air, aided by a moderate degree of heat, suffices to bring about the combination, and this is what happens to all vegetable substances capable of passing on to acid fermentation. In the greater number of cases one has to resort to the science of affinities and to employ the acidifying principle already united in another compound.

The example which I am going to give to-day is of this last sort, and I shall take it from an experiment, well known for several years, following the memoirs of M. Bergman. It is the formation of the acid of sugar. This acid, in accordance with the experiments which I am going to recount, seems to me to be nothing else than sugar combined with the acidifying principle or oxygen, and I propose to show in order in different memoirs that we can combine this same principle with the substance composing animals' horns, with silk, with animal lymph, with wax, with essential oils, with extracted oils, manna, starch, arsenic, iron and probably with a great many other substances of the three kingdoms. We can thus turn all these substances into genuine acids.

Before entering on the material to be presented, I beg the Academy to recall that the acid of nitre, as shown by the experiments which I have before described, and which I have repeated in your presence, is the result of the union of nitrous air with the purest air or acidifying principle; that the proportion of these two principles varies in the different kinds of acid of nitre, the one which gives off fumes, for instance, containing a superabundance of nitrous air.

CHAPTERS ON THE STARS.

By Professor SIMON NEWCOMB, U. S. N.

Masses and Densities of the Stars.

THE spectroscope shows that, although the constitution of the stars offers an infinite variety of detail, we may say, in a general way, that these bodies are suns. It would perhaps be more correct to say that the Sun is one of the stars and does not differ essentially from them in its constitution. The problem of the physical constitution of the Sun and stars may, therefore, be regarded as the same. Both consist of vast masses of incandescent matter at so exalted a temperature as to shine by their own light. All may be regarded as bodies of the same general nature.

It has long been known that the mean density of the Sun is only one-fourth that of the earth, and, therefore, less than half as much again as that of water. In a few cases an approximate estimate of the density of stars may be made. The method by which this may be done can be rigorously set forth only by the use of algebraic formulæ, but a general idea of it can be obtained without the use of that mode of expression.

Let us in advance set forth an extension of Kepler's third law, which applies to every case of two bodies revolving around each other by their mutual gravitation. The law in question, as stated by Kepler, is that the cubes of the mean distances of the planets are proportioned to the squares of their times of revolution. If we suppose the mean distances to be expressed in terms of the earth's mean distance from the Sun as a unit of length, and if we take the year as the unit of time, then the law may be expressed by saying that the cubes of the mean distances will be equal to the squares of the periods. For example, the mean distance of Jupiter is thus expressed as 5.2. If we take the cube of this, which is about 140, and then extract the square root of it, we shall have 11.8, which is the period of revolution of Jupiter around the Sun expressed in the same way. If we cube 9.5, the mean distance of Saturn, we shall have the square of a little more than 29, which is Saturn's time of revolution.

We may also express the law by saying that if we divide the cube of the mean distance of any planet by the square of its periodic time we shall always get 1 as a quotient.

The theory of gravitation and the elementary principles of force and motion show that a similar rule is true in the case of any two bodies revolving around each other in virtue of their mutual gravitation. If we divide the cube of their mean distance apart by the square of their time of revolution, we shall get a quotient which will not indeed be 1, but which will be a number expressing the combined mass of the two bodies. If one body is so small that we leave its mass out of consideration, then the quotient will express the mass of the larger body. If the latter has several minute satellites moving around it, the quotients will be equal, as in the case of the Sun, and will express the mass of this central body. If, as in the case we have supposed, we take the year as a unit of time and the distance of the earth from the Sun as a unit of length, the quotient will express the mass of the central body in terms of the mass of the Sun. It is thus that the masses of the planets are determined from the periodic times and distances of their satellites,

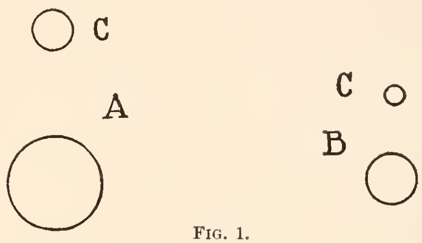

FIG. 1.

and the masses of binary systems from their mean distance apart and their periods. To express the general law by a formula we put

a, the mean distance apart of the two bodies, or the semi-major axis of their relative orbit in terms of the earth's mean distance from the Sun;

P, their periodic time;

M, their combined mass in terms of the Sun's mass as unity.

Then we shall have:

$$M = \frac{a^3}{P^2}$$

Another conclusion we draw is that if we know the time of revolution and the radius of the orbit of a binary system, we can determine what the time of revolution would be if the radius of the orbit had some standard length, say unity.

We cannot determine the dimensions of a binary system unless we know its parallax. But there is a remarkable law which, so far as I know, was first announced by Pickering, by virtue of which we can determine a certain relation between the surface brilliancy and the density of a binary system without knowing its parallax.

Let us suppose a number of bodies of the same constitution and temperature as the Sun—models of the latter we may say—differing from it only in size. To fix the ideas, we shall suppose two such bodies, one having twice the diameter of the other. Being of the same brilliancy, we suppose them to emit the same amount of light per unit of surface. The larger body, having four times the surface of the smaller, will then emit four times as much light. The volumes being proportional to the cubes of their diameters, it will have eight times its volume. The densities being supposed equal, it will have eight times the mass. Suppose that each has a satellite revolving around it, and that the orbit of the satellite of the larger body is twice the radius of that of the smaller one.

Calling the radius of the nearer satellite 1, that of the more distant one will be 2. The cube of this number is 8. It follows from the extension of Kepler's third law, which we have cited, that the times of revolution of the two satellites will be the same. Thus the two bodies, A and B, with their satellites, C and C, form two binary systems whose proportions and whose periods are the same, only the linear dimensions of B are all double those of A. In other words, we shall have a pair of binary systems which may look alike in every respect, but of which one will have double the dimensions and eight times the mass of the other.

Now let us suppose the larger system to be placed at twice the distance of the smaller. The two will then appear of the same size, and, if stars, will appear of the same brightness, while the two orbits will have the same apparent dimensions. In a word, the two systems will appear alike when examined with the telescope, and the periodic times will be equal.

Near the end of the second chapter we have given a little table showing the magnitude that the Sun would appear to us to have were it placed at different distances among the stars. The parallaxes we have there given are simply the apparent angle which would have to be subtended by the radius of the earth's orbit at different distances. It follows that, were the stars all of similar constitution to the Sun, the numbers given in the last column of the table referred to would, in all cases, express the apparent distance from the star of a companion, having a time of revolution of one year. From this we may easily show what would be the time of revolution of any binary system of which the companions were separated by 1″, if the stars were of the same constitution as the Sun.

Periods of binary systems whose components are separated by 1″ and whose constitution is the same as that of the Sun.

Mag.	Period. y.	Annual Motion.
1	1.8	200°
2	3.5	102
3	7.0	51
4	14.1	25
5	28.1	13
6	56.0	6
7	112.	3.2
8	223.	1.6

It will be seen that the periods are very nearly doubled for each diminution of the brilliancy of the star by one magnitude. Moreover, the value of the photometric ratio for two consecutive magnitudes is a little uncertain, so that we may, without adding to the error of our results, suppose the period to be exactly double for each addition of unity to the magnitude. A computation of the period for any magnitude may be made with all necessary precision by the formula:

$$P = 0^{y}.88 \times 2^{m};$$

or, $$\log. P = 9.994 + 0.3m.$$

It will now be of interest to compare the results of this theory with the observed periods of binary systems with a view to comparing their constitution with that of our Sun. There are, however, two difficulties in the way of doing this with rigorous precision.

The first difficulty is that there are very few binary systems of which the apparent dimensions of the orbit and the periods are known with any approach to exactness. This would not be a serious matter were it not that the short, and, therefore, known periods belong to a special class, that having the greatest density. Hence, when we derive our results from the systems of known periods we shall be making a biased selection from this particular class of stars.

The next difficulty is that the theory which we have set forth assumes the mass of the satellite either to be very small compared with that of the star, or the two bodies to be of the same constitution. If we apply the theory to systems in which this is not the case, the results which we shall get will be, in a certain way, those corresponding to the mean of the two components. Were it a question of masses, we should get with entire precision the sum of the masses of the two bodies. The best we can do, therefore, is to suppose the two companions fused into one having the combined brilliancy of the two. Then, if the result is too small for one, it will be too large for the other.

To show the method of proceeding, I have taken the six systems of shortest period found in Dr. See's 'Researches on Stellar Evolution.' The principal numbers are shown in the table below.

The first column, a'', after the name of the star, gives the apparent semi-major axis of the orbit in seconds of arc. The next column gives the period in years. Column Mag. gives the apparent magnitude which the system would have were the two bodies fused into one.

Column P gives the period in years as it would be were the radius of the orbit equal to one second. It is formed by dividing the actual period by A. The next column gives the period as it would be were the stars of similar constitution to the Sun. The last column gives the square of the ratio of the two bodies, which, if the stars had the same surface brilliancy as the Sun, would express the ratio of density of the stars to that of the Sun. Actually, it gives the product:

$$\text{Density} \times (\text{brilliancy})^{\frac{3}{2}}$$

	a."	Per.	Mag.	P.	Sun's Per.	Star's Density.
κ Pegasi	0″.42	11y.4	4.2	41.9	16.2	0.15
δ Equulei	0″.45	11y.4	4.6	37.8	21.0	0.31
ζ Sagittarii	0″.69	18y.8	2.9	32.7	6.7	0.04
F9 Argus	0″.65	22y.0	5.5	42.0	39.7	0.90
42 Comæ	0″.64	25y.6	4.4	50.0	18.5	0.14
β Delphinii	0″.67	27y.7	3.7	50.4	11.4	0.51

The numbers in the last column being all less than unity, it follows that either the stars are much less dense than the Sun or they are of much less surface brilliancy. Moreover, they belong to a selected list in which the numbers of the last column are larger than the average.

To form some idea of the result of a selection from the general average, we may assume that the average of all the measured distances between the components of a number of binary systems is equal to the average radius of their orbits, and that the observed annual motion is equal to the mean motion of the companion in its orbit. Taking a number of cases of this sort, I find that the number corresponding to the last number of the preceding table would be little more than one thousandth.

A very remarkable case is that of ζ Orionis. This star, in the belt of Orion, is of the second magnitude. It has a minute companion at a distance of 2″.5. Were it a model of the Sun, a companion at this apparent distance should perform its revolution in fourteen years. But, as a matter of fact, the motion is so slow that even now, after fifty years of observation, it cannot be determined with any precision. It is probably less than 0°.1 in a year. The number expressing the comparison of its density and surface brilliancy with those of the Sun is probably less than .0001.

The general conclusion to be drawn is obvious. The stars in general are not models of our Sun, but have a much smaller mass in proportion to the light they give than our Sun has. They must, therefore, have either a less density or a greater surface brilliancy.

We may now inquire whether such extreme differences of surface brilliancy or of density are more likely. The brilliancy of a star depends primarily not on its temperature throughout, but on that of some region near or upon its surface. The temperature of this surface cannot be kept up except by continual convection currents from the interior to the surface. We are, therefore, to regard the amount of light emitted by a star not merely as indicating temperature, but as limited by the quantity of matter which, impeded by friction, can come up to the surface, and there cool off and afterward sink down again. This again depends very largely on internal friction, and is limited by that. Owing to this limitation, we cannot attribute the difference in question wholly to surface brilliancy. We must conclude that at least the brighter stars are, in general, composed of matter much less dense than that of the Sun. Many of them are probably even less dense than air and in nearly all cases the density is far less than that of any known liquid.

An ingenious application of the mechanical principle we have laid down has been made independently by Mr. Roberts, of South Africa, and Mr. Norris, of Princeton, in another way. If we only knew the relation between the diameters of the two companions of a binary system and its dimensions, we could decide how much of the difference in question is due to density and how much to surface brilliancy. Now this may be approximately done in the case of variable stars of the Algol and β Lyræ types. If, as is probably the most common case, the passage of the stars over each other is nearly central, the ratio of their diameter to the radius of the orbit may be determined by comparing the duration of the eclipse with the time of revolution. This was one of the fundamental data used by Myers in his work on β Lyræ, of which we have quoted the results. Without going into reasoning or technical details at length, we may give the results reached by Roberts and Norris in the case of the Algol variables:

For the variable star X Carinæ, Roberts finds, as a superior limit for the density of the star and its companion, one-fourth that of the Sun. It may be less than this is, to any extent.

In the case of S Velorum the superior limits of density are:

Bright star..................................	0.61
Companion..................................	0.03

In the case of RS Sagittarii the upper limits of density are 0.16 and 0.21.

It is possible, in the mean of a number of cases like these, to estimate the general average amount by which the densities fall below the limits here given. Roberts' final conclusion is that the average density of the Algol variables and their eclipsing companions is about one eighth that of the Sun.

The work of Russell was carried through at the same time as that of Roberts, and quite independently of his. It appeared at the same time.* His formulæ and methods were different, though they rested on similar fundamental principles. Taking the density of the Sun as

* 'Astrophysical Journal,' Vol. X, No. 5.

unity, he computes the superior limit of density for 12 variables, based on their periods and the duration of their partial eclipses. The greatest limit is in the case of Z Herculis and is 0.728. The least is in the case of S Cancri and is 0.035. The average is about 0.2. As the actual density may be less than the limit by an indefinite amount, the general conclusion from his work may be regarded as the same with that from the work of Roberts.

The results of the preceding theory are independent of the parallax of the stars. They, therefore, give us no knowledge as to the mass of a binary system. To determine this we must know its parallax, from which we can determine the actual dimensions of the orbit when its apparent dimensions are known. Then the formula already given will give the actual mass of the system in terms of the Sun's mass.

There are only six binary systems of which both the orbit and the parallax are known. These are shown in the table below. Here the first two columns after the stars named give the semi-major axis of the orbit and the measured parallax. The quotient of the first number by the second gives the actual mean radius of the orbits in terms of the earth's distance from the Sun as unity. This is given in the third column, after which follow the period and the resulting combined mass of the system. The last column shows the actual amount of light emitted by the system, compared with that of the Sun.

	a."	Par.	*a.*	Period.	Mass.	Light.
	"	"		y.		
η Cassiopiæ	8.21	0.20	41.0	195.8	1.8	1.0
Sirius	8.03	0.37	21.7	52.2	3.7	32.0
Procyon	3.00	0.30	10.0	40.0	0.6	8.5
α Centauri	17.70	0.75	23.6	81.1	2.0	1.7
70 Ophiuchi	4.55	0.19	24.0	88.4	1.8	0.7
85 Pegasi	0.89	0.05	17.8	24.0	9.0	2.2

Even in these few cases some of the numbers on which the result depends are extremely uncertain. In the case of Procyon, the radius of the orbit can be only a rough estimate. In the case of 85 Pegasi the parallax is uncertain. In the case of η Cassiopiæ the elements are still doubtful.

So far as we have set forth the principles involved in the question, we do not get separate results for the mass of each body. The latter can be determined only by meridian observations, showing the motion of the brighter star around the common center of gravity of the two. This result has thus far been worked out with an approximation to exactness only in the cases of Sirius and Procyon. For these systems we have the following masses of the companions of these bodies in terms of the Sun's mass:

Companion of Sirius	1.2
Companion of Procyon	0.2

It will now be interesting to compare the brightness of these bodies with that which the Sun would have if seen at their distance. In a former chapter we showed how this could be done. The results are:

At the distance of Procyon the apparent magnitude of the Sun would be $2^m.8$. At the distance of Sirius, it would be $2^m.3$. Supposing the Sun to be changed in size, its density remaining unchanged, until it had the same mass as the respective companions of Procyon and Sirius, its magnitudes would be:

For companion of Procyon	3.9
For companion of Sirius	2.9

The actual magnitudes of these companions cannot be estimated with great precision, owing to the effect of the brilliancy of the star. From the estimate of the companion of Sirius, by Professor Pickering, its magnitude was about the eighth. It is probable that the magnitude of the companion of Procyon is not very different. It will be seen that these magnitudes are very different from those which they would have were the companions models of the Sun. What is very curious is that they differ in the opposite direction from the stars in general, and especially from their primaries. Either they have a far less surface brilliancy than the Sun or their density is much greater. There can be no doubt that the former rather than the latter is the case.

This great mass of the two companions as compared with their brilliancy suggests the question whether they may not shine, in part at least, by the light of their primaries. A very little consideration will show that this cannot be the case. A simple calculation will show that, to shine as brightly as they do, the diameter of the companion of Sirius would have to be enormous, at least 1-30 its distance from Sirius. Moreover, its apparent brightness would vary so widely in different parts of its orbit that we should see it almost as well when near Sirius as when distant from it. The most likely cause of the small brightness is the low temperature of the body.

Gaseous Constitution of the Stars.

The results of the last chapter point to the conclusion that the stars, or at least the brighter among them, are masses of gas, more or less compressed in their interior by the action of gravitation upon their more superficial parts. We have now to show how this result was arrived at, at least in the case of the Sun, from different considerations, before the spectroscope had taught us anything of the constitution of these bodies.

We must accept, as one of the obvious conclusions of modern science, the fact that the Sun and stars have, for untold millions of years, been radiating heat into space. If we refrain from considering the basis on which this conclusion rests, it is not so much because we consider it unquestionable, as because the discussion would be too long and complex for the present work.

One of the great problems of modern science has been to account for the source of this heat. Before the theory of energy was developed this problem offered no difficulty. In the time of Newton, Kant and even of La Place and Herschel, no reason was known why the stars should not shine forever without change. Now we know that when a body radiates heat, that heat is really an entity termed *energy*, of which the supply is necessarily limited. Kelvin compared the case of a star radiating heat with that of a ship of war belching forth shells from her batteries. We know that if the firing is kept up, the supply of ammunition must at some time be exhausted. Have we any means of determining how long the store of energy in Sun or star will suffice for its radiation?

We know that the substances which mainly compose the Sun and stars are similar to those which compose our earth. We know the capacity for heat of these substances, and we also have determined how much the Sun radiates annually. From these data, it is found by a simple calculation that the temperature of the Sun would be lowered annually by more than two degrees Fahrenheit, if its capacity for heat were the same as that of water. If this capacity were only that of the substances which compose the great body of the earth, the lowering of temperature would be from 5° to 10° annually. Evidently, therefore, the actual heat of the Sun would only suffice for a few thousand years' radiation, if not in some way replenished.

When the difficulty was first attacked, it was supposed that the supply might be kept up by meteors falling into the Sun. We know that in the region round the Sun, and, in fact, in the whole Solar System, are countless minute meteors some of which may from time to time strike the Sun. The amount of heat that would be produced by the loss of energy suffered by a meteor moving many hundred miles a second would be enormously greater than that which would be produced by combustion. But critical examination shows that this theory cannot have any possible basis. Apart from the fact that it could at best be only a temporary device there seems to be no possibility that meteors sufficient in mass can move round the Sun or fall into it. Shooting stars show that our earth encounters millions of little meteors every day; but the heat produced is absolutely insignificant.

It was then shown by Kelvin and Helmholtz that the Sun might radiate the present amount of heat for several millions of years, simply from the fund of energy collected by the contraction of its volume through the mutual gravitation of its parts. As the Sun cools it contracts; the fall of its substance toward the center, produced by this contraction, generates energy, which energy is constantly turned into heat. The amount of contraction necessary to keep up the present supply may be roughly computed; it amounts in round numbers to 220 feet a year, or four miles in a century.

Accepting this view, it will almost necessarily follow that the great body of the Sun must be of gaseous constitution. Were it solid, its surface would rapidly cool off, since the heat radiated would have to be conducted from the interior. Then, the loss of heat no longer going on at the same rate, the contraction also would stop and the generation of heat to supply the radiation would cease. Even were the Sun a liquid, currents of liquid matter could scarcely convey to the surface a sufficient amount of heated matter to supply the enormous radiation. Thus the reason of the case combines with observation of the density of the Sun to show that its interior must be regarded as gaseous rather than solid or liquid.

A difficult matter, however, presents itself. The density of the Sun is greater than we ordinarily see in gases, being, as we have remarked, even greater than the density of water. The explanation of this difficulty is very simple: the gaseous interior is subject to compression by its superficial portions. The gravitation on the surface being 27 times what it is on the earth, the pressure increases 27 times as fast when we go toward the center as it does on the earth. We should not have to go very far within its body to find a pressure of millions of tons on the square inch. Under such pressure and at such an enormous temperature as must there prevail, the distinction between a gas and a liquid is lost; the substance retains the mobility of a gas, while assuming the density of a liquid.

It does not follow, however, that the visible surface of the Sun is a gas, pure and simple. The sudden cooling which a mass of gaseous matter undergoes on reaching the surface may liquefy it or even change it into a solid. But, in either case, the sudden contraction which it thus undergoes makes it heavier and it sinks down again to be remelted in the great furnace below. It may well be, therefore, that the description of the Sun as a vast bubble is nearly true. It may be added that all we have said about the Sun may very well be presumed to apply to the stars. We have now to consider the law of change as a sun or star contracts through the loss of heat suffered by its radiation into space.

This subject was very exhaustively developed by Ritter some years since.* It is not practicable to give even an abstract of Ritter's results at the present time, especially as every mathematical investigation of the subject must either rest on hypotheses more or less uncertain, or

* Wiedemann's 'Annalen der Physik u. Chemie,' 1878 to 1883, etc.

must, for its application, require data impossible to obtain. We shall, therefore, confine ourselves to a brief outline of the main points of the subject. A fundamental proposition of the whole theory is Lane's law of gaseous attraction, which is as follows:

When a spherical mass of incandescent gas contracts through the loss of its heat by radiation into space, its temperature continually becomes higher as long as the gaseous condition is retained.

The demonstration of this law is simple enough to be understood by any one well acquainted with elementary mechanics and physics, and it will also furnish the basis for our consideration of the subject.

We begin by some considerations on the condition of a mass of gas held together by the mutual attraction of its parts. This attraction results in a certain hydrostatic pressure, capable of being expressed as so many pounds or tons per unit of surface, say a square inch. This pressure at any point is equal to the weight of a column of the gas, having a section of one square inch and extending from the point in

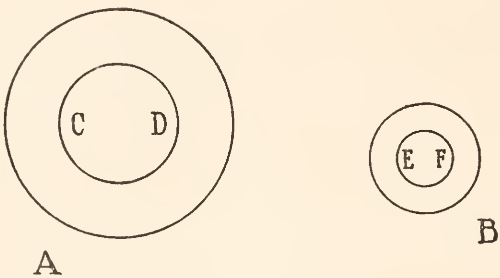

Fig. 2.

question to the surface. It is a law of attraction in a sphere of which the density is the same at equal distances from its center, that if we suppose an interior sphere concentric with the body, the attraction of all the matter outside that interior sphere, on any point within it, is equal in every direction, and, therefore, is completely neutralized. A point is, therefore, drawn towards the center only by the attraction of the sphere on the surface of which it lies.

At every point in the interior the hydrostatic pressure must be balanced by the elastic force of the gas. In the case of any one gas this force is proportional to the product of the density into the absolute temperature. This condition of equilibrium must be satisfied at every point throughout the mass.

Let the two circles in the figure represent gaseous globes, of the kind supposed. The larger one represents the globe in a certain condition of its evolution; the second its condition after its volume has contracted to one half. The temperature in each case will necessarily increase from the surface to the center. The law of this increase is incapable of accurate expression, but is not necessary for our present purpose.

Let the inner circle, C D, represent a spherical shell, situated anywhere in the interior of the mass, but concentric with it. Let E F be the corresponding shell after the contraction has taken place. The case will then be as follows:

The two shells will by hypothesis have the same quantity of matter, both in their own substance and throughout their interior.

In case B the central attraction being as the inverse square from the center, will be four times as great for each unit of matter in the shell.

This force of attraction, tending to compress the shell, is, in case B, exerted on a surface one quarter as great, because the surface of a shell is proportional to the square of its diameter.

Hence the hydrostatic pressure per unit of surface is 16 times as great in case B as in case A.

The elastic force of a gas, if the two bodies were at the same temperature, would be 8 times as great in case B as in case A, being inversely as the volume.

The hydrostatic pressure being 16 times as great, while the elastic force to counterbalance it is only 8 times as great, no equilibrium would be possible. To make it possible, the absolute temperature of the gas must be doubled, in order that the elastic force shall balance the pressure.

That a mass can become hotter through cooling, may, at first sight, seem paradoxical. We shall, therefore, cite a result which is strictly analogous. If the motion of a comet is hindered by a resisting medium, the comet will continually move faster. The reason of this is that the first effect of the medium is to diminish the velocity of the object. Through this diminution of velocity, the comet falls towards the Sun. The increase of velocity caused by the fall more than counterbalances the diminution produced by the resistance. The result is that the comet takes up a more and more rapid motion, as it gradually approaches the Sun, in consequence of the resistance it suffers. In the same way, when a gaseous celestial body cools, the fall of its mass towards the center changes from a potential to an actual form an amount of energy greater than that radiated away.

The critical reader will see a weak point in this reasoning, which it is necessary to consider. What we have really shown is that if the mass, assumed to be in a state of equilibrium when it has the size A, has to remain in equilibrium when it has the size B, then its temperature must be doubled. But we have not proved that its temperature actually will be doubled by the fall. In fact, it cannot be doubled unless the energy generated by the fall of the superficial portions towards the center is sufficient to double the absolute amount of heat. Whether this will be the case depends on a variety of circumstances; the mass of the whole body, and the capacity of its substance for heat. If we are to proceed with mathematical rigor, it is, therefore, necessary to determine in any given case whether this condition is fulfilled. Let us suppose that in any particular case the mass is so small or the capacity for heat so considerable that the temperature is not doubled by the contraction. Then the contraction will go on further and further, until the mass becomes a solid. But in this case let us reverse the process. The body being supposed nearly in a state of equilibrium in position A, let the elastic force be slightly in excess. Then the gas will expand. In order that it be reduced to a state of equilibrium by expansion, its temperature must diminish according to the same law that it would increase if it contracted. When its diameter doubles, its temperature should be reduced to one half or less by the expansion, in order that the equilibrium shall subsist. But, in the case supposed, the temperature is not reduced so much as this. Hence, it is too high for equilibrium by a still greater amount and the expansion must go on indefinitely. Thus, in the case supposed, the hypothetical equilibrium of the body is unstable. In other words, no such body is possible.

This conclusion is of fundamental importance. It shows that the possible mass of a star must have an inferior limit, depending on the quantity of matter it contains, its elasticity under given circumstances and its capacity for heat. It is certain that any small mass of gas, taken into celestial space and left to itself, would not be kept together by the mutual attraction of its parts, but would merely expand into indefinite space. Probably this might be true of the earth, if it were gaseous. The computation would not be a difficult one to make, but I have not made it.

In what precedes, we have supposed a single mass to contract. But our study of the relations of temperature and pressure in the two masses assumes no relationship between them, except that of equality. Let us now consider any two gaseous bodies, A and B, and suppose that the body B, instead of having the same mass as that of A, is another body with a different mass.

Since the mass, B, may be of various sizes, according to the amount of attraction it has undergone, let us begin by supposing it to have the same volume as A, but twice the mass of A. We have then to inquire what must be its temperature in order that it may be in equilibrium. We have first to inquire into the hydrostatic pressure at any point of the interior. Referring once more to a figure like either of those in Fig. 2, a spherical shell like C D will now in the case of the more massive body have double the mass of the corresponding shell of A. The attraction will also be doubled, because the diameter of the spherical shell is the same, while the amount of matter within it is twice as great. Hence the hydrostatic pressure per unit of surface will be four times as great, or will vary as the square of the density. The elasticity at equal temperatures being proportional to the density, it follows that were the temperature the same in the two masses, the elasticity would be double in the case of mass B; whereas, to balance the hydrostatic pressure it should be quadrupled. The temperature of B must, therefore, be twice as great as that of A. It follows that in the case of stars of equal volume, but of different masses, the temperature must be proportional to the mass of density.

But how will it be if we suppose the density to be always the same, and, therefore, the mass to be proportional to the volume? In this case the attraction at a given point will be proportional to the diameter of the body. If, then, we suppose one body to have twice the diameter of the other, but to be of the same density, it follows that at corresponding points of the interior, the hydrostatic pressure will be twice as great in the larger body. The density being the same, it follows that the temperature must be twice as high in order that equilibrium may be maintained. It follows that the stars of the greatest mass will be at the highest temperature, unless their volume is so great that their density is less than that of the smaller stars.

Stellar Evolution.

It follows from the theory set forth in the last chapter that the stars are not of fixed constitution, but are all going through a progressive change—cooling off and contracting into a smaller volume. If we accept this result, we find ourselves face to face with an unsolvable enigma—how did the evolution of the stars begin? To show the principle involved in the question, I shall make use of an illustration drawn from a former work.* An inquiring person wandering around in what he supposes to be a deserted building, finds a clock running. If he knows nothing about the construction of the clock, or the force necessary to keep it in motion, he may fancy that it has been running for an indefinite time just as he sees it, and that it will continue to run until the material of which it is made shall wear out. But if he is acquainted with the laws of mechanics, he will know that this is impossible, because the continued movement of the pendulum involves a constant expenditure of energy. If he studies the construction of the clock, he will find the source of this energy in the slow falling of a weight suspended by a cord which acts upon a train of wheels. Watching the motions, he will see that the scape wheel acting on the pendulum

* 'Popular Astronomy,' by Simon Newcomb; Harper & Bros., New York.

moves very perceptibly every second, while he must watch the next wheel for several seconds to see any motion. If the time at his disposal is limited, he will not be able to see any motion at all in the weight. But an examination of the machinery will show him that the weight must be falling at a certain rate, and he can compute that, at the end of a certain time, the weight will reach the bottom, and the clock will stop. He can also see that there must have been a point from above which the weight could never have fallen. Knowing the rate of fall, he can compute how long the weight occupied in falling from this point. His final conclusion will be that the clock must in some way have been wound up and set in motion a certain number of hours or days before his inspection.

If the theory that the heat of the stars is kept up by their slow contraction is accepted, we can, by a similar process to this, compute that these bodies must have been larger in former times, and that there must have been some finite and computable period when they were all nebulæ. Not even a nebula can give light without a progressive change of some sort. Hence, within a certain finite period the nebulæ themselves must have begun to shine. How did they begin? This is the unsolvable question.

The process of stellar evolution may be discussed without considering this question. Accepting as a fact, or at least as a working hypothesis, that the stars are contracting, we find a remarkable consistency in the results. Year by year laws are established and more definite conclusions reached. It is now possible to speak of the respective ages of stars as they go through their progressive course of changes. This subject has been so profoundly studied and so fully developed by Sir William and Lady Huggins that I shall depend largely on their work in briefly developing the subject.*

At the same time, in an attempt to condense the substance of many folio pages into so short a space, one can hardly hope to be entirely successful in giving merely the views of the original author. The following may, therefore, be regarded as the views of Sir William Huggins, condensed and arranged in the order in which they present themselves to the writer's mind.

There is an infinite diversity among the spectra of the stars; scarcely two are exactly alike in all their details. But the larger number of these spectra, when carefully compared, may be made to fall in line, thus forming a series in which the passage of one spectrum into the next in order is so gradual as to indicate that the actual differences represent, in the main, successive epochs of star life rather than so many fundamental differences of chemical constitution. Each star may be considered to go through a series of changes analogous to those of a human

* Publications of Sir William Huggins's Observatory, Vol. I; London, 1899.

being from birth to old age. In its infancy a star is simply a nebulous mass; it gradually condenses into a smaller volume, growing hotter, as set forth in the last chapter, until a stage of maximum temperature is reached, when it begins to cool off. Of the duration of its life we cannot form an accurate estimate. We can only say that it is to be reckoned by millions, tens of millions or hundreds of millions of years. We thus view in the heavens stars ranging through the whole series from the earliest infancy to old age. How shall we distinguish the order of development? Mainly by their colors and their spectra. In its first stage the star is of a bluish white. It gradually passes through white into yellow and red. Sir William gives the following series of stars as an example of the successive orders of development:

Sirius, α Lyræ.
α Ursæ Majoris.
α Virginis.
α Aquilæ.
Rigel.
α Cygni.
. . .
Capella—The Sun.
Arcturus.
Aldebaran.
α Orionis.

The length of the life of a star has no fixed limit; it depends entirely on the mass. The larger the mass, the longer the life; hence a small star may pass from infancy to old age many times more rapidly than a large one.

A remarkable confirmation of this order is found in the generally yellow or red color of the companions of bright stars in binary systems. The two stars of such a system naturally commenced their life history at the same epoch, but the smaller one, going through its changes more rapidly, is now found to be yellower than the other. Additional confirmation is afforded by the very great mass of the companions of Sirius and Procyon, notwithstanding the faintness of their light.

At the same time, up to at least the yellow stage, the star continually grows hotter as it condenses. A difficulty may here suggest itself in reconciling this order with a well-known physical fact. As a radiating body increases in temperature, its color changes from red through yellow to white, and the average wave length of its light continually diminishes. We see a familiar example of this in the case of iron, which, when heated, is first red in color and then goes through the changes we have mentioned. The ordinary incandescent electric light is yellow; the arc light, the most intense that we can produce by artificial means, is white. When the spectrum of a body thus increasing in temperature is watched, the limit is found to pass gradually from the red toward the violet end. It would seem, therefore, that the hotter stars should be the white ones and the cooler the yellow or red ones.

There are, however, two circumstances to be considered in connection with the contracting star. In the first place, the light which we receive from a star does not emanate from its hottest interior, but from a region either upon or, in most cases, near its surface. It is, therefore, the temperature of this region which determines the color of the light. In the next place, part of the light is absorbed by passing through the cooler atmosphere surrounding the star. It is only the light which escapes through this atmosphere that we actually see.

In the case of the Sun all the light which it sends forth comes from an extreme outer surface, the photosphere. The most careful telescopic examination shows no depth to this surface. It sends light to us, as if it were an opaque body like a globe of iron. This surface would rapidly cool off were it not for convection currents bringing up heated matter from the interior. It might be supposed that such a current would result in the surface being kept at nearly as high a temperature as the interior; but, as a matter of fact, the opposite is the case. As the volume of gas rises, it expands from the diminished pressure and it is thus cooled in the very act of coming to the surface.

In the case of younger stars, there is probably no photosphere properly so called. The light which they emit comes from a considerable distance in the interior. Here the effect of gravity comes into play. The more the star condenses, the greater is gravity at its surface; hence the more rapidly does the density of the gas increase from the surface toward the interior. In the case of the Sun, the density of any gas which may immediately surround the photosphere must be doubled every mile or two of its depth until we reach the photosphere. But if the Sun were many times its present diameter, this increase would be less in a still larger proportion. Hence, when the volume is very great the increase of density is comparatively slow; there being no well-defined photosphere, the light reaches us from a much greater depth from the interior than it does at a later stage.

The gradual passing of a white star into one of the solar type is marked by alterations in its spectrum. These alterations are especially seen in the behavior of the lines of hydrogen, calcium, magnesium and iron. The lines of hydrogen change from broad to thin; those of calcium constantly become stronger.

Of the greatest interest is the question—at what stage does the temperature of the star reach its maximum and the body begin to cool? Has our Sun reached this stage? This is a question to which, owing to the complexity of the conditions, it is impossible to give a precise answer. It seems probable, however, that the highest temperature is reached in about the stage of our Sun.

The general fact that every star has a life history—that this history will ultimately come to an end—that it must have had a beginning in time—is indicated by so great a number of concurring facts that no one who has most profoundly studied the subject can have serious doubts upon it. Yet there are some unsolved mysteries connected with the case, which might justify a waiting for further evidence, coupled with a certain degree of skepticism. Of the questions connected with the case the most serious one is: How is the supply of energy radiated by the Sun and stars kept up? Only one answer is possible in the light of recent science. It is that already given in the last chapter—the continual contraction of volume. The radiant energy sent out is balanced by the continual loss of potential energy due to the contraction.

On this theory the age of the Sun can be at least approximately estimated. About twenty millions of years is the limit of time during which it could possibly have radiated anything like its present amount of energy. But this conclusion is directly at variance with that of geology. The age of the earth has been approximately estimated from a great variety of geological phenomena, the concurring result being that stratification and other geological processes must have been going on for hundreds—nay, thousands of millions of years. This result is in direct conflict with the only physical theory which can account for the solar heat.

The nebulæ offer a similar difficulty. Their extreme tenuity and their seemingly almost unmaterial structure appear inadequate to account for any such mutual gravitation of their parts as would result in the generating of the flood of energy which they are constantly radiating. What we see must, therefore, suggest at least the possibility that all shining heavenly bodies have connected with them some form of energy of which science can, as yet, render no account. This suspicion cannot, however, grow into a certainty until we have either seen the nebulæ contracting in volume or have made such estimates of their probable masses that we can compute the amount of contraction they must undergo to maintain the supply of energy.

In the impressive words of Sir William Huggins:

"We conclude filled with a sense of wonder at the greatness of the human intellect, which from the impact of waves of ether upon one sense-organ, can learn so much of the Universe outside our earth; but the wonder passes into awe before the unimaginable magnitude of Time, of Space and of Matter of this Universe, as if a Voice were heard saying to man: 'Thou art no Atlas for so great a weight.'"

MICROBES IN CHEESE-MAKING.

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CHEMISTS tell us that cheese is one of the most nutritious and, at the same time, one of the cheapest of foods. Its nutritive value is greater than meat, while its cost is much less. But this chemical aspect of the matter does not express the real value of the cheese as a food. Cheese is eaten, not because of its nutritive value as expressed by the amount of proteids, fats and carbohydrates that it contains, but always because of its *flavor*. Now, physiologists do not find that flavor has any food value. They teach over and over again that our foodstuffs are proteids, fats and carbohydrates, and that as food flavor plays absolutely no part. But, at the same time, they tell us that the body would be unable to live upon these foodstuffs were it not for the flavors. If one were compelled to eat pure food without flavors, like the pure white of an egg, it is doubtful whether one could, for a week at a time, consume a sufficiency of food to supply his bodily needs. Flavor is as necessary as nutriment. It gives a zest to the food, and thus enables us to consume it properly, and, secondly, it stimulates the glands to secrete, so that the foods may be satisfactorily digested and assimilated. The whole art of cooking, the great development of flavoring products, the high prices paid for special foods like lobsters and oysters—these and numerous other factors connected with food supply and production are based solely upon this demand for flavor. Flavor is a necessity, but it is not particularly important what the flavor may be. This is shown by the fact that different peoples have such different tastes in this respect. The garlic of the Italian and the red pepper of the Mexican serve the same purpose as the vanilla which we put in our ice-cream; and all play the part of giving a relish to the food and stimulating the digestive organs to proper activity.

The primary value of cheeses is, then, in the flavors they possess. One can hardly realize the added pleasure they give to the life of hundreds of thousands of poor people whose food must be of the coarsest character. A bit of well-flavored cheese adds relish to the humblest meal and gives the highest delight. We must recognize, then, that the chief value of the cheese lies exactly in these flavors which the chemist does not include in his analysis of cheese and which the physiologist refuses to call food or to regard as having any nutritive value whatever. Incidentally, it is true that the cheese also furnishes a considerable amount of food material. Thus it nourishes as well as stimulates and delights; but, after all, we must recognize that its chief value is in its flavor rather than in its nutritive quality.

Hence it becomes a very significant question to inquire into the source of this flavor. We find, first, that the cheese as originally made possesses no flavor, or, at least, none of that peculiar flavor which we know as cheesy. Cheese is made from milk by causing the casein in the milk to be precipitated, *i. e.*, causing the milk to curdle, commonly by the addition of rennet, or, in so-called Dutch cheeses, by simply allowing the milk to sour. The precipitated casein is then separated from the liquids of the milk, and the curd, when subsequently pressed and molded, becomes the cheese. But the freshly-made cheese possesses no flavor, nor does the flavor develop to any degree until after it has passed through a process known as 'ripening.' The ripening of cheese may take several days or several months, or, in some cases, one or two years; but the flavor always arises during this process. Moreover, the various cheeses with their varieties of flavors are mostly made from the same kind of milk, but are subjected to different modes of ripening, and the distinctive quality in the endless types of cheeses is due in large measure to differences in the method of bringing about this ripening. Clearly enough the flavor is a product of cheese ripening, and if we wish to find the source of these most valuable flavors we must seek it in the ripening process.

This cheese ripening proves to be a two-fold process. The first change in the cheese is a chemical one, which results in altering the chemical nature of the cheese in such a way as to render it more easy of digestion. This change appears to be due in part to a certain ferment which is found in milk. This material belongs to the class of chemical ferments or enzymes and is a normal constituent of milk, although its presence was not mistrusted until recently pointed out by two American investigators. With the chemical changes produced by this enzyme we are not here particularly concerned. It is certainly not the cause of all the flavors which develop in the cheeses, and, therefore, this character of the ripened cheese must be chiefly attributed to another factor. There is no doubt that this other factor is a living one. The flavors can generally be traced directly to the growth upon and within the cheese of a variety of plants; and the ripening is carried on in a fashion designed, at the same time, to stimulate the growth of some species of plants and to check the growth of others.

Cheeses are of two kinds, hard and soft. As implied in the name, there is a difference in the consistency of the cheese. But this is not all; for on account of the methods of manufacturing, the ripening is produced by different classes of plants in the two classes of cheeses.

In the soft cheese, the plants contributing most to the ripening and to the formation of the flavor are what are commonly called molds, at least in some cheeses, while in the hard cheeses the molds play probably no part, and bacteria are the most active agents in producing the flavors developed during the ripening.

In making the soft cheeses—little known in this country—the general mode of procedure is as follows: The milk, sometimes whole milk, sometimes partly skimmed, is caused to curdle by the action of rennet. The curd is either cut to pieces by knives designed for the purpose, thus allowing the whey to drain off more readily, or it is simply ladled out of the vessel in which it curdled and placed at once into forms. As the whey is drawn off from the forms, through holes in the sides or through a false straw bottom, the curd soon assumes the shape of the forms. It is at first very soft, since it is subjected to no pressure whatever. At short intervals this soft mass is turned, so as to rest upon a new surface, and this turning is continued for two or three days. By this time the curd has become dry and consistent enough to handle, and it is then carried off to the cheese cellar for ripening. The details of this process differ considerably. In quite a number of cheeses particular methods are adopted to favor and hasten the growth of molds. Sometimes it is laid upon special straw mats or wrapped in straw, which, having been used over and over again in the dairy, has become thoroughly impregnated with mold spores. The cheese is then placed in a cool, damp atmosphere, which causes the spores to germinate and grow upon the cheese, already slightly acid, and in a condition favorable to the growth of molds. They grow rapidly over the whole surface of the cheese, and this step in the process is not ended until a good covering of molds has developed. Sometimes, indeed, special methods are adopted to insure their proper development. In making the Roquefort cheese specially prepared bread is allowed to mold, and after it becomes thoroughly impregnated with the mold it is finely grated to a powder and mixed with the curd as it is placed in the form for shaping. Fine holes are pierced in the cheese by a special machine to let in the air which is necessary for the luxuriant growth of the molds. Such treatment insures, of course, a very rapid growth of these plants, inside as well as outside. Most commonly, however, the cheese-maker depends upon his straw mats for the molds, and expects them to grow chiefly on the surface. The molds which develop in the cheese are not all of the same species. The common blue mold is most usual, but most cheeses are not properly ripened until several species of molds grow together within them.

The development of molds, however, is by no means the end of the ripening, but rather its beginning. Indeed, in some of the soft cheeses their growth is entirely prevented by a thorough salting and washing of the surface. In such cheeses the mold may grow within the mass, but not on the surface. Whichever method is used, however, the cheese is presently removed to the so-called 'cheese cellar' for its proper ripening. These cellars may be cool, damp rooms, or caves, and the flavor of some kinds of cheeses is largely due to the nature of the caves in which the subsequent ripening is carried on. In these cellars there is a constant but not very high temperature, and the atmosphere is generally damp. Since the temperature and the moisture are kept as constant as possible during the whole year, the cheese ripening can continue slowly and indefinitely. To a considerable extent differences in the ripening of soft cheeses are due to the different temperatures of the cheese cellars, and this determines the kind of plant life that shall flourish in this soft, nutritious food.

After the removal to the ripening chambers, a new series of changes begins in the cheese, due to new kinds of plant life. But as yet neither the cheese-maker nor the bacteriologist, who has studied the matter most carefully, can tell us much of the nature of the actual changes which occur during this ripening. When the cheese is placed in the ripening chamber it is certain that the growth of the molds is largely stopped, and it is also certain that here begins a growth of a new class of plants which we call bacteria. This moldy cheese, rendered alkaline by the growth of the molds, furnishes a favorable medium for the growth of different species of bacteria. At high temperatures they would speedily decompose the mass, even to extreme putrefaction, but at the low temperatures of the cheese cellars a complete putrefaction does not occur. Bacteria growth takes place probably in all soft cheeses, and as a result the nature of the cheese is profoundly modified. Numerous new chemical products make their appearance, either as by-products of decomposition or as actual secretions from the growing bacteria and molds. These new products have strong tastes and odors which, as they slowly develop, gradually produce the characteristic flavor of the ripened cheese. If the ripening continue long enough the decomposition grows too advanced even for the strongest palate. But when the proper ripening has been acquired and the tastes and flavors are of the desired character, the cheese is sent to market, highly flavored by the joint action of the bacteria and molds. It is still soft and moist, and the ripening process continues, so that the cheese will not keep good for a very long time. But while it is in the proper condition it furnishes the educated palate with a flavoring product of great intensity, and most highly relished by the numerous lovers of soft cheeses.

While such is the general method of manufacture of the soft cheeses, it must be recognized that the details of the manufacture differ widely. Differences in the kind of milk used, whether whole milk, skim milk, sheep's milk, goat's milk, etc., differences in the handling of the soft curd, differences in the amount of salting and drying, differences in the temperature and moisture of the 'cheese cellar,' all result in the growth of different kinds of molds and bacteria, producing variously flavored products. It is evident, too, that the character of the product will depend upon the abundance and varieties of the plants which furnish the flavor. Unless a dairy is supplied with the proper species of molds and bacteria, it is hopeless to expect the desired results. Here lies the work which the scientist must perform for the further development of the cheese industry.

The second type of cheeses, with which we are more familiar in this country, is the type of hard cheeses. These are not only of denser consistency, but they have commonly a less pronounced taste and odor and are not so suggestive of decomposition. They are, also, commonly made in much larger form, their denser nature making it possible for them to be made in very large sizes. They keep longer and are, therefore, much more generally exported into different countries.

The difference between the hard and soft cheeses, great as it is in the perfected article, is due to quite slight variations in the method of manufacture. The hard cheeses are made from curdled milk, curdled in just the same way as in the making of soft cheeses. But, after the curdling and the cutting up the curd to allow the whey to separate, the curd is broken up into small bits and placed in forms, where it is subjected to heavy pressure. Sometimes, immediately after the cutting of the curd, it is subjected to a moderate heat. For example, the Swiss cheeses are heated to about 110° Fahr. for a short time after cutting up the curd. This heating changes the nature of the curd somewhat and gives it a tougher and more elastic texture. In all the hard cheeses the curd is finally placed in wooden forms and then subjected to pressure, moderate at first, but soon increased until the pressure is quite high. This pressure converts the curd into a very dense, compact mass, and one in which microscopic plants cannot so readily grow.

But the hard cheeses require a ripening to develop the flavor as well as the soft cheeses, and the ripening is a longer and slower process. The pressed cheese is placed in rooms, or caves, or other locality where the temperature is not very variable or where it can, perhaps, be artificially controlled. Here it remains for weeks and frequently for months, during which time it slowly changes its chemical nature as a result of the action of the chemical or organic ferments, and simultaneously acquires the flavors which characterize the perfected product.

It is generally believed that the flavors here, as well as in the soft cheeses, are due to the growth of microscopic plants; but the subject has proved a very difficult one to investigate. Molds play little or no part in ripening the hard cheeses. Indeed, their growth is prevented by salting, oiling and rubbing the surface. But bacteria appears to have, if not the chief share, certainly a large share in the production of the flavors. Experiment has shown that bacteria grow abundantly in the cheese during the ripening; that some species of bacteria can produce in milk flavors similar to those found in the ripened cheese; that treatment which prevents the growth of bacteria prevents also the development of the flavors in the cheese. Further, in the manufacture of the famous Holland cheese (Edam cheese), the cheese-makers have learned that by planting certain species of bacteria in the milk out of which the cheese is to be made, the ripening may be hastened and made more uniform. In Holland about one third of the cheese is made by thus inoculating the milk with 'slimy whey,' which is simply a mass of whey containing in great numbers certain species of bacteria. These facts indicate strongly that the bacteria are agents in this flavor production. But, at the same time, the subject has proved so difficult of investigation that our bacteriologists are as yet by no means satisfied with the results. Indeed, they differ very decidedly in their conclusions. Some believe that the ripening is chiefly due to the same class of bacteria which produce the souring of milk; others think it due to bacteria which produce an alkaline rather than acid reaction; some believe it to be a combination of the two, while others, again, decide that cheese ripening is a long process, involving the action of many species of bacteria and perhaps of molds as well. The difficulty lies in the fact that, since the ripening is a long process, many species of bacteria are found in the cheese at different times. This makes it almost impossible to determine what is the cause of the ripening and what is only incidental.

It will be readily understood that the problem of cheese ripening is one most eagerly studied by bacteriologists. The immense financial interests involved in the discovery of definite methods of handling the manufacture and the ripening of cheese would insure this, entirely independently of any scientific interest. A very large per cent. of cheeses are ruined by improper ripening, and the discovery of methods for preventing this loss would mean the saving of millions of dollars annually. Moreover, many favorite cheeses have hitherto been capable of manufacture only in certain localities, probably because these localities are filled with the peculiar species of micro-organisms needed for their ripening. If it were possible to cultivate the requisite organisms and use them for artificial inoculation, it might be possible to manufacture any type of cheese anywhere. Already it has been found that new cheese factories may sometimes be stocked with the proper micro-organisms by rubbing the shelves and vessels with fresh cheeses imported from localities where the desired variety is nominally made. It is evident that immense financial interests may be involved in the proper scientific solution of the micro-organisms for cheese ripening, and the practical application of the facts to cheese making.

As the result of these facts, many bacteriologists are engaged in the study of the problems connected with cheese ripening. Many new discoveries have been made, and various practical suggestions in cheese making have resulted from these researches. But every bacteriologist has been studying a different problem. In Holland some valuable studies of the ripening of Edam cheese have been made, but naturally, the results differ decidedly from those obtained by Swiss bacteriologists in their study of the ripening of Swiss cheeses, inasmuch as the Holland cheese itself is such a different product from that made in Switzerland. The study of cheese ripening in our own country will probably show little agreement with the researches in Europe, since our cheeses differ so much in taste from most of the continental cheeses, although they are not so very unlike the English cheeses. In short, the problems to be solved are as numerous as the varieties of cheese, and each problem has shown itself to be so complex as, thus far, almost to baffle the most patient investigation. It is true that one or two bacteriologists have announced that they have discovered the species of bacteria and molds which produce the ripening of the particular type of cheese that they have been studying, and in some cases cultures of these bacteria have been placed on the market for use in cheese making. In one case, a scientist announces that he has made many thousands of pounds of cheese by means of his artificial cultures and has met with the highest success. But, in general, these cultures have been of problematical value, none of them having, as yet, resulted in the extension of the manufacture of special types of cheeses in localities where it had been hitherto impossible.

As stated before, this country is perhaps more interested in the successful issue of these investigations than any other. Hitherto, Swiss cheeses have been made in Switzerland, Holland cheeses in Holland and all other types of cheeses in their own rather limited localities. This includes hard cheeses as well as soft. If we desire any of these products we are obliged, in the main, to import them. Certain imitations have been produced in this country, it is true; but the imitations are more in shape than in quality. If it were possible, however, for our dairymen to learn a method of making, not inferior imitations of European cheeses, but products actually their equal in flavor and quality, it is certain that an immense market would be speedily opened to them. This condition is probably dependent upon the success of the scientist in solving the problem of regulating the growth of bacteria and molds in the ripening cheese. As fast as the bacteriologist succeeds in showing how the ripening process may be so controlled as to make it possible for our dairymen to produce cheeses similar in character and equal in grade to those of the European market, we may look for the expansion of the industry.

What the future may develop cannot be foretold. The problem is a large one, but the fruits of successful solution are great. Students of dairy bacteriology recognize the possibilities and have in recent years turned their attention quite largely to this subject. From continued experiments and investigations we may confidently expect some practical results, and it is not at all improbable that in a few years at all events, we may see an almost complete revolution in the manufacture of cheeses, especially in such a large country as this, where the possibilities for the development of cheese manufacture are almost unlimited, and where the demand must be as varied as the population.

SUBMARINE NAVIGATION.

By Professor W. P. BRADLEY,
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IN a paper read before the Society of Naval Architects, Nov. 11, 1898, Lieut. Commander W. W. Kimball, who commanded the torpedo flotilla during the war with Spain, said: "If it be granted that the surface torpedo boat has a place in naval warfare, and that her primary duty is the attack by night upon ships attempting blockade or raiding operations, then most assuredly the submarine torpedo boat has a most important tactical place, since she, and she alone, is competent to deliver a torpedo attack by day upon ships attempting blockading, bombarding or raiding operations. She is the only kind of inexpensive craft that can move up to a battleship in daylight, in the face of her fire and in spite of her supporting destroyers, and force that ship to move off or receive a torpedo. That there is no physical difficulty in the problem, is amply proved by the accurate functioning of the boat now in this harbor (the 'Holland'), which has shown to scores of doubters that perfect control in both the vertical and horizontal planes has been accomplished, that the boat can be held at any depth to within a foot, and be made to take porpoise-like dives, exposing the conning tower for only six or eight seconds, and can be steered on any desired course."

Rear-Admiral Jouett testified before the Senate Committee on Naval Affairs: "If I commanded a squadron that was blockading a port, and the enemy had half a dozen of these Holland submarine boats, I would be compelled to abandon the blockade and put to sea, to avoid destruction of my ships from an invisible source from which I could not defend myself."

Lieut. A. P. Niblack, who commanded the torpedo boat 'Winslow' during the latter part of the war, wrote in 'Marine Engineering,' December, 1898: "The crowning virtue of a submarine boat is that it makes blockades almost impossible. Strategically in war, it has a place all to itself." He is authority also for the statement: "If Spain had had the 'Holland' at Santiago, the blockade of that port by the United States would have been impossible, within the radius of action of the boat."

Admiral Dewey testified before the House Committee on Naval Affairs, April 23, 1900: "I saw the operation of the boat ('Holland') down off Mount Vernon the other day. I said then, and I have said it since, that if they (the Spanish) had had two of those things in Manila, I never could have held it with the squadron I had."

Rear-Admiral Philip Hichborn, Chief of the Bureau of Construction, writes in 'Engineering Magazine' for June, 1900: "Submarines can secure our coasts more perfectly than they can be secured in any other way at present practicable."

Mr. W. R. Eckert, consulting engineer of the Union Iron Works, of San Francisco, which built the 'Oregon' and the 'Olympia,' said, after the trial of the 'Holland' of September, 1899, in Peconic Bay, Long Island: "I have been on the trial trips of many of the new vessels built for the Government, and would say that I would feel safer in the Holland boat when under water than in the engine or fire rooms of any of the fast torpedo boats."

Rear-Admiral Endicott says: "The Holland submarine torpedo boat will revolutionize the world's naval warfare. It will make the navies of the world playthings in the grasp of the greatest naval engine in history."

However successful or safe submarine navigation may be to-day, the story of its development shows sufficiently that the risks to be taken have been very great, even though the actual loss of life incurred has been, on the whole, remarkably slight. To the venturesome spirits who have sought thus to master the ocean depths the risk involved has only added a new fascination.

The history of man's attempts to penetrate the depths of the ocean is not brief. The diving-suit, indeed, is modern, but the diving-bell appears to have been known in the time of Aristotle and diving itself is as old as man.

But essential mastery of the depths can never be attained by these means. The expert diver can remain below but two minutes or so, at the most. The tenant of a diving bell or suit is not, indeed, so limited in time, but, because absolutely dependent upon the flexible tube by means of which air is pumped down to him by companions at the surface, he is limited in space, and, by conditions of weather and sea, is limited also as to times. In no such sense is he independent as is the captain of an ocean greyhound or man-of-war, or even as the lone lobsterman at the helm of an undecked boat. To be master under water one must navigate under water, and any contrivance deserving the name of submarine boat must be able not only to sink beneath the surface, but also by its own power to move about under water for a reasonable time freely and independently. They who go down to the sea in suits and bells are not navigators.

The number of recorded attempts truly to navigate under water is surprisingly large. In a report of the United States Fortifications

Board made in 1885 to the Forty-ninth Congress may be found a selected list of about fifty submarine boats. This list extends over a period of three centuries. It includes no boats which have been projected or described merely, nor even those which have been patented merely, but only such as had been actually built and practically tried up to that date. In the invention of these boats and in experimenting with them have been engaged the citizens of England, France, Holland, Spain, the Scandinavian countries, Italy, Russia and the United States—nearly all of the civilized countries. England has probably accomplished as little in this direction as any nation. France has shown by far the greatest zeal as a nation, and, on the whole, has been the most prolific. But the greatest practical success has been attained undoubtedly in our own country.

It would be a thankless as well as a wearisome task merely to enumerate the vessels of this list, still more so to describe them all, however briefly. Most of them were of ephemeral interest only. But there are some which should be mentioned in any account of submarine navigation, however concise.

Thus, in 1624 a Hollander named Cornelius Van Drebbell constructed a boat which was tried with some success in the Thames at London. James I. is said on one occasion at least to have been a witness of the experiments. But navigation under water in that day was an uncanny thing. Drebbell was regarded first as a magician, then as a madman, and then as an agent of the devil. Meeting no encouragement he died, and his secret died with him. It is curious to notice that Drebbell claimed to have discovered a certain fluid which possessed the power of purifying air vitiated by respiration. He called it 'Quintessence of Air.' From the standpoint of present knowledge this singular name and Drebbell's claim for the liquid are very suggestive. Oxygen was not discovered, as we believe, until a century and a half after Drebbell's time. But oxygen is the life-giving component of air. Moreover, volumetrically oxygen is the 'quintessence'—the fifth part—of air. Is it possible that Drebbell had discovered some liquid which easily disengaged the then unknown oxygen gas and thus was able to restore to vitiated air that principle of which respiration deprives it? Undoubtedly not. It is much more likely that he possessed a solution capable of absorbing the carbonic acid gas which is produced by respiration, and that the name given it was entirely fanciful and without special significance. But even if Drebbell's claim was a piece of pure quackery, with no substantial basis at all, it is nevertheless not without interest, for it shows, as we might have anticipated, that the problem of ventilation, one of the most important with which the inventors of submarines have had to deal, was at least appreciated by Drebbell the pioneer.

In the latter half of the eighteenth century, an engineer named Day made one successful dive in the harbor of Plymouth, England, in a boat of his own designing. He went down a second time and did not return.

It may be said in general that the necessities and opportunities of war have always been the greatest, indeed, almost the only incentive to experiments under water. The War of Independence proved remarkably stimulating to submarine invention. In 1775 David Bushnell, of Connecticut, constructed a diving boat for use against English men-of-war. A minute description of this boat is contained in a letter written by him to Thomas Jefferson in 1787. It resembled externally two upper turtle shells joined together by their edges, whence its name 'Tortoise.' It carried a crew of one man, but this man was not David

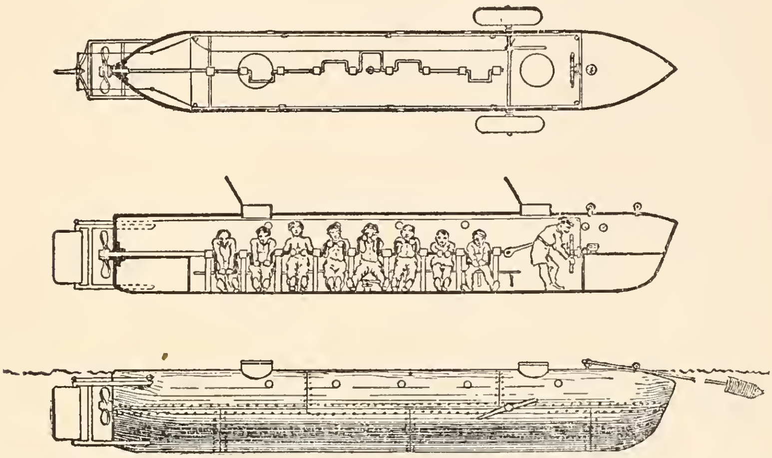


FIG. 1. THE CONFEDERATE SUBMARINE BOAT WHICH SANK THE U. S. STEAMSHIP 'HOUSATONIC IN CHARLESTON HARBOR DURING THE CIVIL WAR.

Bushnell, as it appears! During the harbor trials the boat was connected with the dock by means of a rope so that it might be recovered in case of accident. David Bushnell manipulated the safer end of this rope on the dock, while his brother, Ezra, and afterwards Sergeant Lee, did their best to learn the proper use of the mechanism within.

The following year, the first of the war, Sergeant Lee steered the 'Tortoise' beneath the hull of the British ship 'Eagle,' of 64 guns, lying off Governor's Island in New York harbor. He attempted to fix to her bottom a torpedo by means of a wood screw, but being rather unskillful still in maneuvering the 'Tortoise,' he lost the 'Eagle' altogether and was finally forced to the surface for air. Daybreak prevented further operations at that time. Two similar attempts were afterwards made on the Hudson, but they also failed and the 'Tortoise' was finally sunk by a shot.

In 1800 Robert Fulton, the father of steam navigation, built a very successful diving boat for Napoleon. It was called the 'Nautilus,' and possibly suggested the theme of that fascinating story, 'Twenty Thousand Leagues Under the Sea.' By its use, he actually succeeded in blowing up in the harbor of Brest an old hulk which had been provided for the purpose. But Napoleon's favor proved fickle, and Fulton's success led to nothing further at the time.

Early in the Civil War the Federal government entered into negotiations with a certain Frenchman to build and operate a submarine boat against Confederate vessels. It was desired in particular to blow up the Confederate 'Merrimac' in Norfolk harbor. Ten thousand dollars was to be paid for the boat when finished and $5,000 for each successful attack with her. The boat was constructed at the navy yard at Washington and paid for, whereupon the wily Frenchman decamped with his money, leaving the government to learn the secret of running the craft. This they never did. In fact, it seemed the general opinion that even the Frenchman would have experienced some difficulty in so doing.

Much more successful were the Confederates. The following account is condensed from Admiral Porter's 'Naval History of the Civil War': On the 17th of February, 1864, the fine new Federal vessel 'Housatonic,' 1,264 tons, lay outside the bar in Charleston harbor. At 8:45 P. M. Acting Master Crosby discovered something about 100 yards away which looked like a plank moving through the water directly toward his ship. All the officers of the squadron had been officially informed of the fact that the Confederates had constructed a number of diving boats, called for some reason 'Davids,' and that they were planning mischief against the Northern navy. Moreover, a bold, though unsuccessful, attempt of four months before to blow up the Federal 'Ironsides' was fresh in the minds of all. When, therefore, the officer of the deck aboard the 'Housatonic' saw this object approaching, he instantly ordered the anchor chain slipped, the engines backed and all hands called on deck. It was too late. In less than two minutes from the time of first discovery the infernal machine was alongside. A torpedo carried at the end of a pole thrust out from the bow of the stranger struck the 'Housatonic' just forward of the mainmast on the starboard side in direct line with the magazine. A terrific explosion took place, and the 'Housatonic' rose in the water as if lifted by an earthquake, heeled to port and sank at once, stern foremost. The crew, who most fortunately had reached the deck, took to the rigging and were soon rescued by boats from the 'Canandaigua,' which lay not far off. The 'David' was afterwards found fast in the hole made by her own torpedo. She had been sucked in by the rush of water which filled the sinking wreck. Her crew of nine were all dead

—killed doubtless not by drowning, though they must eventually have been drowned, nor as it would seem by suffocation, though in the end that would have followed; but probably by the concussion of their own torpedo.

The sublime heroism of these men is accentuated by the previous history of the 'David' to which they entrusted their lives. In her trial trip this boat sank for some unknown reason and her entire crew was drowned. Lieutenant Payne, her commander, escaped as by a miracle and succeeded in making his way to the surface. No sooner was the boat recovered from the bottom than he offered to try again. A new crew volunteered, and all went well for a time. But one night off Fort Sumter the boat capsized and four only escaped. The next essay was made under the lead of one of the men who had constructed the boat. This time she sank again and all hands were drowned. It was

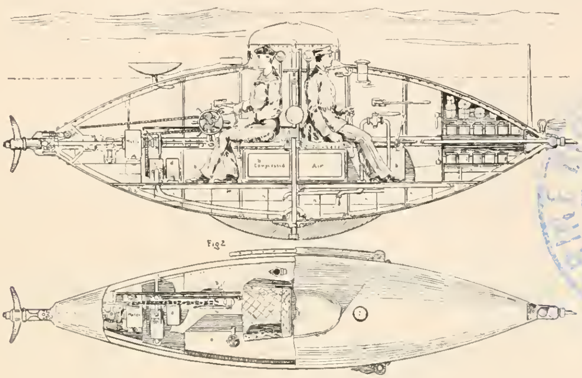


FIG. 2. GOUBET'S SUBMARINE TORPEDO BOAT.

such a boat, with such a history, in which that gallant crew of the 17th of February faced death and found it. North and South are united to-day as never before. We are permitted to treasure the memory of these brave men. They belonged to the same section as Hobson and displayed the same sublime heroism at Charleston as did he and his comrades at Santiago harbor.

The close of the Civil War marks an era in the history of submarine navigation. Previous to that time nearly all the boats were crudely designed and crudely built. Moreover, the nature and magnitude of the problems to be solved had not as yet been adequately understood. Whatever practical success has been achieved since is due to the fact that these problems have been thoughtfully and carefully studied, that those who have studied them have been in general better equipped therefor by education and training and have laid under requisition all the wealth of modern mechanical and physical science.

Of the many boats of this period, some of which have been quite successful, one may easily recall the French 'Le Plongeur,' the 'Gustav Zédé,' the 'Morse,' the 'Narval,' the Nordenfeldt boats and those of Goubet and Baker. Here also belong, of course, the latest and most successful boats of all, the 'Holland' and Mr. Lake's 'Argonaut,' of which some account will follow.

Turning now from the history of submarine navigation to a consideration of certain practical problems connected with it, we are brought at the outset face to face with a fact of fundamental significance, namely, that even with the aid of very powerful electric illumination it is not possible to see clearly through ordinary sea water for more than a few feet. According to Mr. Lake of the 'Argonaut,' about fifteen feet is the limit of visibility in our Northern waters, and about twice that in Southern. Submarine navigation is like navigation in the densest sort of a fog. High speed under water is just as possible mechanically as upon the surface. But the fact just stated is a death blow to high speed. Unless there shall be discovered some hitherto unsuspected means of perceiving at a distance invisible objects, high speed will unquestionably be fraught with great peril.

For the same reason it will probably be found impracticable to attempt very long journeys under water. There will probably never be trans-sub-atlantic lines, much less submarine greyhounds.

In fact, practical inventors of submarine craft, at least of late years, have ceased to attempt to provide more than a *surface-going* boat which shall be able at any time or place to *dive* beneath the surface to the depth desired, to remain under water for considerable periods of time, either stationary or moving, with both safety and comfort to the crew, and then, the purpose of the dive having been accomplished, to return speedily and safely to the surface. Even these requirements constitute a pretty large contract, but that they have been met satisfactorily appears sufficiently, so far as the 'Holland' at least is concerned, from the quotations given at the beginning of the article, and from the further fact that our government, ultra-conservative in adopting new devices for use in warfare, has purchased the 'Holland,' which is now at Newport in charge of Lieutenant Caldwell, Admiral Dewey's aid at Manila, and that Congress has authorized the building of six more 'Holland' boats of an improved type. Two of these are now being built at the Union Iron Works, at San Francisco, the rest at Elizabethport, N. J.

Obviously, a prime essential for any sojourn under water is an ample supply of pure air. When possible to make use of it there is but one rational source of pure air, and that is the exhaustless supply at the surface. Provided she herself secures it, a submarine boat does not in the least surrender her independence by utilizing this supply. This the 'Argonaut' does at ordinary depths by means of a pair of vertical tubes, one for inflow, the other for discharge.

The method answers very well for the peaceful commercial work of the 'Argonaut.' In war, however, this would usually be impossible. The 'Holland' in action must be entirely concealed from the enemy for considerable periods of time. The normal air capacity of her hull is, therefore, supplemented by compressed air tanks capable of withstanding pressures upwards of a ton to the inch, and of holding 4,000 feet of free air compressed into the volume of thirty cubic feet. These tanks are recharged by her own engines when at the surface.

Ever since the days of Drebbell's 'Quintessence of Air' a great deal of thought has been given to the problem of purifying the air once

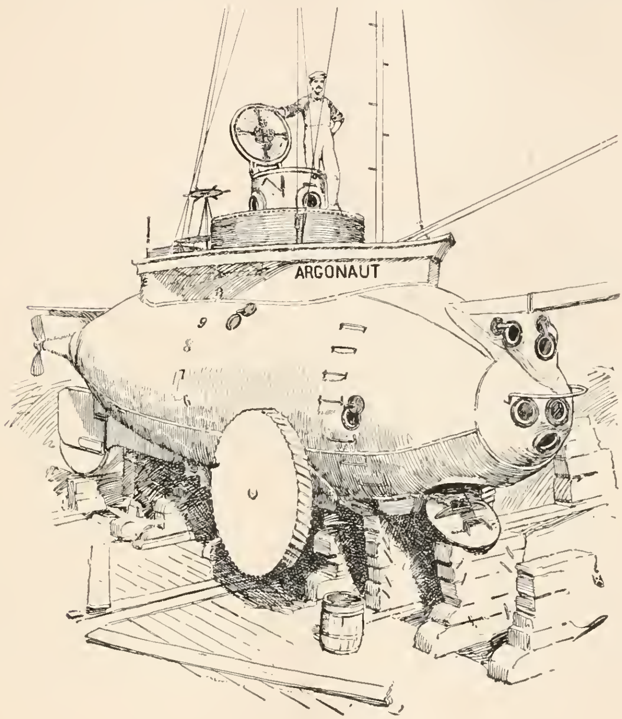


FIG. 3. THE 'ARGONAUT' IN DRY DOCK.

vitiated by respiration and thus rendering it fit for use again. While it would seem to be a very simple task to restore from tanks or by chemical generation within the boat the oxygen which respiration consumes, and to absorb the water vapor and carbonic acid gas which respiration produces, those who have built the latest boats seem to have abandoned the attempt entirely. It is easy to imagine emergencies where fresh air could not well be obtained, and where such means of restoring air once breathed would be of prime value.

Objects under water are subject to pressure, which varies with the depth of submergence. At a depth of thirty-three feet this water pressure is about fifteen pounds to the square inch, or more than a ton to the foot. Solid construction is naturally in order for a submarine boat. But power to resist pressure depends also upon shape. A circular section, because it involves the principle of the arch, is the strongest. With a given thickness of metal, therefore, a spherical boat could safely dive deeper than one of any other form. But the exterior of such a boat is ill-adapted to propulsion, and the interior for the arrangement of machinery.

Since the days of Captain Nemo and the fabulous 'Nautilus' the cigar shape has doubtless been associated with submarine navigation in

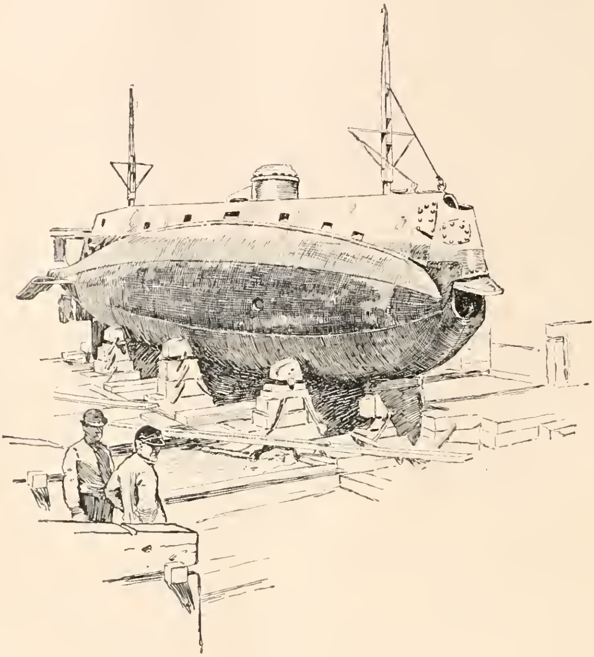


Fig 4. The 'Holland' in Dry Dock.

the minds of ninety-nine out of every hundred persons who have thought of the matter at all. And it is equally a matter of sober history that this form has been almost universally adopted. Some inventors in the earlier days, with the vision of high speed in mind, have trimmed down the lines to almost needle-like fineness, as in the 'Gustav Zédé.' Now that attempts at high speed have been abandoned, the elongated spheroidal or egg-shape is the favorite, as illustrated both by the 'Holland' and the 'Argonaut.'

But what of power for locomotion under water? Obviously steam power, at least as ordinarily produced elsewhere, will not do. Even supposing the necessary draft to be secured, how shall the smoke be concealed, and how shall the crew endure the excessive temperature to which coal fires with little ventilation would subject them? Fortunately, the problem of power for propulsion is much simplified by the fact already mentioned, that for the most part, even a submarine boat lives and moves and has its being on the surface. When at the surface, steam power may be used as on any boat. Many of the earlier boats were thus equipped with boilers and steam engines. These served not only for surface propulsion, but were used also to store up

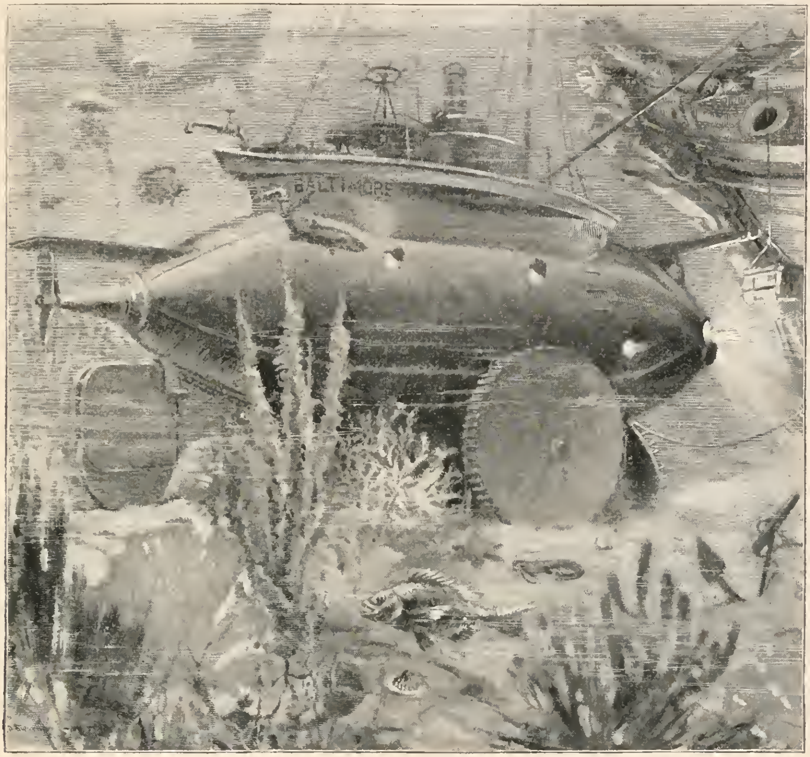


FIG. 5. SKETCH OF THE 'ARGONAUT' AS SHE MIGHT APPEAR AT THE BOTTOM OF THE SEA.

energy in the form of electricity or compressed air to be available as power when diving.

Nowadays gasoline and oil motors have been so perfected and they allow such economy of fuel space and withal such freedom from the dust, smoke and heat incident to a steam plant that they are coming into very general use, both afloat and ashore, where moderate amounts of power are required. Both the 'Holland' and the 'Argonaut' are equipped with gasoline engines. As these require for their operation much larger quantities of air than can be conveniently supplied from compressed air tanks, wherever concealment is necessary and a supply of air from the surface is out of the question, recourse is still had as before to some form of storage power for propulsion. At present this is always electric.

The problem of diving demands attention next. For surface sailing a submarine boat, like any other, needs considerable buoyancy, so as to float with a considerable fraction of its bulk free above water. For diving, on the other hand, her buoyancy must be very small. These conditions are met by varying the amount of ballast carried. This is universally done by admitting water into, or expelling it from, suitable air-tight tanks distributed through the bottom of the boat. The filling of these tanks requires only the opening of a valve. To empty them

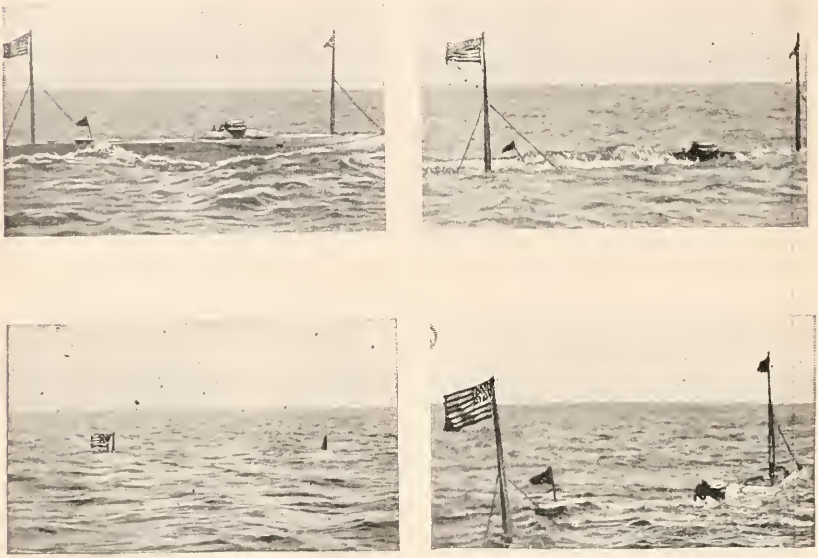


Fig. 6. Photographs of a Trial of the 'Holland,' showing her in Cruising Trim, in Diving Trim, Diving, and Rising after the Dive.

requires power. Formerly this was done by means of pumps. But pumping is slow work. A much more expeditious method of emptying the water tanks is to blow out the water by admitting compressed air from the reservoirs. The air so used is finally delivered into the living rooms for breathing, and the pressure in the reservoirs is restored again when at the surface. By thus varying the quantity of ballast a boat may be caused to sink, or, if already beneath the water, be caused to rise to the surface either slowly or rapidly as may be desired. It is easy to imagine circumstances, either accidental or otherwise, where a very sudden return to the surface might be imperative. To provide for this in emergencies the most practical boats are furnished with a very heavy false keel of iron, which may almost instantly be detached by the throwing of a lever or the turning of a screw within the boat. The effect is precisely the same as that produced by throwing out a large quantity of ballast from the car of a balloon.

To sink a boat, take on sufficient ballast; to rise, discharge ballast, as in a balloon. But the ballast that will sink a boat beneath the surface at all will sink her to the bottom, and on the other hand if ballast be discharged until the rise begins, the rise will continue till the boat is again at the surface. To regulate the depth of submergence, therefore, something more is needed than mere adjustment of ballast. Practically there are but two ways of securing this regulation. One, repre-

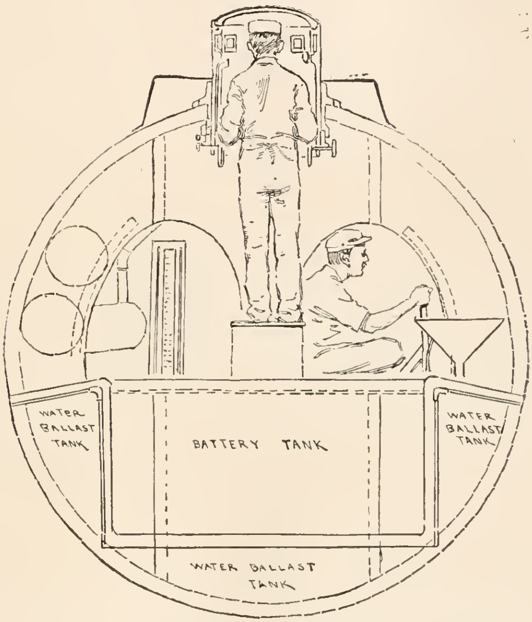


FIG. 7. CROSS SECTION OF THE 'HOLLAND' AMIDSHIPS.

sented in the Nordenfeldt boats and in some others, depends on the action of propellers arranged to act vertically instead of horizontally as do the ordinary. Although this method has the advantage of being applicable whether the boat is progressively in motion or not, it is now entirely abandoned. No sane person would advocate lateral propellers for moving a boat to right or left, and the disadvantages of vertical propellers for vertical motion are of the same order. The 'Holland' dives, rises or runs at a constant depth by the use of a rudder at the stern set at right angles to that for steering to right and left. By means of this rudder in the hands of a skilled steersman the 'Holland' can be held for a mile or over to within less than a foot of any depth desired.

As may be inferred from the quotations at the beginning of this article, the 'Holland' certainly embodies the highest attainments ever made in a submarine war vessel. In the words of Rear Admiral Hichborn, "The 'Holland' is an improvement upon anything that has ever been built in the history of the world." She is fifty-four feet long and is able with her forty-five H. P. gasoline engines to run considerably more than a thousand miles on the surface without recourse to any base of supplies, and, with her storage batteries and electric motors, thirty miles under water. Her offensive equipment is represented by an expulsion tube and three Whitehead torpedoes.

Her plan of operations when in the presence of a hostile vessel is to dive beneath the surface and steer by compass straight for the enemy. At intervals of a mile or so she rises till the top of her conning tower only protrudes, corrects her course and dives again. An emergence of eight to ten seconds only is required. Having arrived within a few hundred yards of the enemy the 'Holland' emerges for the last time, fires her torpedo, dives, turns back on her course and runs home.

During all this time she is perfectly protected by her invisibility. Even when rising she exposes so small a surface and that so low in the water that the chances are all against her being detected at all, especially as no one can tell when or where she will appear. Or if seen by the enemy there is no time to train guns upon her, and if there were, the chances are infinitesimal that so small an object could ever be hit. On the other hand, no defensive armor could save from absolute destruction a vessel once hit by the 'Holland's' torpedo.

After all is said which may be, of the terribly destructive power of the 'Holland,' or of any other submarine boat, it seems unquestionable that the greatest argument in favor of her adoption into a navy is not based thereupon, but rather upon the moral effect which would follow the knowledge that a nation possessed such a boat at all. "There is nothing more terrifying and demoralizing than to be attacked by an invisible foe; nothing more trying, bewildering and ineffective than striving to answer such an attack." If a captain of a battleship should see the turret of a submarine appear at the surface, straighten her course toward him, and then in ten seconds, before a shot could be fired, sink out of sight again, what would be his duty as a brave man, charged with responsibility for millions of property and hundreds of lives and with the performance of effective service for his country? To seek means of defense? There is no defense but flight, swift and immediate.

Hostile transports especially would not dare to approach a coast where the proximity of such a boat was suspected. High authorities insist that blockading also would be impossible if a harbor contained half a dozen of these terrible engines, which strike where no armor can afford protection, which come one knows not whence nor when, and which are invulnerable because invisible. Any nation suitably equipped with such means of defense would be impregnable on the side of the sea.

Every submarine boat with a single exception, so far as the writer knows, has been designed solely or at least chiefly with reference to use in war. That exception is the 'Argonaut,' designed by Simon Lake and owned by the Lake Submarine Company.

The 'Argonaut' is intended for peaceful pursuits and is built and equipped accordingly. Her purpose is to save property, not to destroy it. Her work is to be quiet and prosaic, but none the less efficient and valuable. The success of her inventor and his company depends not upon the favor of governments and department officials, but upon the successful performance of forms of work which have a direct commercial value.

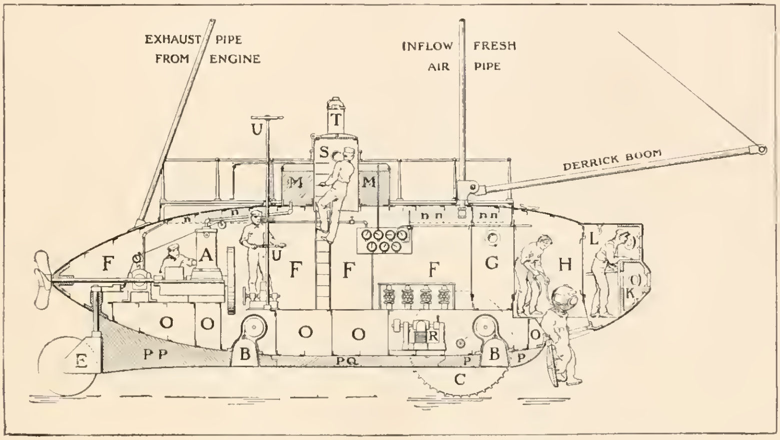


FIG. 8. LONGITUDINAL SECTION OF THE SUBMARINE BOAT 'ARGONAUT.'

She is built to travel on the bottom and is provided accordingly with wheels like a tricycle. Except in war, there is scarcely a single valuable object which can be served by navigation between the surface and the bottom. The treasures of the deep are on the bottom. On the bottom are the sponges, the pearls, the corals, the shell fish, the wrecks of treasure ships and coal ships and the gold-bearing sands. On the bottom are the foundations of submarine works, explosive harbor defenses and cables. To the bottom the 'Argonaut' goes, and on it she does her work.

Propelled at the surface by her gasoline engines, she looks much like any other power boat. The upper part of her hull is that of ordinary surface-going boats. Underneath she has the ovoidal form. Conspicuous on her deck are the two vertical pipes by means of which during submergence fresh air is drawn from the surface and the vitiated air within expelled. On the deck are also a derrick and a powerful sand pump for use in wrecking or in submarine construction, while a powerful electric lamp in her conical under-water bow illuminates the field of her operations. Most interesting is the sea door at the bottom forward, through which divers enter and leave the boat when on the ocean floor, the inrush of water into the diving compartment being prevented in the meantime by air pressure within, equal to and balancing the water pressure without. The 'Argonaut' has already traveled, it is said, hundreds of miles on the surface and scores on the ocean

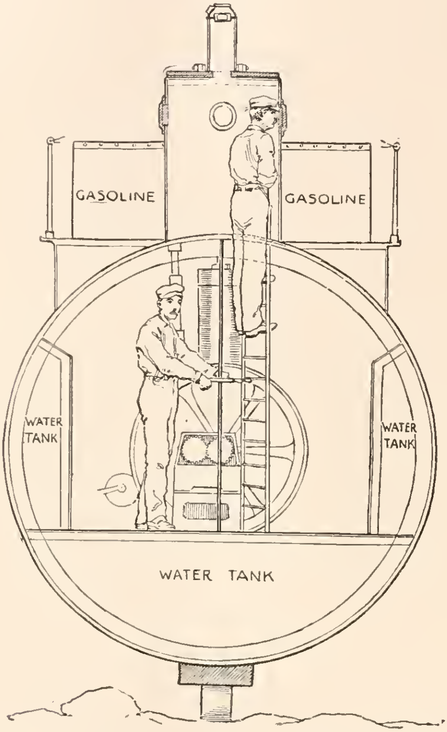


FIG. 9. CROSS SECTION OF THE 'ARGONAUT' AMIDSHIPS.

bottom. She can remain at the bottom as long as her gasoline and provisions hold out, with no other inconvenience to her crew than is occasioned by the somewhat restricted room within.

Mastery is the motto of mankind. Instinctively the race is ever obedient to that ringing commission of the Omnipotent: "Replenish the earth, and subdue it—and have dominion." Man longs to explore every unknown realm. He thirsts for knowledge, which is power, and by it he masters the mighty forces of nature and makes them his servants. It seems a little thing to have dominion over the habitable portions of the earth—he must search the stretches of the desert, the realms of frost and eternal snow and the expanse of the sea. It is not enough to know the length and breadth of the earth—he must scale the heights of the mountains and penetrate the seerets of the great deep. Alexander weeping because, as he thought, there were no more worlds to eonquer, is an aneient type of that same masterful spirit of whieh Kipling is the mighty modern prophet. But modern Alexanders find no place for tears.

Aceording to competent judges, the submarine is to-day ready to serve mankind; the 'Holland' to make war less popular, the 'Argonaut' to make peaee more valuable.

We should take genuine pride, should we not, in the fact that eitizens of our own country are to-day foremost in the construction and use of these mighty engines?

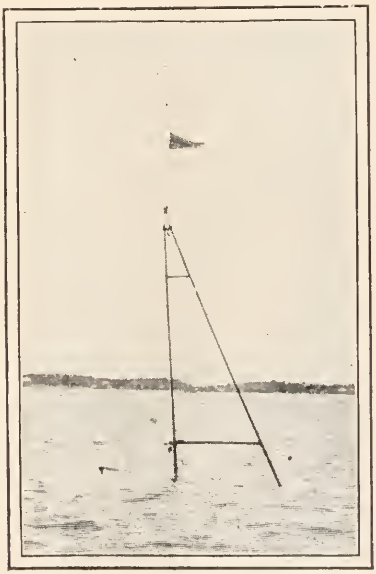


FIG. 10. THE 'ARGONAUT' SUBMERGED.

MUNICIPAL WATER-WORKS LABORATORIES.

By GEORGE C. WHIPPLE,

MT. PROSPECT LABORATORY, BROOKLYN, N. Y.

THE laboratory idea is fast taking hold of our municipalities. It is the natural result of modern science and American practicality. More and more our civilization is making use of the great forces of nature, and more and more is it becoming necessary that nature's laws should be understood: hence the need for the precise data of the expert and the long-continued observations of the specialist. This is emphatically true in the domain of sanitary science, where the advances in chemistry, microscopy and bacteriology have wrought revolutionary changes. The microscope is no longer a toy, it is a tool; the microscopic world is no longer a world apart, it is vitally connected with our own. The acceptance of the germ-theory of disease has placed new responsibilities upon health authorities and has at the same time indicated the measures necessary to be taken for the protection of the public health. With the knowledge that certain diseases are caused by living organisms and that these may be transmitted by drinking-water has come the need of careful supervision of public water supplies, which has resulted in the establishment of many laboratories devoted to water analysis.

The pioneer work of the Massachusetts State Board of Health and the Board of Health of New York City has been followed by the installation of laboratories in most of our large cities. In many cases these are operated in connection with departments of health, and the supervision exercised over the water supplies is of great benefit to the communities. An instance of this is furnished by the Health Department of Chicago. The water supply of Chicago is taken from Lake Michigan, and before the operation of the drainage canal the sewage of the entire city was discharged into the lake. The location of the water-works intakes was such that the water pumped to the city was subject to great changes in quality, varying from day to day according to the direction of wind and currents. For a long time it has been the practice of the department to issue daily bulletins as to the sanitary condition of the water in the city. Samples from the various sources of supply are received at the laboratory each morning, and upon the results of certain rapid methods of analysis the chemist bases his judgment as to the probable character of the water in the city mains during that day. The report is promptly given to the representatives of the press, and the consumers are thus warned of approaching danger.

The work of supplying water to a community is, however, an engineering problem, and for some years water-works' officials and engineers have felt the need of having in their own hands the means of determining the quality of the water. This has not been because they wished to assume duties pertaining to the health authorities or because they stood in fear of criticism, but because the management of the water supplies demands immediate information of a character not always appreciated by a physician and not always promptly obtainable from the laboratory of a health department. Accordingly, there has been developed in this country during the last decade an interesting group of water-works laboratories devoted to sanitary supervision and to experiments upon water purification.

The first of these laboratories was that of the Boston Water Works, established in 1889 by Mr. Desmond Fitzgerald, C. E., then Superintendent of the Western Division. At that time, and for several years previous, the water supplied to the city was in ill favor with the consumers because of its brown color and its vegetable taste. The primary object of the laboratory was the study of these objectionable conditions and the means for relieving them, but as the work proceeded it developed along broader lines. The laboratory, situated on the shore of Chestnut Hill Reservoir, consisted of a small frame building of two rooms, one used for general biological work and the other fitted up as a photographic dark room. The working force consisted of one biologist and three assistants, besides a number of attendants at the reservoirs, who devoted a portion of their time to the collection of samples and the observation of the temperature of the water. The following were the general outlines of the work:

The water supply of the city was derived from Lake Cochituate and from a series of storage reservoirs on the Sudbury River. The waters from these sources differed from each other and varied at different seasons of the year. Accordingly, a system of inspection and analysis was arranged in such a way that the superintendent knew at all times the exact condition of the water throughout the system. Samples of water were collected regularly from all streams tributary to the supply, from reservoirs at various places and at different depths, and from the aqueducts and distribution pipes. When these reached the laboratory they were examined microscopically and bacteriologically, the presence of any odor-producing organism was carefully noted and an immediate report was rendered when necessary. Careful observations of color were also made. When the work in Boston was started the methods of biological examination of water were in their infancy. The Sedgwick-Rafter method of ascertaining the number of microscopic organisms in water had just been devised and the methods of plate culture of bacteria were just becoming popular. The new methods were adopted in the Chestnut

Hill laboratory and constant use resulted in important improvements. The old method of obtaining the temperature of water beneath the surface by the use of a weighted thermometer gave way to the electrical 'thermophone,' and new methods for measuring the color of water were devised. An apparatus for photography was installed, and excellent photographs were made of all the important microscopic organisms in the water. A set of these photographs was on exhibition at the World's Fair in Chicago. In addition to the routine work, many lines of experimental work were undertaken. Studies were made upon the seasonal distribution of various organisms, the effect of temperature, light and air upon their growth, and upon the cause and nature of the odor imparted by organisms to drinking water. The effect of swamp-land upon water

Fig. 1. Mt. Prospect Laboratory, Brooklyn, N. Y.

supplies, the stagnation of deep lakes, the bleaching action of sunlight upon colored waters were likewise considered, while for several years the laboratory was operated in connection with an experimental filter plant.

After the Metropolitan Water Board assumed control of the water supply of Boston and its suburbs the laboratory was moved from Chestnut Hill Reservoir into the city, where it now occupies rooms at No. 3 Mt. Vernon street. In 1897 Dr. F. S. Hollis succeeded the writer as biologist, and he in turn has been succeeded by Mr. Horatio N. Parker. During recent years the conditions of the water supply have changed. New reservoirs of large capacity have been built, and the great Wachusett Reservoir is in process of construction. Swamps have been drained and filters have been installed where there was danger of polluted water entering the supply. Thus new fields of work have been opened to the laboratory. The center of gravity of the system is now much farther from the city than formerly, and the logic of the situation points to the future establishment of a laboratory upon the watershed operated in connection with a department of sanitary inspection and equipped for chemical as well as biological work.

In 1893 the Public Water Board of the city of Lynn, Mass., fitted out a small room in the basement of the City Hall to serve as a laboratory for microscopical work. Weekly samples were collected from the supply ponds and examined by one of the lady assistants in the office. The results of the examinations were used by the superintendent in the operation of the works, and in several instances

FIG. 2. MT. PROSPECT CHEMICAL LABORATORY.

they proved the direct means of preventing the consumers from receiving water of an inferior quality. They also resulted in the undertaking of improvements in one of the reservoirs and tributary swamp areas that materially reduced the growths of troublesome algæ.

Bad tastes and odors in the water supply of Brooklyn, N. Y., led to the establishment of Mt. Prospect Laboratory by the Department of Water Supply in 1897. As this laboratory is typical of its class it deserves more than a passing notice. Situated upon the shore of Mt. Prospect Reservoir, near the entrance to Prospect Park, the laboratory has a fortunate location. In addition to being within convenient distance of the office of the department, the main distribution reservoirs of the city and the railway depot at which samples from the watershed are received, its isolation and elevation make it comparatively free from noise and dust, while the building is well lighted by large windows, heated by hot water and provided with gas, electricity and telephone. The upper portion of the building contains three rooms, known as the general laboratory or preparation room, the biological laboratory and the chemical laboratory. In the basement are the physical laboratory, the furnace room and the general storeroom. The general laboratory is used for the shipment of samples, the washing of glassware, the sterilization of apparatus, the preparation of culture media and for such chemical processes as might charge the air with ammonia and the fumes of acids. The biological laboratory is devoted to the bacteriological and

Fig. 3. Laboratory of the Sewer Department, Worcester, Mass.

microscopical examination of samples of water and to the study of the various organisms found. It also serves as the office of the director. The chemical laboratory is the largest of the three rooms. Its atmosphere is kept free from ammonia and acid fumes in order not to vitiate the results of the water analyses there carried on. Analyses of coal are also made in this room. A storage room opens from the chemical laboratory and there is also a small dark room. All three laboratories have marble tiled floors, and the tables and shelves are covered with white tiles throughout. The partitions between the rooms are largely of glass. The apparatus is of the most complete description, much of it having been designed for the particular work at hand. The physical laboratory in the basement contains all the necessary apparatus for testing cement, analyzing sand, etc. The laboratory force consists of one biologist and director, one chemist, one assistant chemist and three assistants.

The routine work of the laboratory consists of the regular examination of samples of water from all parts of the watershed and distribution system, *i. e.*, from the driven wells, streams, ponds, aqueducts, reservoirs and service taps. The complicated and varied character of the water supply requires the examination of an unusually large number of samples, and it is safe to say that no water supply in this country is examined more thoroughly and minutely than that of Brooklyn. During the three years that the laboratory has been in operation over eight thousand samples have been analyzed.

The problems of the Brooklyn supply are very different from those met with in Boston. The supply is drawn, not from a few storage reservoirs of large size, but from a large number of small supply ponds, supplemented by an almost equal amount of water from deep and shallow driven wells. There are no extensive swamp areas, but the watershed is sandy and serves as a natural filtering medium. The entire supply, therefore, partakes largely of the character of ground water. The storage of ground water in an open reservoir has been almost always attended with troubles due to growths of microscopic organisms, and the Brooklyn supply has proved no exception to the rule. The mingling of surface water, seeded with plant life, and ground water, laden with plant food, has resulted in the enormous development of microscopic organisms in the distribution reservoirs. During the summer and autumn of 1896 the condition of the water in the city caused general complaint because of its bad odor. An examination, made by Dr. Albert R. Leeds, showed that the diatom asterionella was responsible for the trouble, and that the fishy odor was caused by an oil-like substance secreted by this microscopic plant. Since 1896 growths of asterionella and other odor-producing organisms have recurred regularly in the distribution reservoirs, but by the use of the new by-pass, through which water may be pumped around the reservoirs direct from the aqueduct to the distribution pipes, the water in the city has been kept comparatively free from them. The organisms appear and disappear according to laws that are now beginning to be understood, and while their growth in the Brooklyn reservoirs cannot be wholly prevented under present conditions, the laboratory is doing an important service by constantly noting their condition of growth and by forecasting their effect on the city supply for the guidance of the engineer in his manipulation of the reservoirs. The chief service of the laboratory, however, is in connection with the sanitary condition of the watershed, and upon this most of the bacteriological and chemical work is concentrated. The laboratory was installed and equipped under the direction of Mr. I. M.

De Varona, Engineer of Water Supply, with the writer in immediate charge.

The filtration of all surface water used for domestic supply is one of the probabilities of the future. For years many of the large cities of Europe have been supplied with filtered water, and in England alone more than ten million people are using water from which all danger from disease germs has been removed. In America filtration has gained ground but slowly, and in some of our cities the condition of the drinking-water is a disgrace to civilization. A German health officer once said to me: 'You Americans are a queer people; you filter sewage, but you drink water raw.' One reason for our tardiness in following the practice of the Old World is the fact that the conditions here are not in all respects the same as in Europe. The old methods of filtration cannot be successfully applied to many of our American waters, and water-works' engineers have felt that before expensive works were undertaken the problems should be carefully studied by direct experiment with respect to existing conditions. Thus, recent years have witnessed the operation of experimental filter plants unequalled in magnitude, in the scope of their work and in the accuracy of their methods of investigation.

The experiment station of the Massachusetts State Board of Health at Lawrence was started in 1897 and is still in operation. The results of the investigations of the principles involved in the purification of water and sewage by sand filtration have become classic in the annals of sanitary engineering, and the annual reports are still furnishing results of the highest scientific value. At the present time the work is in charge of Mr. H. W. Clark, Chemist of the Board. One practical result of these experiments was the construction of a sand filter of novel type for the purification of the water supply of the city of Lawrence, and the immediate reduction of the typhoid fever rate showed the success of the undertaking. The water of the Merrimac River, at Lawrence, though polluted, is comparatively clear, and it became evident that methods of filtration that were applicable to water of this character would not be necessarily successful where the water was highly colored and turbid. Experiments were, therefore, begun in other cities.

In Boston, where the water was of higher color than at Lawrence, and where microscopic organisms were sometimes numerous, a filtration station was in operation from 1892 to 1895. Six sand filters, each with an area of one-thousandth of an acre, and a large number of smaller filters, were used under varying conditions. The station was in charge of Mr. Wm. E. Foss, under the direction of Mr. Desmond Fitzgerald, C. E. The analytical work was done partly at the Massachusetts Institute of Technology and partly at the Biological Laboratory described above. It is much to be regretted that the results of these experiments were never published.

In 1893 Mr. Edmund B. Weston, C. E., of Providence, R. I., conducted for the water department of that city a series of experiments upon the purification of the water of the Pawtuxet River by means of mechanical filters. Though less extensive than the experiments above mentioned, they are of historic interest as giving the first adequate demonstration of the possibilities of that method of purification.

The system of mechanical filtration, or the 'American System,' as it is sometimes called, differs from natural sand filtration by the use of alum or some similar coagulating substance before sedimentation and filtration, by the higher rate of filtration employed and by the use of certain mechanical devices for cleaning the sand beds. The application of this process to the treatment of turbid water was next investigated. In 1895 the Louisville Water Company undertook a most extensive series of experiments to determine the relative efficiency of various types of mechanical filters in the purification of the water of the Ohio River. The work was placed in charge of Mr. Geo. W. Fuller, C. E., who was assisted by a large corps of trained assistants. For nearly a year the experiments were carried on without interruption: the filters were operated by the companies interested in them, and their efficiency was determined by Mr. Fuller on behalf of the water company, who had at hand a complete laboratory equipment and who used every means known to science in the analysis of the water before and after treatment. The most important result of these experiments was to prove beyond doubt the applicability of mechanical filtration to the purification of water rendered turbid by the presence of fine particles of clay.

The experiments in Louisville were followed in 1898-9 by a somewhat similar investigation at Cincinnati, O., also conducted by Mr. Fuller. As in Louisville, the water supply is taken from the Ohio River, but the character of the water at this point is not in all respects the same as that farther down stream. The problem in Cincinnati was to determine whether the English system of sand filtration or the American system, involving the use of a coagulant, was best suited to the purification of the water, and whether any preliminary treatment of the water before filtration was advisable. To solve this problem the Board of Trustees, Commissioners of Water Works, decided to appropriate for needed experiments a sum equivalent to about one year's interest on the probable cost of a plant for filtering the supply of the city. The equipment consisted of four steel tanks, each with a capacity of 100,000 gallons, fifteen experimental filters, arranged for operation under different conditions, and a large laboratory fully equipped for chemical and bacteriological work. After a period of continuous operation, covering about ten months, the evidence showed that either the American system or the English system operated with preliminary coagulation and sedimentation would satisfactorily purify the water, but that the American system could be operated with less difficulty and with somewhat less expense.

In 1896 the city of Pittsburg, Pa., appointed a commission to consider the character of the water supply and the advisability of its purification by some means of filtration. The supply is taken from the Allegheny and Monongahela rivers, streams which are often turbid and which are subject to contamination by sewage. The conditions were such that direct experiment was necessary to determine the most suitable system of purification. Accordingly, an experimental station was located on the shore of the Allegheny River and placed in charge of Mr. Morris Knowles, under the direction of Mr. Allen Hazen, Consulting Engineer. Arrangements were made for the comparative study of sand filters and mechanical filters, and a laboratory was built and equipped for making all necessary analyses. The plant was in continuous operation for more than a year, and the results seemed to show that while satisfactory clarification of the water could be obtained by either system, the method of sand filtration could be depended upon to remove more completely the effect of pollution.

The report of a similar series of experiments made to determine the feasibility of purifying the water of the Potomac River at Washington, D. C., has been issued by the War Department. The work was carried on in a manner similar to that at Cincinnati and Pittsburg, the object of the studies being to find the best method adapted to the local conditions. Col. A. M. Miller, U. S. A., had charge of the investigations, and Mr. Robert Spurr Weston conducted the analytical work. Recently the Department of Public Works, of Philadelphia, Pa., has established a testing station near the Spring Garden Pumping Station for the purpose of studying the problems of filtration incident to the construction of filter beds for the water supply of the entire city, for which the sum of ten million dollars has been already appropriated. The work is in charge of Mr. Morris Knowles. Still more recently a testing station has been established by the Sewerage and Water Board of New Orleans, with Mr. Robert Spurr Weston as Resident Expert.

In July, 1899, the newly-constructed water filtration plant at Albany, N. Y., was put in operation, Mr. Allen Hazen having been Chief Engineer of construction and Mr. Geo. I. Bailey Superintendent of Water Works. In connection with this plant is a small laboratory in which are made daily bacteriological examinations of the water before and after filtration. Physical, chemical and microscopical examinations are also made at frequent intervals. The results obtained indicate the amount of purification that is taking place, and they already have shown that the filter is rendering efficient service in protecting the community from water-borne diseases.

The combined work of these various laboratories of supervision and experiment has been of incalculable benefit to sanitary science, and the results have been not only of local and immediate value, but they have acquired a world-wide reputation and form a permanent contribution to scientific literature. If one doubts the practical worth of a laboratory in the management of a water-works system, no more convincing argument could be presented than the fact that a private water company in Wilkesbarre, Pa., has recently gone to the expense of establishing a laboratory for chemical, microscopical and bacteriological analyses of the water sold to the community, and this in spite of the fact that the water supply is taken from a watershed not seriously open to the danger of contamination. The work is in charge of Prof. Wm. H. Dean.

It is an interesting fact that in many instances the laboratories have been found to have a wider field of usefulness than that for which they were originally intended. For example, the laboratory in Cincinnati did not cease its existence when the filtration experiments were completed; it was continued as a laboratory for testing the materials of engineering construction. It is now in charge of Mr. J. W. Ellms, Chemist, under the direction of Mr. Gustav Bouscaren, Chief Engineer. The building has seven rooms and contains not only the apparatus necessary for water analysis and general chemical work, but a complete outfit for testing cement. The work now includes the chemical analysis of paints and oils, asphalts, rock, sand and cement, physical tests of cement, besides experimental investigations of the properties of cement mortars and asphalts.

At Pittsburg, also, the laboratory has been made permanent. The Department of Public Works has erected a two-story brick building, known as the Herron Hill Laboratory. The first floor and basement are used by the Bureau of Water Supply for water analysis, tests of supplies purchased and experimental work upon the filtration of water; the second floor is used by the Bureau of Engineering as a cement laboratory. In the water laboratory the floor and operating-shelves are covered with white tiles and the walls are painted with white enamel, so that the room may be washed from ceiling to floor. Steam from a neighboring boiler house is used for heating the water-baths and for distilling water. The incubators used for bacteriological work are placed in the basement, where the temperature can be kept more constant than on the floors above. The ammonia stills, sterilizers, autoclav and other apparatus are of the most modern type. A safe in the basement serves to protect the records in case of fire. One biologist, one chemist and one attendant are employed in the water laboratory, and a chemist is employed in the department of cement testing. Mr. Wm. R. Copeland is the biologist in charge.

In the Mt. Prospect Laboratory, of Brooklyn, the miscellaneous work is constantly increasing. The coal used at the various pumping stations is purchased under specifications that require the analysis of a sample that must accompany every bid, and the determination of the heating power of a sample from every consignment. Lubricating oils, boiler compounds, samples of steel and other materials are analyzed and the laboratory is also equipped for the chemical and physical testing of cements.

Other departments of municipal work are taking up the laboratory idea. The Sewer Department of Worcester, Mass., has two laboratories. One is located at the disposal works and is devoted wholly to the supervision of the process of treatment of the sewage. The other occupies attractive rooms in the City Hall. Here a great variety of work is undertaken. During the year 1899 more than a hundred carloads of cement were used by the department, and over eight thousand samples were tested for tensile strength; many chemical analyses were also made. Bricks were frequently tested for absorption, and several samples of steel used in the construction of shovels and offered to the department by different dealers were analyzed. Coal, oil, lime and many other materials purchased by the department were analyzed. In addition to this, over seventy-five samples of butter and oleomargarine were examined for the Department of Milk and Butter Inspection, and a number of water analyses were made for the water department. A large amount of experimental work was carried on in connection with the problem of sewage disposal. Both laboratories are under the general direction of Mr. Harrison P. Eddy, Superintendent of Sewers.

It seems apparent, therefore, that the laboratory is destined to be an important factor in municipal engineering as well as in municipal sanitation, and it is not difficult to foresee a time when every city of importance will be provided with a laboratory equipped in accordance with its needs. In large cities, work of this kind is preferably specialized and distributed through different departments, in order that it may be under the control of those directly interested in the results, but in small cities, all the analytical work can be more economically accomplished in a single laboratory. In such a laboratory the work would cover a very broad field. Coal, cement, oil, brick, asphalt and various structural materials would be tested before purchase and during delivery; illuminating gas regularly examined; water, milk and various food products analyzed to determine their purity and healthfulness; bacteriological cultures made for diagnosis of diphtheria, typhoid fever, tuberculosis and kindred diseases; disinfection of buildings supervised, etc. All this would require the services of an engineer, a chemist and a bacteriologist, or of these three combined in one person. The expense of such an institution would be small in comparison with the saving that would result to the citizens in the purchase of supplies and in the protection of the public health.

FREEDOM AND 'FREE-WILL.'

BY PROFESSOR GEORGE STUART FULLERTON,
UNIVERSITY OF PENNSYLVANIA.

LET us suppose two men before a jury on the accusation of homicide. Each admits that he has occasioned the death of a man, but each has his own account of how the thing came about. In the first instance, the accused was holding the gun that sped the fatal bullet; his finger was on the trigger and pressed it; the discharge followed; the victim fell. But it seems that the gun had been forced into his unwilling hands by one stronger than he; an iron finger lay above his own, and it was under its pressure that his finger became the proximate cause of a series of events which he cannot even now contemplate without horror. He was the unwilling instrument of a bloody deed, and does not account himself the responsible cause; he slew because he 'couldn't help it.'

The second man lays before his jurors a story in many respects different, but ending with the same words. He was alone when the shooting occurred. He was under no compulsion at the hands of another, but was shooting at a mark, and taking delight in dotting the target near the bull's-eye, when lo! across the field, above the hedge that bounds the horizon on that side, appears a tempting mark, the rubicund face of a rustic whose open mouth strikes his joyous mood at just that instant as an irresistible target, and one altogether too delightful to be passed by. "I had not the faintest intention, a moment before, of shooting any man," he explains; "but, really, it was too good a shot to miss, and I simply couldn't help it."

Let us suppose it possible for the same jury to hear these two explanations, one after the other. The action of a petit jury is said to be most uncertain, but there can be little doubt that even a jury would detect an important distinction between these two 'couldn't help's.' The world seems to be full of 'couldn't help's' of the two sorts: the man who stumbled on the stairs couldn't help rolling to the bottom; the man who was thrown from a window couldn't help descending to the street; the man who was seized by the police couldn't help failing to meet his engagement; the greedy boy couldn't help taking the larger muffin; the devoted mother couldn't help spoiling her only child; the emotional philanthropist couldn't help feeling in his pocket on hearing the plausible tale of the wily tramp.

Probably most jurymen would refuse to recognize 'couldn't help's' of the second class as worthy of the name at all. Certainly, as jurymen, they have little concern with them. It is only with those of the first class that the law has to do, except in cases in which the sanity of the accused is in question. But suppose one of the jurymen happens to be a philosopher, and is accustomed to reflect upon matters which most men are in the habit of passing by without much thought. He may say to himself: "As a juryman I cannot think of listening to the absurd excuse for homicide offered by this second fellow. If I did I should have to admit that no man is a moral agent and that no crime should be punished. The smuggler, the burglar, the murderer, may be assumed to be influenced by motives of some sort. There is no case in which something may not be pointed to as that which occasioned the deed. Human life must be protected; society must be preserved; evil-doers must be punished. If some men find the attractions of crime irresistible, so much the worse for them. And yet, as a philosopher, I find that I must accept the fact that, in a certain sense of the words, the guilty man couldn't help doing what he did. He was what he was; the target was attractive; the result followed. He was free from external compulsion, but he was not and could not be free from himself and his own impulses."

The man who reasons thus is called a determinist. Whether our determinist is wise to express things exactly as he does will appear in what follows. But the thought which he is at least trying to express is sufficiently clear. A determinist is a man who accepts in its widest sense the assumption of science that all the phenomena of nature are subject to law, and that nothing can happen without some adequate cause why it should happen thus and not otherwise. The fall of a rain-drop, the unfolding of a flower, the twitching of an eyelid, the penning of a sentence—all these, he maintains, have their adequate causes, though the causes of such occurrences lie, in great part, beyond the line which divides our knowledge from our ignorance. Determinism is, of course, a faith; for it is as yet wholly impossible for science to demonstrate even that the fluttering of an aspen leaf in the summer breeze is wholly subject to law; and that every turn or twist upon its stem must be just what it is, and nothing else, in view of the whole system of forces in play at the moment. Much less is it possible to prove in detail that that complicated creature called a man draws out his chair, sits down to dinner, gives his neighbor the best cut of the beef, discusses the political situation, and resists the attractions of the decanter before him, strictly in accordance with law—that every motion of every muscle is the effect of antecedent causes which are incalculable only because of the limitations of our intelligence and our ignorance of existing facts. And yet the faith of science seems to those trained in the sciences a reasonable thing, for, as is pointed out, it is progressively justified by the gradual advance of human knowledge, and even in fields in which anything like exact knowledge is at present unattainable the little we do know hints unmistakably at the reign of law. There are few intelligent men who would care to maintain that the fall of a rain-drop or the flutter of an aspen leaf could not be completely accounted for by the enumeration of antecedent causes, were our knowledge sufficiently increased; but there are a considerable number who take issue with the determinist in his view of the subjection to law of all human actions. They maintain that there is a necessarily incalculable element present in such cases, and that all the antecedents taken together can only in part account for the result. As opposed to determinism they hold to the doctrine of indeterminism, or, as it has too often unhappily been called, the doctrine of 'free-will.'

I say as it has unhappily been called, because it is a thousand pities that an interesting scientific question, and a most difficult one, should be taken out of the clear atmosphere of passionless intellectual investigation, and, through a mere confusion, brought down among the fogs of popular passion and partisan strife. We have all heard much about fate and free-will, and no man with the spirit of a man in him thinks, without inward revolt, of the possibility that his destiny is shaped for him by some irresistible external power in the face of which he is impotent. No normal man welcomes the thought that he is not free, and the denial of free-will can scarcely fail to meet with his reprobation. We recognize freedom as the dearest of our possessions, the guarantee, indeed, of all our possessions. The denial of freedom we associate with wrong and oppression, the scourge and the dungeon, the tyranny of brute force, the despair of the captive, the sodden degradation of the slave. The very word freedom is enough to set us quivering with emotion; it is the open door to the thousand-fold activities which well up within us, and to which we give expression with joy.

But it must not be forgotten that the antithesis of freedom is compulsion, that hateful thing that does violence to our nature and crushes with iron hand these same activities. The freedom which poets have sung, and for which men have died, has no more to do with indeterminism than has the Dog, a celestial constellation, with the terrestrial animal that barks. St. Thomas and Spinoza, who differ in many things, have both pointed out that one must distinguish between the two latter, and the distinction is not broader than that which exists between the former. Determinism is not fatalism, and indeterminism is not the affirmation of freedom in any proper sense of that word, the sense in which men take it when it sets their pulses bounding and fills their breasts with high resolve. We have seen that even a determinist can distinguish between the two 'couldn't helps,' and recognize that they must be differently treated. We may now go so far as to insist that, since they do differ so widely, they should be given different names, and we may call upon the determinist to avoid altogether, as other men do, the use of the term 'couldn't help' in the second sense. He may then say, without serious danger of being misunderstood, that the first prisoner at the bar couldn't help doing what he did, but that the second could have helped doing it if he had so elected. Without doing violence to the common use of speech, nay, strictly in accordance with common usage, he may declare that the one man was *not free*, but was under compulsion, while, on the other hand, the second man *was free*. He may very well do this without ceasing to be an out-and-out determinist.

Before going on with the topic which is the main interest of this paper, it is right that I should say just a word as to what determinism does not imply. It does not imply that all the causes which may be assumed to be the antecedents of human actions are material causes. A determinist may be a materialist, or he may be an idealist, or he may be a composite creature. As a matter of fact, there have been determinists of many different kinds, for the dispute touching the human will is thousands of years old; and the fact that the doctrine happens at the present time to be more closely associated in our minds with one of the 'isms' I have mentioned than with another, says little as to their natural relationship. Nor need the determinist necessarily be either an atheist, a theist, or an agnostic. He may, of course, be any one of these; but if he is, it will not be because of his determinism. As a determinist he affirms only the universal applicability of the principle of sufficient reason—the doctrine that for every occurrence, of whatever sort, there must be a cause or causes which can furnish an adequate explanation of the occurrence. I say so much to clear the ground. It is well to remember that materialists have been determinists, idealists have been determinists, atheists have been determinists, theologians have been determinists. The doctrine is not bound up with any of the differences that divide these, and it should not be prejudged from a mistaken notion that it necessarily favors the position taken by one of these classes rather than that taken by another. We may approach it with an open mind, and make an effort to judge it strictly on its own merits.

But to judge it on its own merits, the very first requisite is to purge the mind completely of the misconception that the 'freedom' of the will, or indeterminism, has anything whatever to do with *freedom* in the ordinary sense of the word—freedom from external compulsion. Here I sit at my desk; my hand lies on the paper before me; can I raise it from the paper or not, just as I please? To such a question, both determinist and indeterminist must give the same answer. Of course I can raise it or not, as I please. Both must admit that I am free in this sense. The question that divides them lies a little farther back; the determinist must hold that, if I please to raise my hand, there is some cause within me, or in my environment, or both, that brings about the result; and if I please not to raise it, he must believe that there is some cause or complex of causes that produces just that result. He does not deny that I can do as I please. He merely maintains that my 'pleasing' is never uncaused. On the other hand, the advocate of the 'liberty of indifference' maintains that under precisely the same circumstances, internal and external, I may raise my hand or keep it at rest. He holds, in other words, that, if I move, that action is not to be wholly accounted for by anything whatever that has preceded, for under precisely the same circumstances it might not have occurred. It is, hence, causeless.

Now it would be a horrid thing to feel that one were not free to move or not to move. Freedom is a pearl of great price. But there is nothing especially attractive in the thought of causeless actions, in themselves considered. They strike one, at first glance, as at least something of an anomaly. It seems reasonable to suspect that the great attraction which the doctrine of indeterminism exercises upon many minds must be due to a confusion between it and something else. That this is indeed the case I can best illustrate by citing a passage from Professor James' delightful 'Talks to Teachers.'* It reads as follows:

"It is plain that such a question can be decided only by general analogies, and not by accurate observations. The free-willist believes the appearance to be a reality; the determinist believes that it is an illusion. I myself hold with the free-willists—not because I cannot conceive the fatalist theory clearly, or because I fail to understand its plausibility, but simply because, if free-will *were* true, it would be absurd to have the belief in it fatally forced on our acceptance. Considering the inner fitness of things, one would rather think that the very first act of a will endowed with freedom should be to sustain the belief in the freedom itself. I accordingly believe freely in my freedom; I do so with the best of scientific consciences, knowing that the predetermination of the amount of my effort of attention can never receive objective proof, and hoping that, whether you follow my example in this respect or not, it will at least make you see that such psychological and pyschophysical theories as I hold do not necessarily force a man to become a fatalist or a materialist."

I have taken this extract because it may stand as the very type of a 'free-will' argument, and as an ideal illustration of the persuasive influence of the ways of expressing things natural to a gifted writer. The school-teacher who has no prejudice against fatalism and materialism, to whom the idea of being endowed with freedom is not attractive, who

* Chapter XV., pp. 191-192.

is willing to have even good things fatally forced upon his acceptance, and who is not inspired by the thought of believing freely in his freedom, must be a poor creature indeed. But suppose Professor James had expressed his thought baldly; suppose he had said: "I myself hold to indeterminism, not because I fail to see the plausibility of the opposite doctrine, but because, if human actions *were* causeless, what more natural than that man should causelessly believe in their causeless origination? Accordingly, I causelessly believe in the causelessness of my actions, confident that no one knows enough about the matter to prove me in the wrong." Would the doctrine thus stated—and this only means the doctrine stripped of misleading associations—have proved particularly attractive?

It is not attractive even when superficially considered; it only seems arbitrary and unreasonable; a something to be taken rather as a play of fancy than as a serious argument. But looked into more narrowly, the doctrine is seen in its implications to be something very serious and terrible. So little has been said upon this topic in the vast literature of the dispute regarding the will, that I make no excuse for discussing it at some length. The issue has too often been clouded by the associations which hover about the words 'liberty,' 'freedom' and 'free-will,' and the true significance of indeterminism has not been clearly seen. I have said above that it is a pity to stir the emotions when one is trying to settle a question of fact; but as very much has been said upon the topic of the terrors of determinism that it is allowable, as an antidote to this poison, to point out the much more real terrors of 'free-will.'

Let us suppose that the 'libertarian' or 'free-willist'—the indeterminist—is right, and that human actions may be causeless. I am, then, endowed with 'freedom.' This is not freedom in the usual sense of the word, remember; and I have put it into quotation marks to indicate that fact. It means only that my actions cannot wholly be accounted for by anything that has preceded them, even by my own character and impulses, inherent or acquired. But, I ask myself, if I am endowed with 'freedom,' in what sense may this 'freedom' be called *mine*. Suppose that I have given a dollar to a blind beggar. Can *I*, if it is really an act of 'free-will,' be properly said to have given the money? Was it given because *I* was a man of tender heart, one prone to benevolent impulses, and naturally incited by the sight of suffering to make an effort to relieve it? Not at all; in just so far as the gift was the result of 'free-will,' these things could have had nothing to do with the matter. Another man, the veriest miser and skinflint, the most unfeeling brute upon the streets, might equally well have been the instrument of the benevolent deed. His impulses might all be selfish, and his past life a consistent history of sordid greed; I am a lover of my kind; but what has all this to do with acts of 'free-will'? If they are 'free,' they must not be conditioned by antecedent circumstances of any sort, by the misery of the beggar, by the pity in the heart of the passer-by. They must be causeless, not determined. They must drop from a clear sky out of the void, for just in so far as they can be accounted for they are not 'free.'

Is it then *I* that am 'free'? Am *I* the cause of the good or evil deeds which—shall I say?—result from my 'freedom'? I do not cause them, for they are uncaused. And, since they are uncaused, and have no necessary congruity with my character or impulses, what guarantee have I that the course of my life will not exhibit the melancholy spectacle of the reign of mere caprice? For forty years I have lived quietly and in obedience to law. I am regarded as a decent citizen, and one who can be counted upon not to rob his neighbor, or wave the red flag of the anarchist. I have grown gradually to be a character of such and such a kind; I am fairly familiar with my impulses and aspirations; I hope to carry out plans extending over a good many years in the future. Is it this *I* with whom I have lived in the past, and whom I think I know, that will elect for me whether I shall carry out plans or break them, be consistent or inconsistent, love or hate, be virtuous or betake myself to crime? Alas! I am 'free,' and this *I* with whom I am familiar cannot condition the future. But I will make the most serious of resolves, bind myself with the holiest of promises! To what end? How can any resolve be a cause of causeless actions, or any promise clip the erratic wing of 'free-will'? In so far as I am 'free' the future is a wall of darkness. One cannot even say with the Moslem: 'What shall be, will be;' for there is no shall about it. It is wholly impossible for me to guess what I will 'freely' do, and it is impossible for me to make any provision against the consequences of 'free' acts of the most deplorable sort. A knowledge of my own character in the past brings with it neither hope nor consolation. My 'freedom' is just as 'free' as that of the man who was hanged last week. It is not conditioned by my character. If he could 'freely' commit murder, so can I. But I never dreamt of killing a man, and would not do it for the world! No; that is true; the *I* that I know rebels against the thought. Yet to admit that this *I* can prevent it is to become a determinist. If I am 'free' I cannot seek this city of refuge. Is 'freedom' a thing that can be inherited as a bodily or mental constitution? Can it be repressed by a course of education, or laid in chains by life-long habit? *In so far as any action is 'free,'* what I have been, what I am, what I have always done or striven to do, what I most earnestly wish or resolve to do at the present moment—these things can have no more to do with its future realization than if they had no existence. If, then, I really am 'free,' I must face the possibility that I may at any moment do anything that any man can 'freely' do. The possibility is a hideous one; and surely even the most ardent 'free-willist' will, when he contemplates it frankly, excuse me for hoping that, if I am at least not very 'free,' I am at least not very 'free,' and that I may reasonably expect to find some degree of consistency in my life and actions. An excess of such 'freedom' is indistinguishable from the most abject slavery to lawless caprice.

And when I consider my relations to my fellow-men the outlook is no better. It is often said that the determinist may grant rewards or inflict punishments as a means of attaining certain desired ends, but that for him there can in all this be no question of justice or injustice. One man is by nature prone to evil as the sparks fly upward; another is born an embryo saint. One is ushered into this world, if not 'trailing clouds of glory,' yet with such clouds, in the shape of civilizing influences, hovering about the very cradle in which he is to lie; another opens his eyes upon a light which breaks feebly through the foul and darkened window-pane, and which is lurid with the reflections of degradation and vice. One becomes the favorite of fortune, and the other the unhappy subject of painful correction. Unless there be 'free-will,' where can we find even the shadow of justice in our treatment of these? We have all heard the argument at length, and I shall not enter into it further; nor shall I delay over the question of the true meaning of the terms *justice* and *injustice*, though this meaning is often taken for granted in a very heedless way. I shall merely inquire whether the assumption of 'freedom' contributes anything toward the solution of the problem of punishment.

Let us suppose that Tommy's mother is applying a slipper to some portion of his frame for having 'freely' raided the pantry. Does she punish him for having done the deed, or does she punish him to prevent its recurrence? In either case, she seems, if the deed was a 'free' one, to be acting in a wholly unreasonable way. Was the deed really done by Tommy— *i. e.*, was it the natural result of his knowledge of the contents of the pantry, his appetite for jam, and the presence of the key in the door? Not at all. The act was a 'free' one, and not conditioned by either Tommy's character or his environment. The child's grandfather might have 'freely' stolen jam under just the same circumstances. Thus, in a true sense of the words, the child did not do it. Who can cause what is causeless? Moreover, by no possibility could he have prevented it. Who can guard against the spontaneity of 'freedom'? No resolve, as we have seen, can condition the unconditioned. Then why beat the poor child for what he did not do and what he could not possibly have prevented? Surely this is wanton cruelty, and worthy of all reprobation!

Is the punishment intended to prevent a recurrence of the deed? How futile a measure! Does the silly woman actually believe that she can with a slipper make such changes in Tommy's mind or body as to determine the occurrence or non-occurrence of acts which are, by hypothesis, independent of what is contained in Tommy and his environment? Does she forget that she is raining her blows upon a 'free' agent? As well beat the lad to prevent the lightning from striking the steeple in the next block.

The utter absurdity of punishing a 'free' agent, in so far as he *is* a 'free' agent, must be apparent to every unprejudiced mind. It is unjust and it is useless. And it seems clear that it is equally useless to make an effort to persuade him. To what end shall I marshal all sorts of good reasons for not doing this or that reprehensible action? To what end shall I pour forth my torrent of eloquence, painting in vivid colors the joys of virtue and the varied miseries which lurk upon the path of the evil-doer? Are my words supposed to have effect, or are they not? If not, it is not worth while to utter them. Evidently they cannot have effect in determining 'free' actions, for such actions cannot be effects of anything. It seems, then, that Tommy's mother and his aunts and all his spiritual pastors and masters have for years approached Tommy upon a strictly deterministic basis. They have thought it worth while to talk, and to talk a great deal. They have done what all pedagogues do—they have adjusted means to ends, and have looked for results, taking no account of 'freedom' at all. Of course, in so far as Tommy upon a strictly deterministic basis. They have thought it worth of the melancholy situation of the man who finds himself the father of half a dozen little 'free-will' monsters who cannot possibly be reached either by moral suasion or by the rod!

It is a melancholy world, this world of 'freedom.' In it no man can count upon himself and no man can persuade his neighbor. We are, it is true, powerless to lead one another into evil; but we are also powerless to influence one another for good. It is a lonely world, in which each man is cut off from the great whole and given a lawless little world all to himself. And it is an uncertain world, a world in which a knowledge of the past casts no ray into the darkness of the future. To-morrow I am to face nearly a hundred students in logic. It is a new class, and I know little about its members save that they are students. I have assumed that they will act as students usually act, and that I shall escape with my life. But if they are endowed with 'free-will,' what may I not expect? What does 'free-will' care for the terrors of the Dean's office, the long green table, and the Committee of Discipline? Is it interested in Logic? Or does it have a personal respect for me? The picture is a harrowing one, and I drop the curtain upon it.

Fortunately for us all, 'freedom' is the concern of the philosophers; *freedom* is what we have to do with in real life. The judge, the philanthropist, the moralist, the pedagogue, all assume that man may be a free agent without on that account being forced beyond the pale into the outer darkness of utter irrationality. Men generally regard a man as free when he is in a position to be influenced by those considerations by which they think the normal man not under compulsion naturally is influenced. They do not think that he is robbed of his freedom in so far as he weighs motives, seeks information, is influenced by persuasion. What would become of our social system if men were not affected by influences of this sort? It would be the annihilation of all the forces which we have put in motion, and upon which we depend, for the amelioration of mankind.

There is scarce any tyranny so great as the tyranny of words. It is as reasonable to believe that strong drink will make a man strong, as that 'freedom' will make a man free, and yet how many believe it! So difficult is it to escape the snares of verbal confusion that I cannot be confident that some of my readers will not suppose that I have been arguing against human freedom. The forms of expression which have been chosen by some determinists are in part responsible for their error. The 'free-willists' are not wholly to blame. I feel, then, that I ought to close this brief paper with an unequivocal and concise statement of my position. It is this:

I believe most heartily in freedom. I am neither fatalist nor materialist. I hold man to be a free agent, and believe that there is such a thing as justice in man's treatment of man. I refuse to regard punishment as the infliction of pain upon one who did not do the thing for which he is punished, could not have prevented it, and cannot possibly be benefited by the punishment he receives. I view with horror the doctrine that the teacher's desk and the pulpit, the force of public opinion and the sanction of law, are of no avail. I am unwilling to assume without evidence that each man's breast is the seat of uncaused and inexplicable explosions, which no man can predict, against the consequences of which no man can make provision and which set at defiance all the forces which make for civilization.

CHINESE COMMERCE.*

BY WILLIAM BARCLAY PARSONS.

THE foreign commerce of China is carried on through and at twenty-nine Treaty Ports. Previous to 1840 trade with foreigners was much hampered owing to its being subject to local regulations, all of which were annoying, many of them ridiculous, and some actually jeopardizing to both life and property. In 1842 Great Britain, availing herself of the successful outcome of what is known as the Opium War, stipulated that as one of the indemnities, China should declare the ports of Canton, Amoy, Fu-chow, Ning-po and Shanghai to be thrown entirely open to British trade and residence, and that commerce with British subjects should be conducted at these ports under a properly regulated tariff and free from special Chinese restrictions. Although Great Britain nominally secured for herself special considerations, she intended and actually accomplished the establishing of commerce between China and all other nations on a sound and liberal basis. The treaty of Nan-king was immediately followed by similar treaties with other powers, that with the United States being executed in 1844. Additional ports, decreed by treaties or other arrangements by the Chinese Government, have been added from year to year. At the end of the year 1899 the Maritime Customs reported twenty-nine of these ports, with several branch or sub-ports in addition. At nearly all of them there is a special reservation, called the foreign concession, where foreigners are allowed to reside and regulate their method of living in their own way. Although foreigners are permitted to dwell in the Chinese quarter if they so desire, the right to hold property in the concessions is usually denied to Chinese, and they are discriminated against in other ways.

Previous to 1860 the management of foreign commerce had been in the hands of Chinese officials, with the usually unsatisfactory result attending any official department handled by native overseers. In that year the business of the port of Shanghai was placed temporarily in the hands of English, American and French Commissioners, who were able to so improve the receipts by efficient and honest management that the Chinese Government, recognizing the desirability of continuing foreign supervision, organized the Imperial Maritime Customs and placed

* This article will form part of a book entitled 'An American Engineer in China' to be published shortly by Messrs. McClure, Phillips & Co.

the management of the whole foreign trade in the hands of a single Commissioner, called an Inspector-General, and appointed to this position Mr. Lay, succeeded in 1863 by Mr., afterward Sir, Robert Hart, who has continued in the control since then, and to whom is due the present very satisfactory condition of the management of this Bureau, to which has since been attached, in order to secure efficiency, a Marine Department, covering lighthouses and harbor regulations and the Chinese Imperial Post-office.

The ports open in 1899 were: Niu-chwang, Tien-tsin, Che-foo, Chung-king, I-chang, Sha-si, Yo-chow, Hankow, Kiu-kiang, Wu-hu, Nan-king, Chin-kiang, Shanghai, Soo-chow, Ning-po, Hang-chow, Wen-chow, San-tuao, Foo-chow, Amoy, Swa-tow, Wu-chow, Sam-shui, Canton, Kiung-chow, Pak-hoi, Lung-chow, Meng-tsz and Szmao. Of these Niu-chwang is located in the north, at the terminus of the Chinese Imperial Railway, and is the gateway through which the trade passes from China to Russian Manchuria. Two ports, Tien-tsin and Che-foo, are situated on the Gulf of Pe-chi-li, while the next eleven on the list, Chung-king to Soo-chow, are on the Yang-tze Kiang or its tributaries. Seven ports, Ning-po to Swa-tow, are on the East Coast. Wu-chow and Sam-Shui are on the West River. Canton is the great port of Southern China and the oldest seat of foreign trade in the country. Kiung-chow is on the Island of Hainan, and Pak-hoi, Lung-chow, Meng-tsz and Sz-mao are on the Franco-China frontier of Tong-king. The last three and Niu-chwang are the only places not situated on important waterways. Of the total foreign trade about three-quarters is transacted through Canton, Shanghai, Tien-tsin and Hankow, which are the great distributing points for the south, middle coast, north and interior.

The importance of Canton, Shanghai, Tien-tsin and Hankow is fixed by geographical conditions. Canton is at the head of the Canton River, which is really the estuary for the combined flow of the West, the North and the East Rivers, the three principal streams and consequent trade routes of Southern China. With its fine harbor and juxtaposition to Hongkong, it is of necessity, and must always continue to be, the gateway to the southern part of the Empire. In like manner, Shanghai, at the mouth of the Yang-tze, is the controlling point for the whole of the central zone; while Tien-tsin, the port of Peking, is the entrance to the north, the northwest and Mongolia. Hankow is at the head of steamship navigation on the Yang-tze, and at the junction of that stream and its principal tributary, the Han, and if the extreme western part of the country be omitted, which part is mountainous and very thinly populated, Hankow is approximately the geographical center of the Empire.

Native vessels trading between native ports report at custom-houses administered by native officials, where the records are hopelessly confused, and which, as a source of income to the Chinese Government, need not be considered in this place.

The foreign commerce of China, both import and export, is growing steadily, having doubled since 1891, the figures for 1899 showing that foreign goods to the value of 264,748,456 Haikwan taels ($185,324,000) were imported, and native goods to the value of 195,784,332 Haikwan taels ($137,049,000) were exported, or a total commerce of 460,533,288 Haikwan taels.

Owing to the lack of internal communication, the distribution of Chinese commerce is singularly restricted. Of the imports more than one-half is confined to two classes of articles alone; thus cotton and cotton goods in 1899 accounted for 40.2 per cent., and opium, unfortunately, for 13½ per cent. In like manner the exports, silk and tea, stand out almost without competition with other articles; these two together also aggregating more than 50 per cent. of the total. Silk provided no less than 41.8 per cent. and tea 16.3 per cent. Kerosene oil, metals, rice, sugar and coal are other articles largely imported, and beans, hides and furs, mats and matting, and wool other exports.

Although the extent of the traffic entered at native custom-houses, or, at least, not passing through the Maritime Customs, cannot be ascertained, that it is considerable is well understood, as can be shown by the single item of the export of rice. The exportation of this article was in 1898 prohibited in order to prevent a possible shortage at home. The Maritime Customs, therefore, report no rice as having been shipped outward during that year. The Japanese Customs, however, report having received rice from China to the value of $2,000,000 United States gold. It had been smuggled out in native vessels through the native customs and the Government deprived of revenue. An amusing explanation of this is given, which so thoroughly illustrates Chinese methods as to be worth repeating. As rice forms the greatest single item in Chinese food, any falling off in supply threatens a famine, the one thing the Government most dreads. Such being the case in 1898, stringent orders were sent to the Customs Tao-tai in Shanghai to prohibit any export of the grain, the greatest source of supply for which being the Yang-tze Valley, Shanghai is the natural point of shipment. On account of the power attached to it, and the opportunities offered, the position of Shanghai Tao-tai is one specially sought after, and it is generally believed that the price paid for a three-year appointment, in the way of 'presents' to the Palace officials, is about 200,000 taels. Since the authorized emoluments are about 20,000 taels per annum, out of which expenses exceeding that amount must be paid, it is evident that great financial skill must be displayed by the official in order to make both ends meet. On receipt of the restraining order the Tao-tai, under the advice of the syndicate who were 'financing' him, held the order for some days, during which time the energetic syndicate members bought all the rice in sight, put it in vessels and rushed it abroad to Japan, a country which buys the inferior grade of Chinese rice for home consumption and ships abroad its own superior article. As soon as the embargo was published, the value of rice afloat at once rose and the Tao-tai syndicate cleared a handsome profit. This illustrates Chinese fiscal methods, and warrants the statement that the actual foreign commerce of the country is greater than the figures indicate.

China levies on its foreign commerce a tariff for revenue only. The rate charged on nearly all articles is five per cent. on imports and exports alike, although there are some special rates and a number of articles on the free list. The actual average rate on imports and exports runs from three to four per cent. It is the general opinion of merchants in China that, should it become necessary to add to the Government's income, this rate could be increased without any serious detriment to foreign commerce. In Japan the Government has found it necessary, in order to derive more revenue, to seriously increase its customs tariff, so that the present charges range from thirty to fifty per cent. ad valorem.

Foreign articles destined for consumption at the treaty ports or places of importation pay no further taxes. When, however, they are sent into the interior they are obliged to pay internal transportation taxes, called 'Likin,' collected at various stations along the trade routes. These likin charges, although they form a perfectly legitimate method of taxation, are objected to by the Chinese quite as much as by foreign traders, on account of their uncertain amount, which, according to Chinese custom, is left largely to the official in charge, who collects as much as he can. The foreign nations, in order to obviate these difficulties, have arranged with the Chinese Government to permit foreign articles destined for the interior to pay a single tax of two and a half per cent. to the Imperial Maritime Customs and then to receive what is called a 'transit pass' entitling the goods to pass the interior likin stations without further charge. Unfortunately, these transit passes are not always respected by officials in the interior, unless they think that the shipper will appeal to a foreign government, and, therefore, the officials are apt to levy likin in accordance with their own needs, and of the total collected but a small part finds its way into the public treasury.

The native merchant has no such advantage as the foreigner in securing immunity from likin extortion, and has to resort to all sorts of subterfuges to escape the impositions of his own countrymen, one of the most frequent of such resorts being to keep his goods under the name of a foreign merchant if possible. Another device was told to me by a customs official on the West River, where the local farmers raise tobacco which is consumed mostly in Northern Kwang-tung. If it were shipped direct it would be charged en route a large and uncertain likin tax, the uncertainty of the amount being the worst feature, as it may easily convert an apparently profitable transaction into a serious loss. To avoid this the tobacco is loaded on a sea-going junk and shipped to Hongkong. From there the junk brings it back and enters it at the point of original shipment as a foreign importation. For this the merchant secures a transit pass under which he ships it to its destination. He has paid the freight and import taxes of five per cent. each; the transit pass fee of two and a half per cent., and the shipping charges both ways to Hongkong, and the expense of rehandling. These items he can ascertain accurately beforehand, and, therefore, prefers paying them rather than run the likin gauntlet, which may be from ten per cent. to fifty per cent. or more.

The Chinaman is by very instinct a trader, is quick to see and seize an opportunity to turn a profit, and has, what few other Eastern Asiatics have, a high sense of commercial honor. Although the great mass of them is poor, yet there is a wealthy class, and there exists, even in the interior, a demand for much more than the mere necessaries of life.

Now, what have the United States done in the past in this great country, how do they stand there to-day, what can they do and what should they do in the future? These are the considerations that most concern us.

To answer the first two of these questions there are two sources of statistics which we can examine—the returns of the United States, and of the Imperial Chinese Maritime Customs. Unfortunately, both of these sources are rendered valueless for exact deductions because of Hongkong. This, as is well known, is a British colony, and one of the few places on the globe where actual free trade exists. Being a British colony, enjoying free trade and possessing a magnificent harbor, it has become a great depot, or warehouse, where goods, whose ultimate destination, either in China or anywhere else in the Far East, is not definitely fixed, are shipped in the first instance, and thence rebilled to the point of consumption.

In this act their nationality is lost, for the returns of the shipping nation classes them as exports to Hongkong, while China, of course, treats them as imports from that place. The import returns of the Imperial Maritime Customs show that nearly one-half of the foreign commerce entering China comes from Hongkong. Thence many writers fall into errors, either by taking the direct trade between China and any other country as limited to the reported figures, or by classing Hongkong under the head of Great Britain and Colonies. The conclusions reached in these ways are grievously wrong. Although foreign goods are transshipped from Hongkong to Japan, the Philippine Islands, Siam and other parts of the Orient, yet at least three-quarters of all goods (of American probably a higher proportion) received there find their final market in China; so to determine approximately the exports from the United States, or from any other country to China, the only way is to add to the direct exports three-quarters of the shipments to Hongkong. And to determine the relative standing of the trade of several nations, we should deduct the Hongkong trade from China's total as shown by the returns of the Imperial Maritime Customs, and then compare the reported direct imports or exports. This last calculation will not yield the actual amount of trade by about one-half, but it will show with fair closeness the percentage of trade secured and the rate of increase. I have in this manner obtained the figures for the year 1893, the period just previous to the Japanese War; those of 1883 and 1873, respectively the tenth and the twentieth year preceding 1893; and those for 1898, the fifth year following, and also for 1899, the last complete year of normal trade conditions existing before the Boxer revolution. This table shows the import trade of China exclusive of Hongkong and the relative standing of the leading commercial powers, the actual trade of which is not as stated, for the table does not include shipments through Hongkong.

DIRECT EXPORTS TO CHINA.

	1875. Hk. Tls.	1883. Hk. Tls.	1893. Hk. Tls.	1898. Hk. Tls.	1899. Hk. Tls.
Total, except Hongkong	44,202,000	45,863,000	72,435,922	116,737,079	146,652,248
Great Britain	20,991,000	16,930,000	28,156,077	34,962,474	40,161,115
India	16,709,000	17,154,000	16,739,588	19,135,546	31,911,214
Japan	3,207,000	3,738,000	7,852,068	22,581,812	31,414,362
Continent of Europe	662,000	2,385,000	5,920,363	10,852,073	13,405,637
United States	244,000	2,708,000	5,443,569	17,161,312	22,288,745

In the above table all the Continental powers of Europe are grouped as one. From this it will be seen that the export trade of the United States, an insignificant amount in 1873, has now outstripped the combined exports from the whole Continent of Europe, and will be soon contesting for second place with India and Japan. Had it not been for sudden increased shipments in 1899 of certain special articles like coal on the part of these countries, which articles China can and should produce, the United States would have passed the Indian trade and be close on to that of Japan. In point of exports from China the United States trade in 1899 had reached a point surpassing that of any other country except Great Britain.

But along what lines have these increases been made? Do they represent only a greater outturning of raw material—the direct products of the soil—or of manufactured articles, carrying with them the results of American ingenuity and American labor, a form of export trade always the most desirable?

Taking the full list, there were, according to the United States Government classification, exports in 1893 under fifty-seven heads, but in 1898, according to the same classification, exports under seventy-six heads. The greater part of the increase in the five years (amounting to a total of $6,091,613) was due to manufactures of cotton, which increased $3,558,794; to raw cotton, which increased from nothing to $370,670; to manufactures of iron and steel, including machinery, $416,048; and to oils, chiefly kerosene, $1,055,797. The manufactures of cotton, which in 1898 amounted to $5,193,427, reached, during the next United States fiscal year (1899), $9,844,565. That is to say, the value of cotton cloths alone was, in the year 1899, almost as large as the value of the total American imports into China during the preceding year of all articles of whatsoever nature. This class of goods, the products of our New England and Southern mills, is the greatest single item of American commerce, and has already reached a point where, in certain grades, it dominates absolutely the Chinese market.

Taking drills, jeans and sheetings, the three great items of cotton goods consumed by the Chinese, and examining the trade of the three northern ports of Niu-chwang, Tien-tsin and Chefoo, American goods comprise of total receipts at the first: ninety-eight per cent., and at the second and third ninety-five per cent., the small remaining balance being divided between the English, Indian, Dutch, Japanese and other manufacturing nations. But quite as extraordinary as this there must be kept in mind the fact that of the total exports to all countries of American manufactures in cotton cloths, the Chinese market consumes just one-half.

Another article of American commerce that figured very small in the early returns, but now shows a great and increasing importance, is flour. It is shipped almost wholly to Hongkong, and thence forwarded to Canton, Amoy or other southern Chinese ports. In the fiscal year ending June 30, 1898, no less than $3,835,727 worth was exported from here, and during the corresponding period of 1900, a value of $4,502,-081. Wheat is not grown in southern China, and American flour has captured the demand, just as American cottons have done in the north. Next to Great Britain and Germany our best customer for American flour is China.

Such is the state of our Chinese trade to-day, and no one can find fault with its present condition and its recent development. But what of the future?

The success of the American commercial invasion depends absolutely on the maintenance of the existing status. China, in the liberality of the regulations affecting foreign commerce, is second to no other nation. In levying a tax, amounting to less than four per cent., she gives preferential duties to none, special privileges only as compelled by the stress of force in Manchuria and Shan-tung, and extends a freedom of welcome to all. It is true that nations occupying Chinese territory make so far no invidious distinction between their own and other people; but it must be remembered that their tenure is only nominal, and while the title to these lands remains vested in China, it would be difficult, in the face of existing treaties, to impose discriminating rules. Let Russia, however, become legally, as she is virtually, possessed of Manchuria; let her Trans-Siberian railway be completed, and let her claim openly as her own, not only Manchuria, but also the metropolitan province of Chi-li, is it to be supposed for one moment that the present freedom and equality of trade that China offers will be maintained? If anyone believes this let him talk with those in China who direct the course of Muscovite affairs. These officials, when in a confidential mood, will explain that the Trans-Siberian railway is a Government enterprise, and that it is much more important for Russia to give low and special rates to Russian cotton and other manufactures which the Government is fostering at home than to look for a direct profit from the operation of the railway. And yet Manchuria and the northeastern part of China are to-day the best market for American goods. During the year 1899 no less than $6,297,300 worth of our cottons alone entered the port of Tien-tsin, and $4,216,700 worth entered the port of Niu-chwang in addition. The latter amount was for consumption in Manchuria, Chinese and Russian. It is interesting to note that the whole import trade (including exports through Hongkong) from Russia, Siberia and Russian Manchuria to the whole of the Chinese Empire amounted to less than the imports of two grades of American cotton goods at Niu-chwang alone. When, therefore, Russia seized Lower Manchuria, the country most interested next to China, whose territory was being despoiled, was not Japan, who was being robbed of her fruits of victory; was not Russia, who was adding another kingdom to her empire; was not Great Britain, the world's great trader, but it was, little as it was appreciated, the United States. The American interests in seeing commercial equality maintained, far and away transcend those of any other nation.

Foreign trade in China to-day is confined exclusively to the treaty ports located along the coast and up the Yang-tze River. When goods are shipped to China, they are resold by the foreign houses resident in these treaty ports to Chinese merchants, and by them in turn are retailed in the interior. So far, therefore, as the foreigner directly is concerned, his trade is confined simply to the outer edge of the country; to him the interior is a *terra incognita*. The success of a commercial invasion depends, not on these treaty ports, not on the purchase of goods along the outer edge of the country, but on the possibility of reaching directly that great mass of population which lies far away from the sea, out of reach of existing means of transportation, and practically buried in the interior. If they cannot be got at, or if, when reached, they cannot and will not trade, then it is not worth while to consider any general forward movement.

In the course of my journey in the interior of China, I went through the province of Hu-peh, which the Yang-tze Kiang traverses; the province of Kwang-tung, lying along the China Sea, and, between these two, the province of Hu-nan, which practically had not been traversed before by white men. Here evidently was virgin soil, and its condition can, therefore, be taken as a criterion of what the Chinaman is when unaffected by foreign influences. Even here I found that, although the foreigner's foot might never before have trodden the streets of the cities, his goods were already exposed for sale in the shop-windows.

In thinking of the Chinese, especially those in the interior, we are wont to consider them as uncivilized; and so they are, if measured scrupulously by our peculiar standards. But, on the other hand, they might say with some justice that we are not civilized according to the standards that they have set for themselves, founded on an experience of four thousand years. With all its differences from ourselves, a nation that has had an organization for five thousand years; that has used printing for over eight centuries; that has produced the works of art that China has produced; that possesses a literature antedating that of Rome or Athens; whose people maintain shrines along the highways in which, following the precepts of the classics to respect the written page, they are wont to pick up and burn printed papers rather than have them trampled under foot; and which, to indicate a modern instance, was able to furnish me with a native letter of credit on local banks in unexplored Hu-nan, can hardly be denied the right to call itself civilized. In the interior—in those parts where no outside influence has ever reached—we found cities whose walls, by their size, their crenelated parapets, and their keeps and watch-towers, suggested mediæval Germany rather than Cathay. Many of the houses are of masonry, with decorated tile roofs, and elaborately carved details. The streets are paved with stone. The shops display in their windows articles of every form, of every make. The streams are crossed by arched bridges unsurpassed in their graceful outline and good proportions. The farmer lives in a group of farm buildings enclosed by a compound wall—the whole exceeding in picturesqueness any bit in Normandy or Derbyshire. The rich mandarin dresses himself in summer in brocaded silk, and in winter in sable furs. He is waited on by a retinue of well-trained servants, and will invite the stranger to a dinner at night composed of ten or fifteen courses, entertaining him with a courtesy and intricacy of etiquette that Mayfair itself cannot excel. Such are actual conditions in parts of China uninfluenced by foreign presence, and so far the civilization of the interior is a real thing. That the Chinaman allows his handsome buildings to fall into disrepair; that his narrow city streets reek with foul odors; that the pig has equal rights with the owner of the pretty farm-house; and that the epicure takes delight at his dinner in sharks' fins instead of terrapin—these are merely differences in details; and if they are faults, as we consider them to be, they will naturally be corrected as soon as the Chinaman, with his quick wit, perceives his errors, when the opportunity to study Occidental standards comes to him.

Chang-sha, the capital of Hu-nan, is one of the most interesting cities in the whole Empire, as marking the very highest development of Chinese exclusiveness and dividing with Lhassa in Tibet the boast of shutting its gates tightly in the face of foreign contamination. In a previous chapter an account was given of how the present conservative governor had closed the schools organized by his more liberal predecessor, and had tried to root up the budding movement toward reform and progress. But he made one interesting and highly suggestive omission in allowing the electric-light plant to continue. When, at the end of our first day at Chang-sha, as I stood on my boat watching the city wall, the picturesque roofs, the junks on the shore and the surging crowd slowly lose their distinctness in the twilight, and then saw them suddenly brought into view again by the glare of the bright electric arcs as the current was turned on to light the narrow streets, I smiled as I realized the utter impossibility of stopping the onward march of nineteenth century progress, and that the Chinese themselves, even at the very heart-center of anti-foreignism, are ready to turn from the old to the new.

In the shop-windows at Chang-sha there are displayed for sale articles with American, English, French, German, Japanese and other brands. One shop, I noticed, displayed a good assortment of American canned fruits and vegetables. This is the condition of affairs, not in Shanghai or Amoy, open ports, but in the most exclusively Chinese section in the whole Empire. That the Chinaman will buy, that he will adopt foreign ways, there is no question; and he is just as ready to make the greater changes in his life that must result from the introduction of railways as to buy a few more pieces of cotton or a few more tons of steel.

But in order to buy more the Chinaman must be able to sell more; for no matter what his inclination may be, unless he has something to give in return, he cannot trade. The exports from China have been expanding gradually, and in step with the imports. In 1888 they were 92,401,067 taels; had increased to 116,632,311 taels in 1893, and had further advanced to 195,784,332 taels in 1899. The two great items of Chinese export, as was shown above, are silk and tea. The output of silk is increasing steadily, especially in the manufactured form. The amount of tea exported, however, is not on the increase, being about the same that it was ten years ago, the tea trade having been adversely affected by the competition of Japan, Ceylon and India, where more favorable transportation facilities have given advantages. Both tea and silk, however, are staple articles, with no chance of substitutes being found, and the world's demand for both is steadily increasing. The possibility of enlarging the output of silk is great, for there are in Northern Kwang-tung alone large areas of land capable of producing mulberry, that are lying idle at present because there are no transportation facilities.

The idea we have of the interior of China as overpeopled, and with every square foot of land under cultivation, is entirely without foundation, except possibly in certain portions of the great loess plain in the north. There is a great amount of land, capable of producing crops of various kinds and of supporting a population, that to-day lies fallow and untilled. Given the means of sending their produce to the sea and so to the foreigner, the people of the interior will see to it that the produce is ready.

Then there are vast mineral resources that are practically untouched. China, with coal-fields exceeding in quantity those of Europe, imported last year no less than 859,370 tons of coal, valued at $4,477,670 gold, nearly the whole of which came from Japan. With railways to bring the output of the mines to market, there will not only be no importing, thus permitting at least that amount to be expended for other foreign goods, but there should be a large export of coal to Hongkong for foreign shipping, and to other Eastern countries for local consumption. In addition to the coal, there are beds of copper, iron, lead and silver that, to-day untouched, are only awaiting the screech of the locomotive whistle.

In short, the resources, both agricultural and mineral, are at hand to permit a foreign commerce to be carried on—to pay the cost of building of railways and to provide sustenance for a commercial invasion.

But as yet China has made no effort to develop her latent powers. As was shown, the bulk of her exports are confined to two articles, due to her people not utilizing their natural advantages in diversity of soil and climate. Each locality produces that single article which gives the best local result, without considering broad market conditions. Thus in the south it is mostly silk and rice; in the central zone, rice and tea, and in the north, millet and wheat. Every bit of valley land is cultivated, but the hills are let go waste. There are great areas of grazing land where some day the Chinese will let herds roam, producing beef and hides, which they will turn to commercial profit; while on other hillsides, as I saw being done in places, they will set out forests, and arbor culture will be well suited to their patient ways. As yet they have worked their lands only with a view to home consumption; there are many ways in which they can devote them and their energies to furnish export articles for the imports they will buy.

The position of the United States in China is peculiarly advantageous, because, in the first place, China regards our country as friendly in the desire to protect rather than despoil her territory, and because, in the second place, other nations have been willing to see ours come forward when they would have objected most strenuously to the same advancement on the part of one of their own number. The men who guide our national affairs and foreign commerce should always see to it that China's confidence is not abused. But as for the friendliness of other nations toward us in relation to China, so soon as the pressure of American trade begins to be felt by them, efforts will be made to thwart it if possible; and it must be remembered that to-day all the machinery of commerce, in the way of banks, transportation companies, cable lines, and other forms, is in their hands. When the meeting of the American and European invasions takes place, unless we have an organization, a base and rallying point, a tangible something besides mere labels on boxes or bales as representing American force, the struggle will be a hard one, for the native is apt to judge his associates by the outward visible signs, and with a natural tendency to deal with the strongest. In this respect commerce in the Far East stands, and will stand for a long time, on a different footing from that of commerce in Europe.

In order to be thoroughly successful, to expand our trade far beyond its present boundaries, we should make a careful and intelligent study of the Chinaman in his tastes and habits. If we wish to sell him goods, we must make them of a form and kind that will please him and not necessarily ourselves. This is a fact too frequently overlooked by both the English and ourselves, but one of which the Germans, who may be our real competitors in the end, take advantage. For example, at the present moment, if a careful study were made of Chinese designs, the market for American printed goods could be largely broadened. It is not for our people to say that our designs are prettier; the Chinaman prefers his own, and he will not buy any other. The United States Minister to China, talking upon this subject, gave me a striking instance of foolish American obstinacy. The representative of a large concern manufacturing a staple article in hardware, let us say screws, had been working hard to secure an order for his screws, which he knew were better than the German article then supplying the demand. At last he obtained a trial order, amounting to $5,000, which he cabled out; but it was given on the condition that the screws be wrapped in a peculiar manner, say in blue paper, according to the form in which the native merchant had been accustomed to buy them. Was the order filled? Not at all. The company cabled back that their goods were always wrapped in brown paper and that no change could be made. The order then went to Germany. To the American concern an order for $5,000 was of small moment, perhaps; but they overlooked entirely the fact that this was the thin edge of the wedge, opening a trade that could be developed into tremendous proportions. This instance is not isolated, for, unfortunately, the reports of all our consuls are filled with parallel ones.

A study must also be made of the grade and quality of the article shipped. It is no use to send to China, to be sold in the interior, tools, for instance, of the same high finish and quality that our mechanics exact in their own. A Chinaman's tools are hand-made, of rough finish and low cost. In the interior cities one sees a tool-maker take a piece of steel, draw all the temper, hammer it approximately to the shape of the knife or axe, chisel or razor, or whatever other article he may be about to make; then, with a sort of drawing-knife pare it down to the exact shape required, retemper it, grind it to an edge and fix it in a rough wooden handle. This work is done by a man at a wage of about ten cents a day, and this is the competition that our manufacturer must meet. In spite of the difference in cost of labor he can do so, because his tools are machine-made and are better; but he must waste no money on unnecessary finish.

As an example, the case of lamps is directly to the point. The Chinaman fairly revels in illumination; he hates the dark, and everywhere, even in the smallest country towns wholly removed from foreign influence, it is possible to buy Standard oil or its competitors in the Chinese market, the Russian and Sumatra brands. The importation of illuminating oils is increasing tremendously. In 1892 it was 17,370,600 gallons, and in 1898 it was 44,324,344 gallons. But what of the lamps in which this oil is burned? In 1892 the United States sent to China lamps to the value of $10,813, and in 1898 to the value of $4,690. That is to say, lamps are one of the few articles which show a decrease. While the consumption of oil had increased more than two and one-half times, the importation of American lamps had decreased in almost the same ratio. This was not due to the manufacture of lamps in China, but to the German and Japanese manufacturers making a study of the trade and turning out a special article. These lamps—and I saw them for sale everywhere, even in unexplored Hu-nan—have a metal stand, generally of brass, stamped out from thin sheets, with Chinese characters and decorations; and were it not for a small imprint of the manufacturer's name on the base, they would be considered of Chinese make. They are inexpensive, of the kind desired by the Chinaman, although perhaps not for sale in Hamburg or Berlin. On the other hand, the American article, much more handsome, from our point of view, but also more expensive, is of the same style as is sold on Broadway, in New York.

There is no need to multiply examples. There awaits the American manufacturer an outlet, especially for tools, machinery and other articles in iron and steel. He will find a demand for the smaller and lighter machines, rather than for the larger ones. That is to say, he must appeal first to the individual worker who exists now, rather than aim at the needs of a conglomeration in a factory, which will come about in the future. The tools should be simple in character, easily worked and kept in order, and without the application of quick-return and other mechanical devices so necessary for labor-saving with us. Light wood-working machinery can be made to supplant the present manual-labor methods; and a large field is open for all kinds of pumps, windmills, piping and other articles of hydraulic machinery.

Cotton goods of the finer grades, as well as the coarser which are supplied, household articles of all kinds, glassware, window-glass, wall-paper, and plumbing fixtures will find a ready market, as will also farm equipments, such as light-wheeled vehicles and small agricultural implements of all kinds. In these, as in many manufactured articles, American trade has as yet made little or no impression; and yet the American article has an acknowledged superiority over any other foreign make.

It is necessary for us also to study the Chinaman himself. The English and American traders make but little attempt to learn the language, and, therefore, frequently fail to come into personal contact with the native merchant. They are inclined to leave such negotiations to be conducted through a compradore, a native in the employ of the firm, who makes all the contracts, and who guarantees to his firm all native accounts, receiving a commission for his services. The German, and especially the Japanese, merchants, on the other hand, make a great effort to come into direct relations with those with whom they trade. They are still making use of the compradore system, but within reasonable limits. As to which course is preferable in the long run there can be no question. Our houses should adopt the suggestion made in the report of the Blackburn (England) Chamber of Commerce, "to train in the Chinese spoken language and mercantile customs youths selected . . . for their business capacity. Such a system," the report adds, "would give us a hold over foreign trade in China that present methods can never do."

Finally to be considered, there is the official representative of the United States, the consul. It is bad enough, as our practice is, to send consuls to France, or Germany, or Italy, who are unacquainted with the language of the country. But how much worse to send as our Government agents to China, the nation most difficult of all to come into relations with, men without any idea, not only of the language, but of the customs and the idiosyncrasies of the people.

This is not a reflection upon our present staff, many of whom are excellent and worthy men and who are now acquainted with the characteristics of those to whom they are accredited. But under our system, by the time a man understands his duties, he is removed. Nowhere else in the world is there so great a need for a permanent consular service as in China.

The British Government long ago established a separate consular service for the East, entirely distinct from that elsewhere, so that a man once in the Chinese service stays there, and is not likely to be transferred to a European or American post. Secretary Hay has lately made a beginning toward this end by proposing to establish a school at Peking. If the idea is not carried out now, circumstances will compel its adoption later. We should awake to the realization of our opportunities, and unite for the invasion, not only of China, but of other Oriental lands as well.

DISCUSSION AND CORRESPONDENCE.

ENERGY AND WORK OF THE HUMAN BODY.

In discussing 'The Human Body as an Engine,'* I referred to some experiments made at Middletown with the Atwater-Rosa Respiration Calorimeter, in which a man lived several days in each of the experiments in a sealed chamber of about 180 cubic feet capacity, eating, sleeping and working, while under minute observation. The potential energy supplied to the subject of the experiment through the food which he ate was determined by serving him with accurately weighed portions of the various articles of the prescribed diet, and analyzing and burning in a small calorimeter carefully selected samples of the same. The energy yielded by the subject consisted of three portions, all of which were carefully determined. These were: (1) the heat of radiation and respiration which was measured by the calorimeter, (2) mechanical work done within the calorimeter and (3) potential energy carried off in the refuse products of the body. The immediate purpose of the work was to verify experimentally the law of the conservation of energy for the living body; to show that the total energy taken into the body is equal to the sum of all the energy given out by the body during the same period (provided there is no net gain or loss of energy by the body); to show, indeed, that the fundamental law of physics applies to the animal body, as it does to an engine or a dynamo or any other machine or mechanical system. The law has been amply verified for inanimate systems; it seemed desirable to test it for an organic system. The statement was made in the article referred to that "In some cases the man under investigation worked regularly eight hours a day, the work done being measured by apparatus designed for the purpose." Some inquiry having been made as to how this work was measured, and whether it is possible, after all, to do this, the editor has asked me to answer the inquiry through the columns of the Monthly.

Confusion often arises in considering questions like the present one through inexact ideas concerning force and work. When force is exerted through a finite distance, work is done and energy is transferred from one body to another; and the work done is equal to the energy so transferred. It is also equal to the force exerted in the direction of the motion multiplied by the distance through which the force acts. For example, when a man lifts a stone he exerts a force equal to that of gravity upon the stone through a certain vertical distance; and the work done is equal to the force exerted (that is, to the weight of the stone) multiplied by the height it is lifted. The energy expended by the body is here transferred to the stone in its elevated position. This energy stored up in the stone is called potential energy, and it remains constant in amount so long as the stone remains at the same level. If the stone falls to a lower level its potential energy is reduced, but kinetic energy equal to the decrease of potential energy appears as heat.

If the man lifts the stone one inch the work is only one thirty-sixth part as much as if he lifts it three feet. If he pull on the stone but does not move it, no work is done, in the mechanical sense. Muscle has contracted and work is doubtless done within the body, but

* Popular Science Monthly for September, 1900.

so far as the stone is concerned no work is done. So a man may hold a heavy weight in his hand or on his shoulder, sustaining it with considerable effort against the force of gravity, and yet no work is done on the stone so long as it is not raised to a higher level. If the stone is carried in a horizontal plane, no work is done on the stone; while if it is carried down hill or lowered vertically, *negative* work is done on the stone. That is, since the stone possesses less potential energy at the foot of the hill than at the top (the difference being equal to the weight of the stone multiplied by the difference of altitude), the stone has lost energy, and this energy lost by the stone has been communicated to the man, who has had work done upon him by the stone, albeit he may have lugged it down the hill or lowered it from an elevated position with considerable effort.

When a car is propelled by an electric motor deriving its current from a storage battery carried on board the car, the energy of the car consists of three parts: (A) Mechanical potential energy due to the mass of the car being at some elevation above the surface of the earth. (B) Kinetic energy, due to the motion of the car as a whole and of its parts with respect to one another and the heat of the car. (C) Chemical potential energy stored up in the battery. When the car is running up grade, energy is being expended not only in overcoming friction, but also in lifting the car against the force of gravity. In doing this, energy is transferred from C to A. When the car descends again to its former level the energy stored up in A is given up, less energy is therefore required from the battery to propel the car, and the battery is accordingly in so much spared. If the grade be steep, the motor may actually be driven as a dynamo, and the current which is thereby generated may be stored up in the battery. In this case energy is transferred from A to C, and at the bottom of the hill the energy C may be greater than that at the top. The battery has done negative work on the car coming down the hill: that is, the car has done work on the battery and stored up energy.

The same considerations apply to the animal body. If a man carries himself up a hill, he is doing work upon his body in so elevating it against the force of gravity, and if he weighs 150 pounds and ascends an altitude of 10,000 feet, he has done 1,500,000 foot-pounds of work upon his body. This represents the quantity of energy which has been transferred from his tissues to his body as a mass; from chemical potential energy to mechanical potential energy. The tissues correspond to the storage battery, the muscles to the motor and the man's weight to that of the car. So when the man walks down the mountain again he does negative work, lowering his body (like lowering the car), involving the transfer of potential energy from his body as a mass to his tissues. Just what form the energy takes as it is so transferred is not altogether clear, but the distinction between the potential energy of the body as a mass, due to its elevation above the surface of the earth, and the potential and kinetic energy resident in the tissues of the body, is one of fundamental importance and should be kept clearly in view.

We may consider the man to be a complex machine, weighing, say, 150 pounds and having a quantity of potential and kinetic energy stored up within his body, which store of energy is drawn upon whenever external work is to be done, and which, besides, is being constantly expended in keeping the body warm and performing the internal work of the body. The energy of the body, like that of the electric car, then, consists of three portions, viz.: (A) Mechanical potential energy of the body as a whole, due to its position with respect to the earth. This is zero when it is at the earth's surface, or say the sea level, and increases as it rises above the sea level. (B) Kinetic energy, due to the heat of the body and to the motion of the body as a whole and of its several parts with respect to each other. (C) A store of chemical potential energy in its tissues and in food undergoing assimilation. Now when a man walks up hill, A increases, B remains nearly constant (increasing slightly), while C decreases rapidly, due partly to the increase of A and partly to the loss of heat by radiation and respiration. When he walks down hill, A is transferred to C or B, or both, and because of this acquisition C decreases more slowly than it would do if it received nothing from A, while yet giving off energy at the same rate. The man does positive work upon his body when he lifts it against the force of gravity, storing up potential energy A; he does negative work when he goes down hill, and the energy A passes to the interior of the body.

Suppose a laborer lifts 20,000 pounds of brick 5 feet; he does 100,000 foot-pounds of work, this energy being transferred from A to the bricks, and it will remain in the bricks as long as they remain at their elevated position. Next, suppose he lowers the same bricks to their former position. This 100,000 foot-pounds of energy is now transferred back from the bricks to the laborer's body. Because he is expending energy all the time he will possess less energy at the end of the task than at the beginning. Nevertheless, he does not lose as much as though he had not received the 100,000 foot-pounds of energy from the bricks, and had given off the same amount of energy in other ways.

We do not understand the process whereby the body converts chemical potential energy of tissue into mechanical energy; that is, we do not understand how the body does work. Still less do we understand how negative work is done; that is, how the body receives energy from without when it lowers a weight or walks down hill. That it does so acquire energy we cannot doubt. But whether it appears at once as heat, or as some other form of energy, and where the energy so received first appears, has not been proved. Neither have experiments been carried out to determine the relation between (1) the quantity of negative work done in a given period, (2) the total heat radiated from the body in the same period, (3) the amounts of oxygen absorbed and carbon dioxid respired, and (4) the excess of energy expended over that expended in the same length of time during rest. Indeed, to repeat the experiments already done with the respiration calorimeter balancing the total income and outgo of energy for a given period, with this important difference, that the subject of the experiment was doing negative work (that is, having work done on him by an external agent) would be an extremely interesting and valuable piece of work.

Consider now what occurs in walking on a level. The foot and leg are lifted, work is done in lifting them, and energy is stored up in them; they are advanced and lowered to the ground, and this stored up mechanical potential energy is then recovered by the system. The center of gravity of the body as a whole is also raised slightly at each step, but the work done in raising it is only equal to the energy yielded by the body when it descends again to the former level. Assuming an absence of friction against the ground and the atmosphere, the total external work done in walking on a level is zero. Force is exerted in holding the body erect or in holding the arm in an extended position. But no work is done in either case, for the force is not exerted through any distance. So also force is exerted by the huge cables which sustain the Brooklyn Bridge against gravity, but no work is done by these cables so long as the bridge is not lifted. Force is exerted by the foundations of a building in resisting the attraction of gravitation upon the mass of the superstructure, but no work is done by the foundation in so sustaining the weight. What the internal work of the body may be when muscle is contracted and force exerted without doing external work is another matter. That question is deserving of careful study, and the respiration calorimeter might perhaps lend itself to such an inquiry.

In the experiments referred to, the man under investigation received daily a known quantity of potential energy in the form of food. Part of this was converted into external mechanical energy and was measured; of the remainder, part appeared as heat and part was carried away in the refuse products of the body. The internal work of the body is ultimately converted into heat, and appears in the total heat of radiation and respiration. Thus energy is expended in causing the heart to beat and the blood to circulate and the lungs to expand. This internal work is not stored up, but is transformed into heat and radiated away with that which results directly from combustion. But external work done, like turning a grindstone or sawing wood, is not represented in the heat radiations of the body.

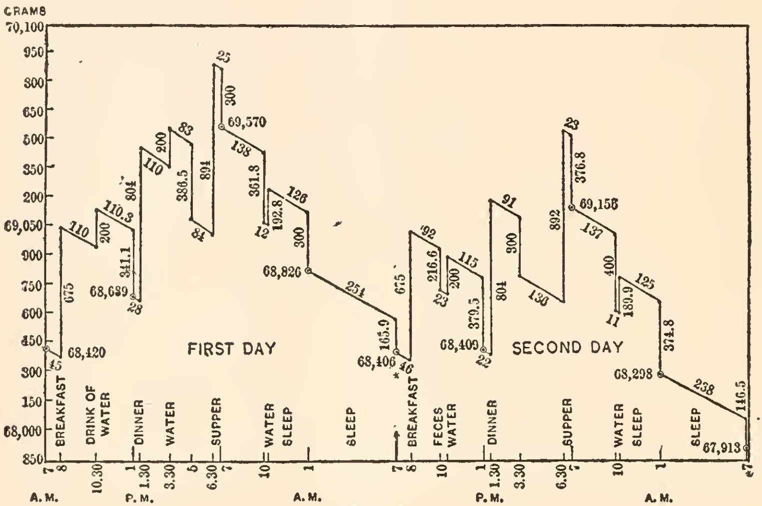
In order to do the desired amount of work within the calorimeter, the man operated a stationary bicycle, which was geared to a small dynamo. The front wheel of the bicycle was removed, and the rear wheel served as a driving pulley for the dynamo. The latter generated a current, the energy of which was measured by an ammeter and a voltmeter. When this current passed out of the calorimeter, its energy was not included in the heat measured by the calorimeter. But in some cases the current flowed through an incandescent lamp inside the calorimeter. Then the mechanical energy done by the man was all turned to heat within the calorimeter; part of it through friction in the bicycle and dynamo, part through the electric current which flowed through the lamp. The former was measured as accurately as possible by seeing how much energy was required to drive the bicycle when using the dynamo as a motor, supplying current to the latter from a battery and measuring the energy so supplied by an ammeter and volt-meter. The quantity of heat resulting from this friction must be subtracted from the total heat measured, in order to ascertain the quantity which was given off from the man's body directly as heat. And in those cases where the electric lamp was inside the chamber (and hence the work done by the subject was converted into heat within the chamber) this total amount must be subtracted from the heat measured to give the amount of heat given off as such by the subject of the experiment.

Thus we measure the quantity of external work done; but nothing is here learned about the internal work. The latter is converted into heat within the body and, when radiated away, is measured with the rest by the calorimeter. The amount of external work done in driving this bicycle-dynamo combination in one of the experiments (which continued for 96 hours) was equivalent to 256 large calories per day. This was about 40 watts for eight hours, or 788,000 foot-pounds, or 394 foot-tons. The total quantity of energy yielded was 3,726 large calories on the average for each of the four days. Since 256 is about 7 per cent. of 3,726, we see that the man converted 7 per cent. of the energy contained in his food into mechanical energy, 93 per cent. appearing in the heat of radiation and respiration. This gives the man, regarded as a machine for doing mechanical work, a 24-hour efficiency of 7 per cent. During the eight hours in which work was done the total consumption of energy was about 1,850 calories. Dividing the work done by this figure, we have for the mechanical efficiency during working time, 14 per cent. But there is still another way of reckoning this efficiency. Inasmuch as a large part of the energy supplied to the body would have been required to do internal work and keep the body warm, if no work had been done, we can fairly charge against the work done only the excess of energy supplied during the days when work was done over that required by the same man when no appreciable external work was done. The average quantity of energy supplied in several experiments in which the man did no considerable external work was 2,500 large calories. The excess in the work experiment was therefore 1,226 calories. Dividing the work done, 256 calories, by the excess of energy absorbed, 1,226, and the quotient is .21. Thus 21 per cent. of this excess of energy absorbed was converted into work, or the efficiency of the man as a machine for doing work is 21 per cent. This is far greater than the efficiency of small portable steam engines, such as could be compared with respect to size or power with a human machine, and equals or surpasses that of the largest compound condensing engines taken in connection with the most perfect water-tube boilers.

The bicycle-dynamo combination is not the most effective device upon which to develop mechanical power; and in the experiments quoted no attempt was made to secure the maximum efficiency of conversion of the potential energy of foodstuffs into mechanical energy. Although many experiments have already been carried out, further experiments are needed to show more fully what the human machine is capable of doing, and what circumstances are favorable to a high efficiency of conversion.

It may be of interest to show how a man's weight varies during twenty-four hours. The accompanying diagrams* give the variation in the weight of the man under investigation in one of the rest experiments; that is, in a four-days' experiment, where no mechanical work was done, except that involved in eating, dressing and making some records and observations within the calorimeter. The routine followed each day was nearly but not exactly the same, and the fluctuations of weight are accordingly similar but not identical each day.

Increase of weight is due to food and drink taken into the body and oxygen respired from the atmosphere. Decrease of weight is due to feces and urine leaving the body, and carbon dioxid and water vapor carried away from the lungs and skin. Part of these changes in weight occur more or less suddenly, while the change due to respiration, in which oxygen is absorbed and carbon dioxid and water vapor are evolved, is gradual. In the diagrams the sudden changes are indicated by vertical lines, the numbers indicating the quantity of the change in grams. The gradual

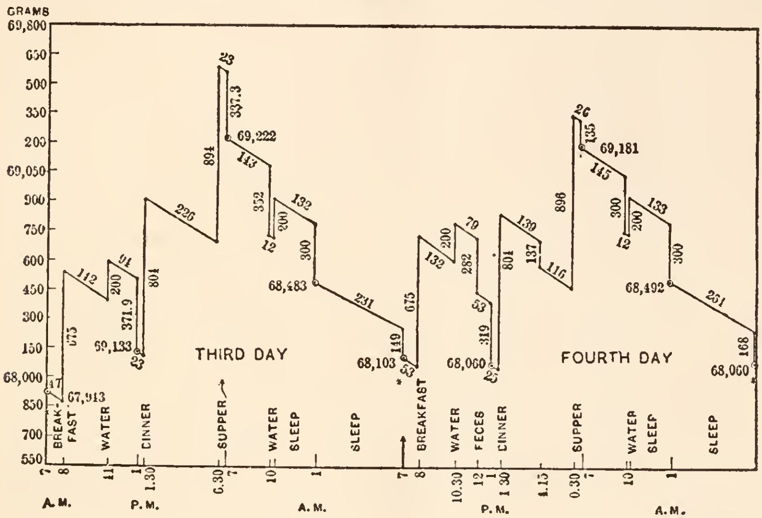


* Copied from an article by the writer in the 'Physical Review' for March, 1900, 'On the Metabolism of Matter in the Living Body.'

changes due to respirations are indicated by sloping lines, the number in each case indicating the net loss in grams; that is, the difference between the quantity of carbon dioxid and water vapor exhaled and the oxygen absorbed. All the vertical lines indicating sudden decrease in weight are due to urine except the two (on the second and fourth days) which are marked 'feces.'

Starting at 7 o'clock on the morning of the first day with a weight of 68,420 grams, the subject loses 45 grams in one hour by respiration. This loss by respiration was determined to be 270 grams in six hours, and in making up this diagram it was assumed to be uniform during the six hours. The loss by carbon dioxid is almost exactly 25 per cent. greater than the gain by oxygen absorbed. Sitting on a good balance, one can literally see one's self grow lighter as one quietly breathes one's self away. Breakfast adds 675 grams, respiration reduces his weight by 110 grams up to 10.30, when a drink of water adds 200 grams; a further loss of 110.3 grams by respiration is followed by a loss of 341 grams of urine, then 28 by respiration, and at 1.30 dinner adds 804 grams. The weight drops during the afternoon and then supper brings it up to the maximum of the day. During the night the weight falls again, so that at 7 o'clock on the second morning it is almost exactly the same as at the start. It is noteworthy that the loss by respiration is nearly as great during sleep as during the morning and afternoon hours, there being a loss of 254 grams in six hours during sleep as compared with 270 in six hours during the day.

The variations in weight in the three succeeding days can be followed from the diagram. These diagrams were made from the records of the experiment, and



the computed weights agreed quite well with actual weighings made at several different times during the experiment.

Such diagrams have not as yet been prepared for work experiments, but they could not fail to be of great interest in the cases we have been considering; namely, where the subject of the experiment does first positive work, then negative work, and, finally, positive and negative work together.

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SCIENTIFIC LITERATURE.

PHOTOGRAPHY OF SOLAR ECLIPSES.

It is often supposed by readers of popular articles on astronomical photography that the introduction of the methods of 'the new astronomy' has done away, once for all, with the difficulties of the old. The photographic plate has taken the place of the observer's eye and the personal equation is supposed to have been abolished. Those who work in astronomical photography are the first to extol the merits of the new methods. But they are fully aware of difficulties peculiar to them which must be treated very much as if they were errors peculiar to an observer. The plate has its own personal equation. It is impossible to overestimate the benefit to eclipse observations, for example, that has resulted from the introduction of photography as a means of registering the forms and details of the solar corona. Yet the photographic plate has serious failings of its own. Some of them have lately been done away with by a device invented by Mr. Charles Burckhalter, Director of the Chabot Observatory, in Oakland, California; and it is the purpose of this paragraph to exhibit the advance made by Mr. Burckhalter's methods.

The solar corona is very bright near the edge of the sun's disc and fades away gradually till at a distance of some 80 to 100 minutes its brilliancy is about the same as that of the sky-background. If a photograph is taken with a very short exposure, only the brighter parts of the corona are registered on the plate. The fainter portions do not appear at all. If a photograph is taken with an exposure sufficiently long to record the fainter portions, all the inner regions of the corona are much overexposed, and all detail is lost near the sun's edge. By the ordinary methods, then, the corona, as a whole, cannot be exhibited on any single plate. Each exposure is suitable for registering one region, and only one. The corona must be studied on a series of negatives of varying exposures.

Mr. Burckhalter has devised and tried at two eclipses (the India eclipse of 1898 and the Georgia eclipse of 1900) a simple plan which has worked very well. He uses an ordinary photographic telescope and plate, but in front of the plate he places a rapidly revolving shield or diaphragm, cut to such a shape that different portions of the corona have different exposures. At the Georgia eclipse, for example, one of his negatives was exposed for eight seconds, but it was, at the same time, screened from the light so that the equivalent exposure at the sun's edge was only 4-100 of a second; at 4′ from the sun's edge, 0s.32; at 8′, 0s.80; at 12′, 1s.38; at 16′, 1s.76; at 24′, 2s.40; at 34′, 3s.20; at 44′, 4s.00; at 64′, 5s.60; at 94′ and at all greater distances, 8s.00. The resulting negative is extremely fine, and it exhibits the corona as it has never before been seen on a single plate. The bright inner corona and prominences are shown in their true form and brilliancy alongside of the faint polar rays and the delicate masses of the outer coronal extensions. Those who are especially interested should consult Mr. Burckhalter's report (illustrated) in the *Publications of the Astronomical Society of the Pacific*, No. 75, for October, 1900. The advance over previous work of the same kind is so marked that it is to be hoped that this method will be adopted at the Sumatra eclipse of May, 1901.

PSYCHOLOGY AS LITERATURE AND FICTION.

Messrs. Harper & Bros. are responsible for the publication of 'Hypnotism in Mental and Moral Culture,' by John Duncan Quackenbos, an unfortunate volume which may be permitted to speak for and condemn itself. To begin with, the work was written 'in premeditated ignorance of recent works on hypnotism.' Hypnotism is presented as a miraculous panacea. "A recent experiment of the writer's establishes the fact that disequilibration may be adjusted; a congenital cerebral deficiency overcome; a personality crippled by thought inhibition, mental apathy and defective attention transformed into a personality without a blot upon the brain, and so impending insanity shunted—by the use of hypnotic suggestion as an educational agency." "Differences induced by objective education are obliterated; and the fundamental endowments of that finer spiritual organ in which under God we have our highest being—endowments conferred by Deity on all human souls without favor and without stint—dominate the intellectual life. The divine image is supreme in the man, and creative communication on the broadest lines and on the most exalted planes becomes possible. Hypnotic suggestion is but inspiration. Not only does the subject share the latent knowledge, but he borrows as well the mental tone of the operator. His memory becomes preternaturally impressible. The principles of science, of language, of music, of art, are quickly appropriated and permanently retained for post-hypnotic expression through appropriate channels. Confidence in talent is acquired; and embarrassment, confusion, all admission of inferiority, are banished from the objective life—by placing the superior self in control." Among the patients are "several ladies who are making a profession of fiction writing. To these latter were imparted in hypnosis, first, a knowledge of the canons of narration, viz., the law of selection, which limits the story-teller to appropriate characteristic or individual circumstances; the law of succession," and other laws of like flavor. The result: "In the light of instantaneous apprehension, barrenness gives place to richness of association, the earnest thought and honest toil of the old method to a surprising facility, disinclination to select details to zest in appropriating whatever is available. Opportunity and mood are thus made to coincide, and the subject spontaneously conforms to the eternal principles of style. Under the influence of such inspiration, rapid progress has been made in the chosen field of authorship." The art of acting is equally easily accomplished. "The response of the woman's soul to such suggestions with post-hypnotic import is followed by her speedy ascent to the heights of histrionic art, and by subsequent triumphs on the stage through an apprehension of her own deathless power as revealed by the creative communication of her hypnotist. An actress once so inspired is inspired forever." For music the same formula holds. "The automatic mind is gently wooed to the summits of soul life, where it becomes susceptible to inspiration and burns to launch itself, through music as a medium of artistic expression, into the objective world." Moral perfection is likewise achieved. Here is a typical case before treatment: "Philetas M., aged twenty-one, an adept in all kinds of deviltry; a cigarette fiend; an incorrigible liar, unblushingly denying scarce-cold crimes with the proofs of their commission in our very hands, and constantly deceiving his parents with rotten-hearted promises; a borrower of money under false pretences, and an out-and-out thief for whom jail had no terrors; a gambler; a profligate ready to pawn the clothes on his back at the bidding of town-dowdies; a trencher-knight of the subloins of the Tenderloin," etc.; and this is the appearance after taking: "The weaknesses of the past are forgotten, vice loses its attractions, and the inspired soul seeks to make reparation for its shortcomings by an exaggerated loyalty to the spirit of the moral law. The young man who has regarded with contempt a father's advice and a mother's love becomes, after treatment, the incarnation of filial reverence and affection. The liar looks his interlocutor in the face and speaks the truth without regard to consequences. The thief parts with all inclination to appropriate what is not his. The libertine accepts the white life. Human saprophytes that thrive on social rottenness are not wholly destitute of moral chlorophyl." Nor is this all. By the same means, "Habits of thought concentration may be made to take the place of habits of rambling, ability to use grammatical English for uncertainty in syntax, a taste that approves elegance for an inclination to slang." Though potent for good, this panacea refuses to work ill. "Fortunately for the protection of society, the power of suggestion to deprave is providentially limited, while its influence for good is without horizon. A mesmerizee quickly discovers the hypocrite in a suggestionist, and a pure soul will always revolt at the intrusion of a sordid or sensual self and spontaneously repel its advances." That the suggestionist must have unusual gifts to accomplish such vast results seems natural enough. "A practitioner of hypnotism should be a proficient in the physical sciences, in literature, language, belles-lettres, art, sociology and theology." "Ignorance in an operator is a disqualifying defect; soul-exalting suggestions are full of atmosphere." Nor is it surprising to learn that the mesmerizee evidences "supranormal perceptive powers, possessed by subliminal selfs, acting at a distance from their physical bodies (a rational explanation of clairvoyance and clairaudience), or of automatic communications between the subliminal selfs of such unconscious mediums and outside personalities not human, who are cognizant of the events described, and are independent of time and space limitations;" and that "human beings are hypnotizable by other human beings, between whom and themselves exists a peculiar sympathy or harmonious relationship known as *rapport*."

There is no need to continue. If the above citations prevent the spread of false notions regarding the contents and character of the work they will in part have fulfilled their purpose. That the volume contains interesting, possibly valuable observations, may be true; but the general distrust of any results so sensationally presented will deservedly prevent recognition of any sound contribution of fact that may happen to be buried beneath this tinsel and paste. Were it not for the 'premeditated ignorance,' the author might have known of similar observations more soberly presented by other writers; and he might have been induced by a knowledge of the present status of hypnotism to present his own results with more reserve, proportion and scientific acceptability. It is difficult to say whether the author offends most deeply our scientific sensibilities by his extravagant, false and misleading representations, or our æsthetic sense by his grotesque and tactless manner of presentation, or our moral judgment by his disregard of obvious relations and his irrelevant and officious appeal to religious beliefs. On account of its popular tone, such a volume has great power for evil, and the condemnation of author and publisher for such abuse of a popular interest should be expressed in no uncertain terms.

'Medicine and the Mind,' translated from the French of Dr. Maurice de Fleury by Stacy B. Collins, M. D., and published by Downey & Co., is the type of work which the scientifically-minded are likely to dismiss as too 'literary,' and the littérateur to disregard as too scientific. Neither disparagement is quite warranted, however natural. If one assumes a proper attitude towards the volume—or perhaps one should say, finds himself in a sympathetic mood for this kind of reading—he may find attraction, suggestiveness and profit in its perusal. But it is distinctly a kind of writing to which the Anglo-Saxon mind is unresponsive; our standards of popular science are totally different in ideal and execution from those of our Gaelic colleagues; and, accordingly, when a book such as Dr. Fleury's leaves its native soil, it comes in contact with forms of critical judgment which it cannot successfully meet. As the author himself almost naively notes, in contrasting French works with those of an English writer, Sir John Lubbock, "With us a philosopher writes books for his own renown. Sir John Lubbock thinks of himself not at all." Dr. Fleury follows the French ideal and produces a chatty volume thoroughly infused with his personal opinions and interests, kaleidoscopic in scope, rather aimless in design, literary in form, and, judged by our own ideals, a very bad exemplar for popular science.

The general point of view is that of a physician who wishes to record for the benefit of other types of professional men, the medical aspect of the large and ever-present problems of civilization. From responsibility in cases of crime, and the methods in use at the Salpêtrière, to an essay on the bad effects of tobacco, and the proper regimen for literary men (illustrated by copious testimonials from men of literary note); and again from disquisitions on the effects of serum and other liquids hypodermically applied and an account of the nervous system, through discussions of mental and physical fatigue and the treatment of indolence and melancholy, to the psychology of love and anger as morbid passions, and the 'physiological analysis of flirtation,'—the volume proceeds at times interestingly, often touching upon new and significant observation, but always aimlessly, self-consciously and with a strained attempt to introduce novelty and paradox. When the author remarks "who knows but the twentieth century may rewrite Werther in its own way, with figures in the text, as a medical publication," he suggests only a moderate exaggeration of some of his own pages. The scientific point of view and useful scientific writing are not dependent upon diagrams and phrases, but on the natural outcome of fullness of learning, of a fundamental training and a combination of enthusiasm and skill. Dr. Fleury's book affords glimpses of an attractive personality endowed with some of these requisites; but his volume can have little influence upon the English reading public.

Of translations, as of the dead, it is generally best to say *nihil nisi bonum.* But the imperfections of the present task are all of that totally unnecessary type which makes them particularly aggravating. The foreignness of the presentation is left unmitigated by skillful phrasing; the existence of appropriate technical terms in English is ignored, and minor errors (such as the wrong retranslation of an English work cited by the French author) are numerous.

Prof. Flournoy's skillful description of a remarkable case of sub-conscious automatism was noticed in a recent issue of this Monthly. It is in every way worthy of presentation to English readers; and such readers are under obligations to Messrs. Harper & Bros. and the translator for the creditable appearance of the English volume. The translation is fluent and acceptable, and the composition of the book eminently satisfactory. Apart from the general query as to the desirability of placing a volume of this type before the public at large in a form intended to suggest its popular assimilability, the temper of the translator's preface demands a word of comment and of protest. To present this volume as a contribution to the mystical aspect of that composite activity, the results of which are denominated 'Psychical Research,' is a wrong to the author's purposes and (with few exceptions) is antagonistic to his own point of view. To put forward the volume as a contribution to a line of investigation that shall scientifically prove to be 'the preamble of all religions,' that shall demonstrate unsuspected and anomalous mental powers, and all but demonstrate immortality, to claim that for any one skeptically inclined and out of harmony with this point of view 'the book will have no interest'—all this serves to place the entire volume in so misleading and unfortunate a position that it would have been far better, rather than have it thus introduced, to have left the work untranslated. Under its present auspices it will prove to be a useful convenience to many, but a source of misconception and a stumbling-block to many more.

EDUCATION.

During the later part of the eighteenth century the conception of education as one phase of the development of the individual was established. There followed attention to the methodological aspect of the subject which resulted in the basing of the method of education upon psychology, instead of upon more or less fantastic analogies with nature. During the latter half of the present century has been established the conception of education as a social process, as one phase of human development. As a result, the historical and social aspects of education are becoming more scientific. There has been no history or historical sketch of education for the English reading public that possessed historic and scientific value until the recent appearance of Prof. Thomas Davidson's 'History of Education.' The author defines education as conscious human evolution and attempts to sketch the history of education in terms of dominant evolutionary thought. Frequently the author is guilty of that generality that has brought much of sociological thought into disrepute. His definition of education is so broad that it would include political and other phases of evolution that are conscious processes so far as the race is concerned. However, the revision of old ideas or the formulation of new ones is certain to provoke disagreement concerning essentials or details. It is the attempt that is significant in this case. It is but an earnest of the future. There is further evidence to this more scientific conception of the history of education. Hitherto the historical aspect of education has not passed beyond the biographical stage. But educational biography is now being written from this broader point of view. The interest is less in the individual and more in his relation to social practices and developing ideas. This attitude is best illustrated in the issues of the 'Great Educator Series,' edited by Prof. Nicholas Murray Butler. The latest issue, 'Comenius and the Beginnings of Educational Reform,' by Will S. Monroe, is well up to the higher standard set by previous issues. Comenius was to education what his contemporaries, Bacon and Descartes, were to science and philosophy. A biographical sketch of Comenius from this point of view, such as Mr. Monroe gives, is a valuable contribution to the literature of the new aspect of education.

Dr. L. Viereck publishes in the *Educational Review* an article narrating how even in the German gymnasium Latin is losing its traditional position. A movement is gaining ground looking toward beginning the study of Latin not in the lowest class of the gymnasium, but only after three years, thus leaving six years for the language. In this case Greek is begun two years later and is confined to the last four years of the course. This plan has the obvious advantage of not requiring boys to decide on their career in life at the age of ten years, but permits students of the 'real' gymnasium and of the traditional gymnasium to carry on the same studies for the first three years. The system, which was first tried in Frankfort in 1892, had a year ago been adopted in twenty-one schools and appears to be favored by the Prussian Government. Other straws showing how the current is setting in Germany are the establishment within a year of a doctorate in applied science and the decision that hereafter the doctor's diploma shall be written in German instead of Latin.

THE PROGRESS OF SCIENCE.

The statue of Lavoisier, shown in the frontispiece of this number, was unveiled at Paris on the 27th of July. It stands facing the Rue Tronchet, near the house in which Lavoisier dwelt. The figure, of bronze, stands upon a granite pedestal, ornamented by bas-reliefs representing Lavoisier before his colleagues at the Academy, and at work in his laboratory. M. Leygues presided at the ceremony, at which the members of the international congress of chemistry were present. In the course of the address written for the occasion M. Berthelot characterized Lavoisier's work as follows: "The labors of Lavoisier are related to a fundamental discovery from which they all spring, namely, the discovery of the chemical constitution of matter and of the difference between bodies possessing weight and imponderable forces—heat, light, electricity—the influence of which extends over these bodies. The discovery of this difference overturned the old ideas handed down from antiquity and held till the end of the last century." Lavoisier was a notable example of the excellence of scientific men in other than scientific fields of activity. He wrote a good book on education, was an efficient officer in a number of public undertakings, and was for some years 'fermier général.' His scientific work is summed up by the inscription on the pedestal of the monument: 'Fondateur de la chimie moderne.'

There is now evidence that yellow fever, as well as malaria, is caused by inoculation by mosquitoes which serve as the intermediate hosts of the parasites. Drs. Reed, Carroll, Agrâmonte and Lazear, who were appointed last summer by the Surgeon-General to investigate infectious diseases in Cuba, have in a preliminary report of their work denied that the bacillus icteroides of Sanarelli is the cause of yellow fever. In general they have not found it present in the blood of yellow fever patients or in the organs of those who have died of the disease, and consider that when present it is a secondary invader. After these results had been reached they tested the hypothesis advanced by Dr. Carlos J. Finlay of Havana in 1881 that yellow fever is transmitted from person to person by mosquitoes. Mosquitoes which had bitten fever patients were allowed to bite eleven persons. In nine cases no evil results followed, but in two cases, Dr. Carroll himself being one, regular attacks of yellow fever followed. It is true that in these cases there was a possibility of infection from other sources, but since out of 1,400 non-immune Americans at the Columbia Barracks there were in two months only three cases and since of the three two had been bitten within five days of the commencement of their attacks by contaminated mosquitoes, the board seems justified in assigning the rôle of efficient cause to the mosquitoes. The positive evidence is increased by the sad history of Dr. Lazear, one of the investigating board. Dr. Lazear was one of the nine who had not suffered in the inoculation experiment just described. While working with yellow fever patients he was bitten by a mosquito, which because of the previous experiment he did not even attempt to avoid. He was bitten on September 13, and became ill on September 17 with the fever, which thereafter ran its course, ending in death. It was not demonstrated that this particular mosquito had previously bitten any yellow fever patient, but of course there was every opportunity for it to do so. Dr. Reed and his associates feel justified in the following conclusion: "The mosquito serves as the intermediate host for the parasite of yellow fever, and it is highly probable that the disease is only propagated through the bite of this insect."

One of the most obscure points in chemistry is the action of ferments. These have been grouped in two classes: Organized ferments like the yeast plant, or the *mycoderma aceti,* which oxidize alcohol to acetic acid; and the unorganized ferments, like diastase, which convert starch into sugar. In both cases a very small quantity of the ferment is capable of converting an indefinitely large amount of the fermenting substance into the fermented product, although the ferment itself does not enter as such into the reaction. Further, the action of ferments can be inhibited by heat and by the action of certain substances which act as poisons. Recent investigations seem to show that the organized ferments may owe their action to unorganized ferments which they secrete. More recently attention has been called by Bredig and von Berneck to the similarity between the action of ferments, and what has been called contact action of metals. For example, finely divided platinum can oxidize alcohol to acetic acid,and can invert cane sugar. Much more marked is the action of a solution of colloidal platinum, obtained by passing a strong current of electricity between platinum poles under water. The action of the platinum in this condition is remarkably like that of a ferment. When its effect upon hydrogen peroxide was studied it was found that one part in about 350,000,000 parts of water was sufficient to decompose hydrogen peroxide appreciably. Minute traces of certain poisons affect the reaction strongly; especially is this true of prussic acid, hydrogen sulfid and corrosive sublimate. Like many ferments the platinum solution gradually recovers from the poisonous effects of traces of potassium cyanid. It also appears that the platinum plays no chemical part in the reaction,and thus it is apparently a true ferment. It seems probable that the study of these inorganic ferments may throw much light upon the action of the very complicated organic ferments.

When the discovery was made some ten years ago that leguminous plants are able to assimilate the free nitrogen of the atmosphere, and thus to supply themselves with one of the necessary elements of plant food, its importance to agriculture as an economical means of maintaining soil fertility was recognized almost immediately. In working out the practical application of the discovery it was found that the micro-organisms which effect this nitrogen assimilation are not the same for all kinds of legumes, but that different kinds have their specific organisms, and furthermore that these micro-organisms are not universally disseminated through the soil. This led to inoculation of the soil, either with pure cultures of the specific bacteria or with soil from a field known to contain them in abundance. What seemed so simple theoretically has been found in practice to be only partially successful, so that the progress in its application has been somewhat delayed. A very interesting account of experiments in inoculating soils for the growth of the soy bean has recently been published by the Kansas Experiment Station as Bulletin No. 96. It is one of the most successful attempts at soil inoculation on a large scale that has been reported in this country or in Europe, where this method for promoting nitrogen assimilation was first suggested. It was found that the Kansas soil contained none of the organisms necessary for the soy bean, and that in such soil the roots produced none of the tubercles which are intimately associated with nitrogen assimilation. A quantity of soil was obtained from the Massachusetts Experiment Station, where the soy bean had been grown for several years, and mixed in very small proportion with the Kansas soil, with the result that the soy bean plants produced root tubercles abundantly, indicating that they were drawing their nitrogen from the air. Local soil which had once been inoculated and produced a crop of soy beans was found to be suitable material for inoculating other soils; and a practical method for treating large fields has been worked out and tested through several seasons. The result is especially important as the soy bean is well suited to a wide range of country, and aside from being a valuable forage crop its growth materially enriches the soil.

The recent announcements of the census bureau, which have been widely circulated in the daily press, throw light on a sociological question often discussed. It has been said that the course of population is toward the great cities, that the metropolis is swallowing up the county centers and small cities. A recent prophet of the future made the England of his fiction a single great city with the rest of the country as its farm and garden. Some alarm has been caused lest this supposed tendency to centralization of population prove disastrous to nervous health and moral welfare. It now appears that such a tendency does not exist. For the eighty-one small cities, those of from 25,000 to 50,000, have increased during the last decade practically as fast as the nineteen great cities of over 200,000, namely, about 32 per cent. New York, it is true, has increased 37.8 per cent. The rate of increase of the cities above 25,000 is about 11 per cent. higher than that of the country at large, but there is no cause for sociologists to lament this difference. The inhabitants of the hundred and twenty cities under 100,000 have in many ways a superior intellectual and moral environment. They are freed from the petty annoyances of rural life, its isolation from broadening institutions and its emptiness of appeal to ambition, without losing outdoor freedom or the chance of participation in community life. They enjoy the good schools, libraries, entertainments, the municipal improvements, the services of superior professional men, etc., of great cities, without suffering from metropolitan restrictions, abuses and vices. The small city is in a measure the golden mean among dwelling-places. It would be interesting to observe on a large scale the magnitude of another great movement in population, that connected with the growth of suburbs. The natural supposition is that the rate of increase of the suburbs has been very much above the average even of the cities. In so far as the nature of our surroundings determines our make-up, such new conditions as we have in suburban life are of vital interest to the student of human nature.

The growth of interest in forestry, one of the youngest of the applied sciences, is attested by the establishment this year of the Yale Forest School, which confers the degree of Master of Forestry on graduates who have obtained the bachelor's degree elsewhere. At the opening of the school there were registered seven regular students, besides seventeen from other departments of the University. The residence of the late Professor O. C. Marsh is used as a school building. Lecture-rooms, a library, a laboratory and an herbarium room have been furnished with such equipment as has been found necessary for the present requirements of the school. A considerable amount of museum material has already been acquired and is being classified and arranged as rapidly as possible. The grounds about the building, ten acres in extent, are already covered with a great variety of trees and shrubs, both native and foreign, and it is the intention to plant a considerable number of varieties which are not represented. A forest nursery will be established on the grounds, but the regular forest planting will be done on waste land on the outskirts of New Haven. The New Haven Water Company has offered to the school the use of several hundred acres of woodland for the practical field work of the students, and several other owners have expressed their desire to devote their wood-lots to this purpose.

SUCH schools as the Yale Forest School and the thoroughly equipped school at Cornell under Professor Fernow's direction meet a definite, practical need, for it is an undeniable fact that the supply of lumber is being diminished beyond safety. Twenty million dollars' worth of native lumber is used annually in the manufacture of wood-pulp alone. Nearly half of the original resources of Washington Territory, the home of supposedly inexhaustible forests, have been used. Indiana once possessed 28,000 square miles covered with valuable timber. It sent timber to the East in large quantities, but now must import 82 per cent. of the lumber it uses. Lumbermen from the Lake States are now taking up timber land on the Pacific coast. Experts agree that if things had been left to take their natural course, a timber famine would have been the probable fate of the next generation or two. The Government with its forest preserves and the awakened landowner with economical methods of timber-cutting will delay and probably avert such a catastrophe, but a future scarcity in lumber is by no means the only bad result of a *laissez faire* policy regarding forests. The forests are the guardians of the water supply; useful water power, regular irrigation and the absence of dangerous freshets are all dependent on the proper condition of the vegetation of watersheds. It is supposed that the freshet which caused the Johnstown flood of May, 1889, was due in part to the denudation of the Mill Creek watershed, and at the request of the Johnstown Water Company this region has been examined by experts from the Division of Forestry of the United States Department of Agriculture, who have recommended that where the land has not been covered by a second growth, it be planted and that careful protection against fire be given to the whole district. When one considers that similar measures, if taken a generation ago, might have prevented the loss of $10,000,000 worth of property, to say nothing of the tremendous loss of life at the Johnstown disaster, one realizes the importance of forest preservation as a prophylactic against floods. We should teach even the children in the schools Humboldt's warning, "In felling trees growing on the sides and summits of mountains, men under all climates prepare for subsequent generations two calamities at once—a lack of firewood and a lack of water."

THESE national forest reservations are located in the western third of the country, and agitation is now in progress for similar reservations in Minnesota at the head-waters of the Mississippi and in the Southern Appalachians in the western part of North Carolina. The proposed Minnesota Park would include over 200,000 acres of water surface and over 600,000 acres of land. It would serve as a game preserve, as well as a profitable forest and an assurance to an important water supply. The only objection seems to be on the ground of the expense of purchase of Indian rights, which General Andrews, Chief Forest Warden of the State, estimates as not over $75,000 per year. $2,250,000 has this year been devoted for deepening and improving the Mississippi River. Yet this is dependent on the proper treatment of the very region in question. The passage of the bill was apparently favored by all those competent to judge of the case. It was postponed and will probably be again considered in December. Concerning the proposed Southern Appalachian reservation Prof. J. A. Holmes said at the New York meeting of the American Forestry Association: "Such a reserve, if judiciously managed, will pay a good interest on the investment, besides proving of inestimable value to the people of this country as a public resort for health and pleasure, as a lesson in practical forestry, and as a means of preserving the head-waters of important rivers."

Two lines of work by the Federal Government along the line of forest preservation are especially worth comment. One is the attempt to get an exact estimate of just what forests the country possesses and just what conditions they are in. This knowledge is required as a basis for all theoretical deductions, and as a starting point for all practical measures. This work is now being extensively carried out by the United States Geological Survey. The other is the attempt definitely to assist land-owners to develop wisely their forest lands and thus to spread over the country practical acquaintance with the principles of forest management. This work is in the hands of the Division of Forestry of the Department of Agriculture. In the nineteenth and twentieth reports of the Geological Survey, Mr. Gannett gives the following statistics concerning the area of woodland in the United States. Of the whole country 37 per cent. is wooded; along the Atlantic border the percentage varies from 40 to 80 per cent.; in Ohio, it is 23 per cent.; in Illinois, 18 per cent.; in Kansas, 7 per cent.; in North Dakota, 1 per cent.; in California, 22 per cent., and in Washington, 71 per cent. The areas reserved and their percentage of the total area of the State and of the wooded area of the State are as follows:

State.	Area in Reservation. Sq. Miles.	Per Cent. of Total Area.	Per Cent. of Wooded Area.
Arizona	6,285	6	27
California ...	13,509	9	30
Colorado	4,848	5	15
Idaho	6,264	7	18
Montana	7,885	5	19
New Mexico.	4,273	3	18
Oregon	7,271	8	13
South Dakota	1,893	2	76
Utah	1,474	2	15
Washington .	12,672	19	27
Wyoming ...	4,994	5	40

One of the most interesting questions concerning human nature is the degree to which special aptitudes may appear as the result of innate organic conditions quite apart from experience. It is well enough known that general mental ability is born in us if we have it at all, but we do not know so well how far any special ability, for instance in mathematics, music or sculpture, is due to inborn structural or functional peculiarities. The 'prodigies' in special fields may be instanced as evidence that such highly specialized gifts are inborn, but in some cases interest in the facts concerned and the habit of thinking about them seem to be sufficient to account for the prodigy's success. The latest mathematical prodigy, a boy who has been carefully studied by Professor Bryan and Dr. Lindley of Indiana University, seemed to owe his success to the habit of constantly thinking about numbers. Any intelligent person who would be as much engaged in the pursuit might do as well. It is hard, however, to explain in this way the case of the musical prodigy exhibited before the International Congress of Psychologists by M. Charles Richet. The boy, then three years, seven months and seven days old, played the piano with at times remarkable skill in both technique and expression, but especially in the latter. He knows a score of pieces by heart, all of which he has learned by ear. If twenty or thirty measures are played before him he can then play them. He also, though with more difficulty, plays on the piano tunes he has heard sung. Of his inventiveness Professor Richet said: "It is certain that when Pepito starts to improvise, he is almost never at a loss, and he often finds extremely interesting melodies which appear more or less new to all those present. There is a variety and richness of tone which would perhaps be astonishing if he were a professional musician, but which in a child three years and a half old are absolutely overwhelming." In all else than music he seems to be an ordinary child. Pepito, according to his mother's narrative, was a good player from the start. His first performance was to play throughout a piece which she had played a number of times. This he did absolutely independently of any teaching whatever. Only a special anatomical basis for musical ability seems competent to explain a case like this.

Among recent events of scientific interest, we note the following: Dr. Henry S. Pritchett, superintendent of the Coast and Geodetic Survey, was inaugurated as president of the Massachusetts Institute of Technology on October 24.—Sir Michael Foster has been reelected a member of the British Parliament, representing the University of London.—Cambridge University has conferred the degree of Doctor of Science on Professor S. P. Langley, director of the Smithsonian Institution. —Professor George F. Barker, for twenty-eight years professor of physics in the University of Pennsylvania, and Professor F. H. Bonney, for thirty-three years professor of geology in University College, London, have retired.—A committee has been appointed to erect a memorial to the late Spencer F. Baird at Wood's Holl. Subscriptions may be sent to the Hon. E. G. Blackford, Fulton Market, New York City.—The Rumford Committee of the American Academy of Arts and Sciences has voted a grant of $200 to Mr. C. E. Mendenhall of Williams College for the furtherance of his investigations on a hollow bolometer, and a grant of $500 to Professor George E. Hale of the Yerkes Observatory in furtherance of his researches in connection with the application of the radiometer and a study of the infra-red spectrum of the chromosphere. — Professor Ernst Haeckel is at present in Java, seeking for further remains of *Pithecanthropus erectus*.—Dr. Robert Koch has returned to Berlin after fifteen months spent in the study of malaria, chiefly in the German colonies.—Harvard Observatory has sent an expedition to Kingston, Jamaica, to observe the planet Eros in its approaching opposition.—Mr. E. P. Baldwin is planning an expedition to the North Polar regions, the expenses of which will be defrayed by Mr. Ziegler, of New York City.—The New York Board of Health is building, at a cost of $20,000, a laboratory to be wholly devoted to the study of the bubonic plague.—The great Serpent Mound of Ohio, which has long been a subject of study and research for American archeologists, has been given by the Harvard Corporation to the Ohio State Archeological and Historical Society.—The fine new lecture hall of the American Museum of Natural History was opened with appropriate exercises on Tuesday, October 30. At the same time the new anthropological collections were exhibited.—The new National Museum at Munich, containing the collection of Bavarian antiquities, has been opened, and the valuable collections can be viewed to much better advantage than hitherto. The building contains more than a hundred rooms and has been erected at a cost of about $1,000,000.—The Authors' Catalogue of the British Museum, containing four hundered large volumes and numerous supplements, has now been completed. The compilation of the catalogue has occupied twenty years and cost $200,000. A subject-catalogue is now in course of preparation.—The Russian Government has decided to adopt the metric system of weights and measures, and the ministry of finance is now engaged in considering the time and manner of introducing this reform.

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ASPHALTUM FOR A MODERN STREET.

BY S. F. PECKHAM.

ASPHALTUM is the solid form of bitumen, as it occurs in nature. It has been known to man from prehistoric times. The word is said to be derived from α privative, and σφάλλο 'I cause to slip.' It, therefore, signifies a substance that prevents one from slipping, and was applied to the solid forms of bitumen that soften in the sun. This substance was not rare in so-called Bible lands, embracing the Valley of the Euphrates, the table lands of Mesopotamia and the Valley of the Jordan. It was of frequent occurrence along the shores of the Dead Sea, and was gathered and sold in the caravan trade that passed through the land of Moab and Petrea into Egypt, where it was used in the preparation of mummies.

During the Middle Ages, asphaltum appears to have found but few uses, and is seldom mentioned. The words asphaltum, petroleum and naphtha appear to have been used with different meanings, and also interchangeably or synonymously; yet the words were generally used to signify a thing that was located and defined by further description, so that the bitumen of the Dead Sea was recognized as asphaltum or solid bitumen.

Within the present century, however, both words and definitions have been more exact. As other and slightly differing material was obtained that in some respects resembled coal, it was claimed that some of the deposits of bitumen were beds of coal, and this claim led, about 1850, to important litigation, in which, as experts, scientific men gave very conflicting testimony, one party claiming that the material of certain deposits was asphaltum, and the other that it was coal. It was finally decided that the material—the albertite of New Brunswick—was not coal, and, therefore, did not belong to the Crown. At about this time a deposit occurring in West Virginia, since known as Grahamite, which, in appearance, is much more like splint coal than albertite, attracted attention. There were veins of material in Cuba that were also included in the argument, Coal vs. Asphalt.

The late Dr. T. Sterry Hunt, as long ago as 1863, separated asphaltum from pyrobituminous minerals, or minerals that on being heated to destructive distillation yield products that resemble bitumens. These pyrobituminous coals, schists and shales are nearly as insoluble in the solvents of bitumen, viz., ethyl ether, chloroform, benzole, etc., as they are in distilled water; hence, Dr. Hunt made the action of these solvents the test of the two classes of substances. All true bitumens are miscible with or almost wholly soluble in chloroform, a test that clearly separates them from pyrobituminous minerals. So-called 'asphaltic coals' are not coals at all, but are geologically old asphaltums.

Besides the asphaltums, almost wholly soluble in chloroform, there are a large number of minerals that consist only in part of true bitumens. These are found as beds of sedimentary or crystalline rock, often of immense extent and thickness, impregnated with bitumens of varying consistency and quality, sometimes very soft and seldom quite solid after being separated from the rock. In some instances the bitumen appears to be convertible into asphaltum, and in others not. The French writers have called these rocks 'asphalte,' but, unfortunately, they have also called asphaltum by the same name, as if the things were identical and the words synonymous. Among English writers no uniform custom prevails, but German authors use generally the French word, at the same time calling asphaltum 'Erdpech' or 'Glanzpech.' I think it would promote clearness of expression if this word 'asphalte' were uniformly introduced into all modern languages to designate those bituminous rocks, with the qualifying words, siliceous, calcareous or argillaceous, added as required.

The so-called Trinidad pitch, as it is found in and around the lake, on the island of Trinidad, is a mixture of bitumen, water, mineral and vegetable matter, the whole inflated with gas. When removed from the deposit, most of the water dries out, the gas escapes, the mass changes in color from brown to blue-black, becoming brittle, and at the same time more or less sticky as it loses water. At a rough estimate, about 25 per cent. of the natural cheese-pitch is bitumen.

Various theories have been formulated by scientific men to account for the origin of asphaltum and other forms of bitumen. By some it is thought that complex chemical changes take place between water, carbonate of lime and iron, and other elements that are supposed to exist in the free state or in combination with carbon as carbides, at great depths from the surface. When they have been formed they are supposed to rise towards the surface with steam and water. This is called the 'chemical' theory. Others think that organic animal and vegetable matter that has been buried in strata near the surface of the earth has been converted by a process of partial decay into bitumen. This is called the 'indigenous' theory. Others think that the natural heat of the crust of the earth generated by pressure and, perhaps, other causes, has distilled bitumens from pyrobituminous minerals, and, in some instances, from coal, and they have penetrated the surrounding and overlying porous formations, often filling crevices and forming veins, when the pressure becomes sufficient to rupture the overlying formations. I am inclined to think this latter theory, of 'distillation,' will best account for all the varying conditions under which the various forms of bitumen occur.

Bitumens occur in all periods of the geological history of the earth's crust, but are mainly confined to the formations anterior to the coal period and to the later formations of the tertiary. While asphaltum is found in some of the oldest formations, the greater number of the deposits of solid bitumen and bituminous rocks occur in the more recent formations.

In order to show graphically the relations of the pyrobituminous minerals to the various forms of bitumen, I have arranged the following table, which represents the development of our present knowledge of these substances from the time when M. Léon Malo first published a similar table about forty years ago:

Mineral Substances of Organic Origin.	Coals.		Anthracite, North America, Wales, Belgium, France, etc.	
		Pyro-Bituminous.	Splint, Cannel, Peat, Shales, Schists.	Found all over the world; yielding bituminous substances by destructive distillation, shales of Autun and Mansfeld, Bog-head mineral, Wollongonite, etc.
	Bitumens.		Natural gas.—In the United States, Indiana, Ohio, Pennsylvania, etc. Russia, France, China, etc.	
			Natural naphtha.—Persia, Cuba and generally in petroleum regions.	
			Petroleum.—Central United States, California, Peru, Cuba, Russia, Borneo, Java, etc.	
			Maltha.—Persia, Albania, Texas, California, Peru, Trinidad, Mexico, Cuba, etc.	
		Asphaltum.	North America.—New Brunswick, West Virginia, Utah, California, Mexico.	
			Central America.—Cuba and other West Indies.	
			South America.—Trinidad, Peru, Venezuela.	
			Europe.—Caucasia, France, Dalmatia, Italy, Germany.	
			Asia.—Asia Minor, Persia, Euphrates Valley.	
			Africa.—Egypt and other localities.	
		Asphaltes (Bituminous Rocks).	North America.—Kentucky, Indian Territory, California, Utah, Texas, Athabasca River.	
			Central America.—Mexico and Cuba.	
			South America.—Island of Trinidad, Venezuela.	
			Europe.—Germany, France, Italy, Russia, Austria, etc.	
			Asia.—Asia Minor, Palestine, Persia, China.	
			Africa.—Egypt and other localities.	

While it might be interesting to describe in detail all the minerals mentioned in this table, we are at present concerned with only two, viz., asphaltums and asphaltes. Again, while it might be interesting to describe asphaltums and asphaltes from all the many localities in which they occur, we are at present concerned only with those in use in street paving, and particularly those in use in the United States.

It is said that the idea of constructing a roadway of asphalte was first suggested by the observation that lumps of asphalte that have dropped from carts upon a road, when trodden by animals and rolled beneath wheels, became compacted into a homogeneous and resisting surface. These observations were made in eastern France, in the valley of the Rhone, where very extensive deposits occur, extending into Switzerland. They were first brought into notice, about 1721, by Eirinis

Fig. 1. The Pitch Lake in Trinidad as it Appeared Before 1890.

d'Erynys, a Greek physician, who published a pamphlet in which were described deposits of sand and limestone saturated with bitumen that he had discovered some years previously in the Val de Travers, Canton of Neufchâtel, Switzerland. He described also a bituminous distillate which he used in the treatment of disease. He compared the deposits to similar beds in the valley of Siddim, near Babylon. They were forgotten for nearly a century and then re-discovered.

By whom this material was first used in road building is unknown. Early in 1850, M. de Coulaine published a paper in the 'Annales des Ponts et Chausses,' in which he discussed the use of bitumen in road building as if it was an established industry. He states, without giving any date, that the first attempt to construct a street of bitumen in Paris was made upon the Place Louis XV., opposite the Church of Saint

Roch. This pavement was formed of fragments of quartz and of mastic of coal-tar, upon a bed of sandstone, the joints of which were filled with the mastic. These coal-tar streets, even with a concrete base, were not satisfactory, thus early establishing the undesirable qualities of coal-tar preparations in the construction of streets.

He states his preference for the asphaltes found at Seyssel, Val de Travers and Lobsan, which are composed principally of carbonate of lime and bitumen or sandstone and bitumen. As found in nature, these asphaltes consist either of chalk, sandstone or coarser gravel which have been filled to saturation with bitumen, which when extracted or separated from the mineral constituents of the rocks, is semi-fluid, resembling mineral tar. The deposits occur in beds between more dense and barren rock, and are mined out by running galleries and tunnels

Fig. 2. Digging and Removing Pitch from the Lake prior to 1890.

into the hills that border the valleys, in a manner similar to the mining of coal in some sections of country.

Other deposits of similar material occur at Ragussa, in Sicily, and at Limmer, in Hanover. The Seyssel and Neufchâtel rocks are generally preferred for streets, as they contain more lime and less sand, and are also freer from sulphur compounds.

On the North American continent there are deposits of vast extent both of asphaltum and asphaltes. Generally speaking, asphaltum is not used in street construction; the deposits being either too pure, and hence too valuable for such uses, or, on the other hand, so impure as to be purified only at too great cost. As the asphalte is used in enormous quantities, freight becomes a very important consideration in the selection of the material used in any given locality. This item of cost has given the deposit on the island of Trinidad very great importance as a source of supply for all the Atlantic Coast cities and even those as far west as Denver, while the Pacific Coast cities have been supplied from deposits in California, which to some extent have competed with Trinidad pitch, not only in the Mississippi Valley, but even in New York and other Eastern cities.

The deposits in Trinidad are comprised in the so-called lake and extensive masses outside of it that have either overflowed from the lake or have been derived from independent sources. In the aggregate the extent of the deposits can only be estimated, as their boundaries cannot be determined with any approach to accuracy. They amount, without any doubt, to several millions of tons.

While I have classed the Trinidad pitch with the asphaltes, it is really a unique substance. I have elsewhere called it 'Parianite,' from

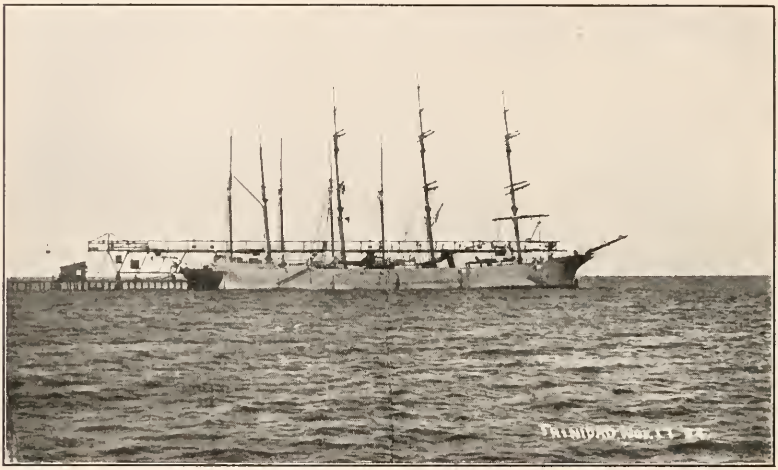

FIG. 3. LOADING SHIPS AT WHARF.

the beautiful bay of Paria, near the coast of which the deposit occurs. The lake is a lake only in name; the deposit, without doubt, filling the crater of an old mud volcano. As described for more than a century preceding 1890, it exhibited an expanse of about one hundred and fourteen acres, with a nearly circular outline, in which irregular areas of pitch are separated by smaller areas of water. Around the borders of the lake, vegetation, commencing at some distance from the edge, is rooted in the pitch itself, and, increasing in vigor as the border is approached, becomes upon the land a tropical jungle of canna and palms, perhaps thirty feet in height. In the center is a circle of islands that float on the pitch. The irregular water areas are many feet in depth, with nearly perpendicular sides, containing very transparent water that apparently has its source in subterranean springs. The areas of pitch are of considerable extent, highest in the middle, but still nearly level and gently sloping on all sides to the precipitous edges of the water areas. These areas are being continually elevated in the center by rising gas, which, forcing up the center in huge bubbles, cause a continual ebullition of the plastic mass and a gradual transference of the material from the center towards the circumference, so that trunks and branches of trees submerged in the pitch come to the surface, rise, and after assuming a perpendicular position, are in time again submerged to an unknown depth. From the escaping gas the whole central portion of the lake is maintained in a constant motion that prevents vegetation

Fig. 1. Tramway and Trucks on Pitch Lake.

from taking root, and leaves the surface of the areas of pitch bare and of a blue-black color.

When the pitch is dug, a negro will drive a long, slender pick to the eye at a single blow, and, by using the handle as a lever, will break out a flake of pitch larger than he can lift. From less than an inch below the surface the pitch is of a brown color, saturated with water and filled with bubbles of gas. A broken mass will soon dry on the surface and melt, forming a pellicle that will enclose the wet mass for years and prevent the escape of the water. In this wet and porous condition it is called 'cheese pitch.' It is not sticky at all, as the water can be squeezed from it in the hand, as if it were a sponge.

Formerly the large lumps of this cheese pitch, as it was broken out, were transported to the beach in carts, but about 1893-4 a wharf was constructed on the Bay of Paria, near the lake, and a trolley line and tramway, leading from the wharf up to and out upon the lake in a loop, by which the pitch since then has been transported direct from the surface of the lake to the vessel being loaded. Formerly the pitch was carried from the beach to ships lying in the bay in lighters, the shipping entailing a great deal of labor from repeated handling. Since the tramway was installed, the pitch is dug along the line of the tramway and thrown into iron buckets, resting on trucks that are propelled along the tramway by an endless cable. Great difficulty was encountered when the tramway was laid to prevent its sinking in the pitch, which, while hard enough on the surface to bear up a loaded team, will slowly engulf any

Fig. 5. A Lot Outside the Lake that has Filled in Six Months after being Excavated 20 Feet.

article of even moderate weight. This trouble was overcome by laying the tramway on a bed of the leaves of the Moriche palm, some of which are twenty-five feet in length. When the car-buckets are loaded they are run to the power-house in groups of three or four, where, after being weighed, they are transferred by an ingenious device from the trucks to a trolley that runs on an endless rope from the lake to the wharf, where the contents of the buckets are dumped into the hold of the ship-like coal. The plant will handle 500 tons a day in the manner described.

Immense quantities of the pitch lie outside the lake, and the pitch from these deposits, wherever worked, is still shipped by means of lighters. The surface of the lake is 148 feet above the sea-level, and the pitch has flowed down to the sea from the lake in an immense stream that resembles a black glacier. Excavations made in this mass soon fill up again and all traces of them are in time obliterated, and buildings, the foundations of which are placed in or upon the pitch, are soon thrown out of perpendicular, from the unstable condition of the pitch, which appears to be moving or flowing towards the sea under a great pressure. These phenomena present the unique spectacle of a mass so solid as to be walked or driven over, and at the same time so plastic as to be in a state of unstable equilibrium, with constant ebullition from escape of gas and also in constant motion towards the sea.

Before the pitch is put to any use it is refined. In the operations attending its shipment and subsequent removal from the hold of the

FIG. 6. BARRELS OF ÉPUREE AT LA BRIA, TRINIDAD, AND PILES OF PITCH AWAITING SHIPMENT IN THE LIGHTERS NEAR SHORE.

ship, it has been very much broken up, and much of the gas has escaped with some of the water. In this condition it is put into enormous kettles, which are heated from above downward, and very slowly, until the contents of thirty tons or more are melted. The heat necessary to melt the pitch expels the water, the fragments of wood and other light impurities rise to the surface, and the heavy mineral matter, in large part, sinks to the bottom. The clean pitch between them is drawn off into barrels.

A more primitive method of refining the pitch is used at the island, where the pitch is boiled in old sugar kettles and skimmed, when the clean pitch is ladled into barrels and enters commerce as 'épurée.'

In the neighborhood of Trinidad, on the mainland of Venezuela, is another so-called Bermudez lake. It is found in a low savannah, extending between a range of mountains and the shore o fone of the estuaries that enter the northern part of the delta of the Orinoco from the Bay of Paria. The lake has an irregularly shaped surface, about one mile and a half by one mile in dimensions, giving an area of something less than 1,000 acres. This area is covered with rank grass and shrubs, from one to eight feet in height, with groves of large Moriche palms. There is no extended surface of clean pitch as at Trinidad; but instead, at certain points, soft pitch wells up as if from subterranean springs. As the general surface of the deposit is not more than two feet above the surrounding swamp, in the rainy season it is flooded, and at other times so low that any excavation will immediately fill with water.

Instead of being more than a hundred feet in depth as at Trinidad, this deposit is a shallow exudation from numerous springs, over a wide surface, from a mere coating to from seven to nine feet in depth, the average being perhaps four feet. The largest of the areas covered with soft pitch is not more than seven acres in extent. The soft material has become hardened in the sun at the edges, but at the center is too soft to walk upon, in this respect resembling many of the deposits of less extent in California. This pitch is also too soft to hold permanently the escaping gas, as at Trinidad, but when covered with water it rises in mushroom-like forms.

Some of these areas have been burned over, producing from the combustion of the vegetation and of the asphaltum itself an intense heat that has converted the bitumen into coke and glance pitch. When this crust of hardened material is removed, beneath it is fonnd asphaltum that may be used for paving.

Under the classification that I have adopted, the bitumen of the Bermudez deposit is nearly pure asphaltum, which has been formed by the heat of the sun and by fire, from an exudation of maltha, or mineral tar, over a wide expanse, beneath the coke and other products of combustion, while here and there are masses of glance pitch, which are the result of less violent action of heat.

Many of the West India islands, from Trinidad around to Cuba, contain deposits of asphaltum. The most noted among them are the Munjack of Barbadoes and the asphaltum veins of Cuba. These, however, have not entered commerce, with the exception, perhaps, of the very pure asphaltum fonnd in Cardenas harbor, which is obtained in limited quantities and is nsed in varnish-making. None of these are used in paving.

In Mexico there are very extensive deposits of asphaltum of great purity, but up to the present time they have not entered commerce.

In Texas, and extending into the Indian Territory, there are large deposits of both siliceous and calcareous asphaltes. In Uralde county, Texas, near Cline, to the west of San Antonio, on the Southern Pacific

Railroad, are very extensive deposits of coquina or shell limestone, filled with bitumen. As found, the material is very tough and difficult to break. When the bitumen is dissolved out with chloroform, there remains a mass of small shells, very light and porous, but with sufficient stability to form a rock. The shells contain from nine to thirteen per cent. of bitumen. While a large sum has been expended on a plant for extracting this bitumen, the enterprise has never proved a pecuniary success. In northern Texas, near the Red River, are extensive deposits of bituminous sand, which has been used locally for sidewalks with success. Across the Red River, near the Arbuckle Mountains, in the Chickasaw Nation, beds of bituminous sand occur of great extent. They extend across the country in anticlinal folds for miles in length. The material is not stone, as the sand falls into a powder as soon as the

FIG. 7. THE 'BIG SPRING' OF TAR, 30 FEET IN DIAMETER, UPPER OJAI, VENTURA COUNTY, CAL

bitumen is removed from it. When the material is broken into small pieces and placed in boiling water, the bitumen rises to the surface nearly free from sand, while the bulk of the sand sinks through the water clean. The bitumen thus obtained is of very superior quality for any purpose. Still farther north and east, near the town of Dougherty, several deposits occur. One is a mass of great extent of fragments of chert and limestone cemented together with bitumen. A mastic has been made by grinding this material. Another mass consists of a magnesian chalk, of carboniferous age, saturated with bitumen. Another is a mass of large shells filled with more than twenty per cent. of bitumen. Other deposits of loose sand occur in beds, saturated with ten per cent. of bitumen. These materials have been used separately and ground together for paving mixtures for street surfaces.

In Utah, upon the Uintah Indian reservation, are found veins of asphaltum of remarkable purity, to which the name 'Gilsonite' has been given. It has been found very useful for insulation and a great variety of purposes, but has only been used in combination with softer material for paving.

Among the coast ranges of California there are deposits of asphaltum and siliceous asphalte of vast extent. At Santa Cruz, to the east and west of Santa Barbara, near the coast near San Buena Ventura and Los Angeles, on the Ojai ranch, and at Asphalto, in Kern County, the principal ones are found. Those of commercial value are at the works of the Alcatraz Company, west of Santa Barbara, and near Asphalto. At the works of the Alcatraz Company the bitumen is dissolved in a

FIG. 8. ASPHALTUM GLACIER, KERN COUNTY, CAL.

solvent and conveyed through pipes some thirty miles to the coast, where the solvent is removed and the bitumen prepared for shipment.

At Asphalto, on the north side of the Coast range, in Kern County, the asphaltum occurs nearly pure in veins of great extent that have been mined to a depth of more than three hundred feet. From these statements it will be seen that the deposits of asphaltum and asphalte in the United States are of vast extent and variety.

While the bitumen in these different deposits in different parts of the world bears a generic relation, there are specific differences between the different varieties that render some of them more desirable for certain purposes than the others. The purest asphaltums are brilliant black, brittle solids that consist of compounds of carbon and hydrogen with small proportions of oxygen, sulphur and nitrogen. The latter of these constituents are not always present and vary widely in amount when present, so that, from a chemical standpoint, the different asphaltums and the bitumens of the different asphaltes are very unlike substances. In the practical uses to which these substances are applied, the selection for any given purpose does not appear to depend upon difference of composition. The purest varieties are used for making fine varnishes and lacquers. Others are used for coarser varnishes that are baked on to iron and other surfaces. Others are applied, softened with solvents that evaporate. These substances find wide uses for insulating purposes, alone and in mixture with other materials.

The widest use to which they are applied is in street-paving surfaces, for which purpose vast quantities are used every year. It has been

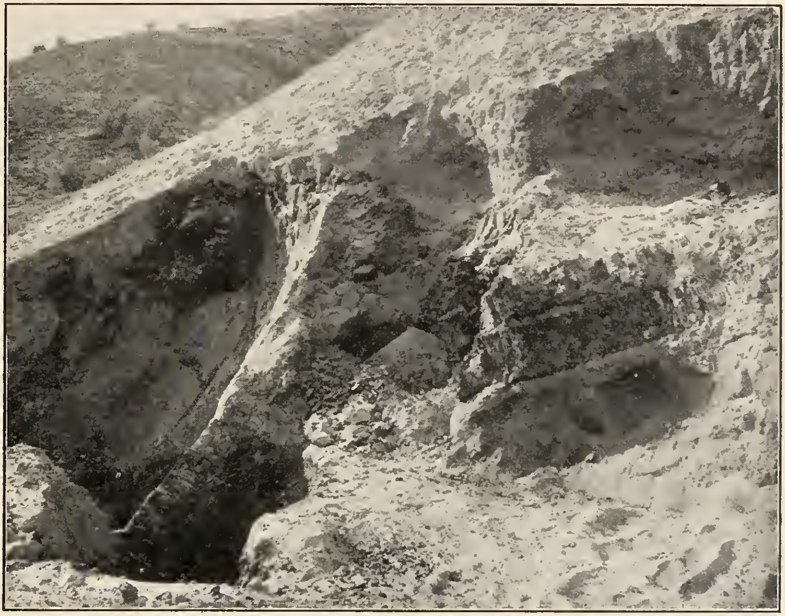

FIG. 9. SHAFT ON ASPHALTUM VEIN NEAR ASPHALTO, FROM WHICH MASS WAS TAKEN WEIGHING 6,500 POUNDS.

found in practice that good streets and poor streets have been made from nearly all the different varieties of asphaltums and asphaltes that can be obtained in such quantity and at such a price as to render their use possible. The different results obtained appear to be due to causes external to the asphaltum or asphalte employed, such as the kind and quality of the materials with which they are mixed and the method, or lack of method, by which they are mixed. These conclusions appear to be warranted by a large number of experiments extending over many years, some of which have been very expensive for the municipalities making them.

THE EFFECT OF PHYSICAL AGENTS ON BACTERIAL LIFE.*

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THE fact that life did not exist upon the earth at a remote period of time, the possibility of its present existence as well as the prospect of its ultimate extinction, can be traced to the operation of certain physical conditions. These physical conditions upon which the maintenance of life as a whole depends are in their main issues beyond the control of man. We can but study, predict and it may be utilize their effects for our benefit. Life in its individual manifestations is, therefore, conditioned by the physical environment in which it is placed. Life rests on a physical basis, and the main springs of its energies are derived from a larger world outside itself. If these conditions, physical or chemical, are favorable, the functions of life proceed; if unfavorable, they cease—and death ultimately ensues. These factors have been studied and their effects utilized to conserve health or to prevent disease. It is our purpose this evening to study some of the purely physical factors, not in their direct bearing on man, but in relation to much lower forms in the scale of life—forms which constitute in number a family far exceeding that of the human species, and of which we may produce at will in a test-tube, within a few hours, a population equal to that of London. These lowly forms of life—the bacteria—belong to the vegetable kingdom, and each individual is represented by a simple cell.

These forms of life are ubiquitous in the soil, air and water, and are likewise to be met with in intimate association with plants and animals, whose tissues they may likewise invade with injurious or deadly effects. Their study is commonly termed bacteriology—a term frequently regarded as synonymous with a branch of purely medical investigation. It would be a mistake, however, to suppose that bacteriology is solely concerned with the study of the germs of disease. The dangerous microbes are in a hopeless minority in comparison with the number of those which are continually performing varied and most useful functions in the economy of nature. Their wide importance is due to the fact that they insure the resolution and redistribution of dead and effete organic matter, which if allowed to accumulate would speedily render life impossible on the surface of the earth. If medicine ceased to regard the bacteria, their study would

* Lecture before the Royal Institution of Great Britain.

still remain of primary importance in relation to many industrial processes in which they play a vital part. It will be seen, therefore, that their biology presents many points of interest to scientific workers generally. Their study as factors that ultimately concern us really began with Pasteur's researches upon fermentation. The subject of this evening's discourse, the effect of physical agents on bacterial life, is important not merely as a purely biological question, though this phase is of considerable interest, but also on account of the facts I have already indicated, viz., that micro-organisms fulfil such an important function in the processes of nature, in industrial operations and in connection with the health of man and animals. It depends largely on the physical conditions to be met with in nature whether they die or remain inactive. Further, the conditions favoring one organism may be fatal to another, or an adaptability may be brought about to unusual conditions for their life. To the technologist the effect of physical agents in this respect is of importance, as a knowledge of their mode of action will guide him to the means to be employed for utilizing the micro-organisms to the best advantage in processes of fermentation. The subject is of peculiar interest to those who are engaged in combating disease, as a knowledge of the physical agents that favor or retard bacterial life will furnish indications for the preventive measures to be adopted. With a suitable soil and an adequate temperature the propagation of bacteria proceeds with great rapidity. If the primary conditions of soil and an adequate temperature are not present, the organisms will not multiply, they remain quiescent or they die. The surface layers of the soil harbor the vast majority of the bacteria, and constitute the great storehouse in nature for these forms of life. They lessen in number in the deeper layers of the soil, and few or none are to be met with at a depth of 8-10 feet. As a matter of fact, the soil is a most efficient bacterial filter, and the majority of the bacteria are retained in its surface layers and are to be met with there. In the surface soil, most bacteria find the necessary physical conditions for their growth, and may be said to exist there under natural conditions. It is in the surface soil that their main scavenging functions are performed. In the deeper layers, the absence of air and the temperature conditions prove inimical to most forms.

Amongst pathogenic bacteria the organisms of lockjaw and of malignant œdema appear to be eminently inhabitants of the soil. As an indication of the richness of the surface soil in bacteria, I may mention that 1 gramme of surface soil may contain from several hundred thousand to as many as several millions of bacteria. The air is poorest in bacteria. The favoring physical conditions to be met with in the soil are not present in the air. Though bacteria are to be met with in the air, they are not multiplying forms, as is the case in the soil. The majority to be met with in air are derived from the soil. Their number lessens when the surface soil is moist, and it increases as the surface soil dries. In a dry season the number of air organisms will tend to increase.

Town air contains more bacteria than country air, whilst they become few and tend to disappear at high levels and on the sea. A shower of rain purifies the air greatly of bacteria. The organisms being, as I stated, mainly derived from the surface of the ground, their number mainly depends on the physical condition of the soil, and this depends on the weather. Bacteria cannot pass independently to the air; they are forcibly transferred to it with dust from various surfaces. The relative bacterial purity of the atmosphere is mainly, therefore, a question of dust. Even when found floating about in the air the bacteria are to be met with in much greater number in the dust that settles on exposed surfaces, e. g., floors, carpets, clothes and furniture. Through a process of sedimentation the lower layers of the air become richer in dust and bacteria, and any disturbance of dust will increase the number of bacteria in the air.

The simple act of breathing does not disseminate disease germs from a patient; it requires an act of coughing to carry them into the air with minute particles of moisture. From the earliest times great weight has been laid upon the danger of infection through air-borne contagia, and with the introduction of antiseptic surgery the endeavor was made to lessen this danger as much as possible by means of the carbolic spray, etc. In the same connection numerous bacteriological examinations of air have been made, with the view of arriving at results of hygienic value. The average number of microorganisms present in the air is 500-1000 per 1000 liters; of this number only 100-200 are bacteria, and they are almost entirely harmless forms. The organisms of suppuration have been detected in the air, and the tubercle bacillus in the dust adhering to the walls of rooms. Investigation has not, however, proved air to be one of the important channels of infection. The bactericidal action of sunlight, desiccation and the diluting action of the atmosphere on noxious substances will always greatly lessen the risk of direct aerial infection.

The physical agents that promote the passage of bacteria into the air are inimical to their vitality. Thus, the majority pass into the air not from moist but from dry surfaces, and the preliminary drying is injurious to a large number of bacteria. It follows that if the air is rendered dust-free, it is practically deprived of all the organisms it may contain. As regards enclosed spaces, the stilling of dust and more especially the disinfection of surfaces liable to breed dust or to harbor bacteria are more important points than air disinfection, and this fact has been recognized in modern surgery. In an investigation, in conjunction with Mr. Lunt, an estimation was arrived at of the ratio existing between the number of dust particles and bacteria in the air. We used Dr. Aitken's dust-counter, which not only renders the air dust particles visible, but gives a means of counting them in a sample of air. In an open suburb of London we found 20,000 dust particles in 1 cubic centimeter of air; in a yard in the center of London about 500,000. The dust contamination we found to be about 900 per cent. greater in the center of London than in a quiet suburb. In the open air of London there was on an average just one organism to every 38,300,000 dust particles present in the air, and in the air of a room, amongst 184,000,000 dust particles, only one organism could be detected.

These figures illustrate forcibly the poverty of the air in micro-organisms, even when very dusty, and likewise the enormous dilution they undergo in the atmosphere. Their continued existence is rendered difficult through the influence of desiccation and sunlight. Desiccation is one of nature's favorite methods for getting rid of bacteria. Moisture is necessary for their development and their vital processes, and constitutes about 80 per cent. of their cell-substance. When moisture is withdrawn most bacterial cells, unless they produce resistant forms of the nature of spores, quickly succumb. The organism of cholera air-dried in a thin film dies in three hours. The organisms of diphtheria, typhoid fever and tuberculosis show more resistance, but die in a few weeks or months.

Dust containing tubercle bacilli may be carried about by air currents, and the bacilli in this way transferred from an affected to a healthy individual. It may, however, be said that drying attenuates and kills most of these forms of life in a comparatively short time. The spores of certain bacteria may, on the other hand, live for many years in a dried condition, e. g., the spores of anthrax bacilli, which are so infective for cattle and also for man (wool-sorters' disease). Fortunately few pathogenic bacteria possess spores, and, therefore, drying by checking and destroying their life is a physical agent that plays an important rôle in the elimination of infectious diseases. This process is aided by the marked bactericidal action of *sunlight*. Sunlight, which has a remarkable fostering influence on higher plant life, does not exercise the same influence on the bacteria. With few exceptions we must grow them in the dark in order to obtain successful cultures; and a sure way of losing our cultures is to leave them exposed to the light of day. Direct sunlight is the most deadly agent, and kills a large number of organisms in the short space of one to two hours; direct sunlight proves fatal to the typhoid bacillus in half an hour to two hours; in the diphtheria bacillus in half an hour to one hour, and to the tubercle bacillus in a few minutes to several hours. Even anthrax spores are killed by direct light in three and a half hours. Diffuse light is also injurious, though its action is slower. By exposing pigment-producing bacteria to sunlight colorless varieties can be obtained, and virulent bacteria so weakened that they will no longer produce infection. The germicidal action of the sun's rays is most marked at the blue end of the spectrum, at the red end there is little or no germicidal action. It is evident that the continuous daily action of the *sun* along with *desiccation* are important physical agents in arresting the further development of the disease germs that are expelled from the body.

It has been shown that sunlight has an important effect in the spontaneous purification of rivers. It is a well-known fact that a river, despite contamination at a given point, may show little or no evidence of this contamination at a point further down in its course. Buchner added to water 100,000 colon bacilli per cubic centimeter, and found that all were dead after one hour's exposure to sunlight. He also found that in a clear lake the bactericidal action of sunlight extended to a depth of about six feet. Sunlight must, therefore, be taken into account as an agent in the purification of waters, in addition to sedimentation, oxidation and the action of algæ.

Air or the oxygen it contains has important and opposite effects on the life of bacteria. In 1861, Pasteur described an organism in connection with the butyric acid fermentation which would only grow in the absence of free oxygen. And since then a number of bacteria, showing a like property, have been isolated and described. They are termed anaerobic bacteria, as their growth is hindered or stopped in the presence of air. The majority of the bacteria, however, are aerobic organisms, inasmuch as their growth is dependent upon a free supply of oxygen. There is likewise an intermediate group of organisms, which show an adaptability to either of these conditions, being able to develop with or without free access to oxygen. Preeminent types of this group are to be met with in the digestive tract of animals, and the majority of disease-producing bacteria belong to this adaptive class. When a pigment-producing organism is grown without free oxygen its pigment production is almost always stopped. For anaerobic forms N and H_2 give the best atmosphere for their growth, whilst CO_2 is not favorable, and may be positively injurious, as, e. g., in the case of the cholera organism.

The physical conditions favoring the presence and multiplication of bacteria in water under natural conditions are a low altitude, warmth, abundance of organic matter and a sluggish or stagnant condition of the water. As regards water-borne infectious diseases, such as typhoid or cholera, their transmission to man by water may be excluded by simple boiling or by an adequate filtration. The freezing of water, whilst stopping the further multiplication of organisms, may conserve the life of disease germs by eliminating the destructive action of commoner competitive forms. Thus the typhoid bacillus may remain frozen in ice for some months without injury. Employment of ordinary cold is not, therefore, a protection against dangerous disease germs.

As regards *electricity*, there is little or no evidence of its direct action on bacterial life, the effects produced appear to be of an indirect character, due to the development of heat or to the products of electrolysis.

Ozone is a powerful disinfectant, and its introduction into polluted water has a most marked purifying effect. The positive effects of the electric current may, therefore, be traced to the action of the chemical products and of heat. I am not aware that any direct action of the X-rays on bacteria has up to the present been definitely proved.

Mechanical agitation, if slight, may favor, and if excessive, may hinder bacterial development. Violent shaking or concussion may not necessarily prove fatal so long as no mechanical lesion of the bacteria is brought about. If, however, substances likely to produce triturating effects are introduced, a disintegration and death of the cells follows. Thus Rowland, by a very rapid shaking of tubercle bacilli in a steel tube, with quartz sand and hard steel balls, produced their complete disintegration in ten minutes.

Bacteria appear to be very resistant to the action of *pressure*. At 300-450 atmospheres putrefaction still takes place, and at 600 atmospheres the virulence of the anthrax bacillus remained unimpaired. Of the physical agents that affect bacterial life, temperature is the most important. Temperature profoundly influences the activity of bacteria. It may favor or hinder their growth, or it may put an end to their life. If we regard temperature in the first instance as a favoring agent, very striking differences are to be noted. The bacteria show a most remarkable range of temperature under which their growth is possible, extending from zero to 70° C. If we begin at the bottom of the scale we find organisms in the water and in soil that are capable of growth and development at zero. Amongst these are certain species of phosphorescent bacteria, which continue to emit light even at this low temperature. At the Jenner Institute we have met with organisms growing and developing at 34-40° F. The vast majority of interest to us find, however, the best conditions for their growth from 15° up to 37° C. Each species has a minimum, an optimum and a maximum temperature at which it will develop. It is important in studying any given species that the optimum temperature for their development be ascertained, and that this temperature be maintained. In this respect we can distinguish three broad groups. The first group includes those for which the optimum temperature is from 15-20° C. The second group includes the parasitic forms, viz., those which grow in the living body, and for which the optimum temperature is at blood heat, viz., 37° C. We have a third group, for which the optimum temperature lies as high as 50-55° C. On this account this latter group has been termed thermophilic on account of its growth at such abnormally high temperatures—temperatures which are fatal to other forms of life. They have been the subject of personal investigation in conjunction with Dr. Blaxall. We found that there existed in nature an extensive group of such organisms to which the term thermophilic bacteria was applicable. Their growth and development occurred best at temperatures at which ordinary protoplasm becomes inert or dies. The best growths were always obtained at 55-65° C. Their wide distribution was of a striking nature. They were found by us in river water and mud, in sewage and also in a sample of sea water. They were present in the digestive tract of man and animals, and in the surface and deep layers of the soil, as well as in straw and in all samples of ensilage examined. Their rapid growth at high temperatures was remarkable, the whole surface of the culture medium being frequently overrun in from fifteen to seventeen hours. The organisms examined by us (fourteen forms in all) belonged to the group of the Bacilli. Some were motile, some curdled milk and some liquefied gelatin in virtue of a proteolytic enzyme. The majority possessed reducing powers upon nitrates and decomposed proteid matter. In some instances cane sugar was inverted and starch was diastased. These facts well illustrate the full vitality of the organisms at these high temperatures, whilst all the organisms isolated grew best at 55-65° C. A good growth in a few cases occurred at 72° C. Evidence of growth was obtained even at 74° C. They exhibited a remarkable and unique range of temperature, extending as far as 30° of the Centigrade scale.

As a concluding instance of the activity of these organisms we may cite their action upon cellulose. Cellulose is a substance that is exceedingly difficult to decompose, and is, therefore, used in the laboratory for filtering purposes in the form of Swedish filter paper, on account of its resistance to the action of solvents. We allowed these organisms to act on cellulose at 60° C. The result was that in ten to fourteen days a complete disintegration of the cellulose had taken place, probably in CO_2 and marsh gas. The exact conditions that may favor their growth, even if it be slow at subthermophilic temperatures, are not yet known—they may possibly be of a chemical nature.

Organisms may be gradually *acclimatized* to temperatures that prove unsuited to them under ordinary conditions. Thus the anthrax bacillus, with an optimum temperature for its development of 37° C., may be made to grow at 12° C., and at 42° C. Such anthrax bacilli proved pathogenic for the frog with a temperature of 12° C., and for the pigeon with a temperature of 42° C.

Let us, in a very few words, consider the inimical action of temperature on bacterial life. An organism placed below its minimum temperature ceases to develop, and if grown above its optimum temperature becomes attenuated as regards its virulence, etc., and may eventually die. The boiling point is fatal for non-sporing organisms in a few minutes. The exact thermal death-point varies according to the optimum and maximum temperature for the growth of the organism in question. Thus, for water bacteria with a low optimum temperature, blood heat may be fatal; for pathogenic bacteria developing best at blood heat, a thermophilic temperature may be fatal (60° C.); and for thermophilic bacilli any temperature above 75° C. These remarks apply to the bacteria during their multiplying and vegetating phase of life. In their resting or spore stage the organisms are much more resistant to heat. Thus the anthrax organism in its bacillary phase is killed in one minute at 70° C.; in its spore stage it resists this temperature for hours, and is only killed after some minutes by boiling. In the soil there are spores of bacteria which require boiling for sixteen hours to ensure their death. These are important points to be remembered in sterilization or disinfection experiments, viz., whether an organism does or does not produce these resistant spores. Most non-sporing forms are killed at 60° C. in a few minutes, but in an air-dry condition a longer time is necessary. Dry heat requires a longer time to act than moist heat: it requires 140° C. for three hours to kill anthrax spores. Dry heat cannot, therefore, be used for ordinary disinfection on account of its destructive action. Moist heat in the form of steam is the most effectual disinfectant, killing anthrax spores at boiling point in a few minutes, whilst a still quicker action is obtained if saturated steam under pressure be used. No spore, however resistant, remains alive after one minute's exposure to steam at 140° C. The varying thermal death-point of organisms and the problems of sterilization cannot be better illustrated than in the case of milk, which is an admirable soil for the growth of a large number of bacteria. The most obvious example of this is the souring and curdling of milk that occurs after it has been standing for some time. This change is mainly due to the lactic acid bacteria, which ferment the milk sugar with the production of acidity.

Another class of bacteria may curdle the milk without souring it in virtue of a rennet-like ferment, whilst a third class precipitate and dissolve the casein of the milk, along with the development of butyric acid. The process whereby milk is submitted to a heat of 65° to 70° C. for twenty minutes is known as pasteurization, and the milk so treated is familiar to us all as pasteurized milk. Whilst the pasteurizing process weeds out the lactic acid bacteria from the milk, a temperature of 100° C. for one hour is necessary to destroy the butyric acid organisms: and even when this has been accomplished there still remain in the milk the spores of organisms which are only killed after a temperature of 100° C. for three to six hours. It will, therefore, be seen that pasteurization produces a partial, not a complete sterilization of the milk as regards its usual bacterial inhabitants. The sterilization to be absolute would require six hours at boiling point. But for all ordinary practical purposes pasteurization is an adequate procedure. All practical hygienic requirements are likewise adequately met by pasteurization, if it is properly carried out, and the milk is subsequently cooled. Milk may carry the infection of diphtheria, cholera, typhoid and scarlet fevers, as well as the tubercle bacillus from a diseased animal to the human subject. For the purpose of rendering the milk innocuous, freezing and the addition of preservatives are inadequate methods of procedure. The one efficient and trustworthy agent we possess is heat. Heat and cold are the agents to be jointly employed in the process, viz., a temperature sufficiently high to be fatal to organisms producing a rapid decomposition of milk, as well as to those which produce disease in man; this is to be followed by a rapid cooling to preserve the fresh flavor and to prevent an increase of the bacteria that still remain alive. The pasteurized process fulfils these requirements.

In conjunction with Dr. Hewlett, I had occasion to investigate in how far the best pasteurizing results might be obtained. We found that 60° to 68° C. applied for twenty minutes weeded out about 90 per cent. of the organisms present in the milk, leaving a 10 per cent. residue of resistant forms. It was found advisable to fix the pasteurizing temperature at 68° C., in order to make certain of killing any pathogenic organisms that may happen to be present. We passed milk in a thin stream through a coil of metal piping, which was heated on its outer surface by water. By regulating the length of the coil, or the size of the tubing, or the rate of flow of the milk, almost any desired temperature could be obtained. The temperature we ultimately fixed at 70° C. The cooling was carried out in similar coils placed in iced water. The thin stream of milk was quickly heated and quickly cooled as it passed through the heated and cooled tubing, and whilst it retained its natural flavor, the apparatus accomplished at 70° C. in thirty seconds a complete pasteurization, instead of in twenty minutes, i. e., about 90 per cent. of the bacteria were killed, whilst the diphtheria, typhoid, tubercle and pus organisms were destroyed in the same remarkably short period of time, viz., thirty seconds. This will serve to illustrate how the physical agent of heat may be employed, as well as the sensitiveness of bacteria to heat when it is adequately employed.

Bacteria are much more sensitive to high than to low temperatures, and it is possible to proceed much further downwards than upwards in the scale of temperature, without impairing their vitality. Some will even multiply at zero, whilst others will remain alive when frozen under ordinary conditions.

I will conclude this discourse by briefly referring to experiments recently made with most remarkable results upon the influence of low temperatures on bacterial life. The experiments were conducted at the suggestion of Sir James Crichton-Browne and Professor Dewar. The necessary facilities were most kindly given at the Royal Institution, and the experiments were conducted under the personal supervision of Professor Dewar. The action of liquid air on bacteria was first tested. A typical series of bacteria was employed for this purpose, possessing varying degrees of resistance to external agents. The bacteria were first simultaneously exposed to the temperature of liquid air for twenty hours (about −190° C.). In no instance could any impairment of the vitality of the organisms be detected as regards their growth of functional activities. This was strikingly illustrated in the case of the phosphorescent organisms tested. The cells emit light which is apparently produced by a chemical process of intracellular oxidation, and the phenomenon ceases with the cessation of their activity. These organisms, therefore, furnished a very happy test of the influence of low temperatures on vital phenomena. These organisms when cooled down in liquid air became non-luminous, but on re-thawing the luminosity returned with unimpaired vigor as the cells renewed their activity. The sudden cessation and rapid renewal of the luminous properties of the cells, despite the extreme changes of temperature, was remarkable and striking. In further experiments the organisms were subjected to the temperature of liquid air for seven days. The results were again *nil.* On re-thawing the organisms renewed their life processes with unimpaired vigor. We had not yet succeeded in reaching the limits of vitality. Professor Dewar kindly afforded the opportunity of submitting the organisms to the temperature of liquid hydrogen—about −250° C. The same series of organisms was employed, and again the result was *nil.* This temperature is only 21° above that of the absolute zero, a temperature at which, on our present theoretical conceptions, molecular movement ceases and the entire range of chemical and physical activities with which we are acquainted either cease, or, it may be, assume an entirely new rôle. This temperature again is far below that at which any chemical reaction is known to take place. The fact, then, that life can continue to exist under such conditions affords new ground for reflection as to whether after all life is dependent for its continuance on chemical reactions. We, as biologists, therefore follow with the keenest interest Professor Dewar's heroic attempts to reach the absolute zero of temperature; meanwhile, his success has already led us to reconsider many of the main issues of the problem. And by having afforded us a new realm in which to experiment, Professor Dewar has placed in our hands an agent of investigation from the effective use of which we who are working at the subject at least hope to gain a little further insight into the great mystery of life itself.

FLIES AND TYPHOID FEVER.

BY DR. L. O. HOWARD,
U. S. DEPARTMENT OF AGRICULTURE.

AFTER the outbreak of the late war with Spain in the early summer of 1898, typhoid fever soon became prevalent in concentration camps in different parts of the country. In many cases—in fact in fully one-half of the total number—the fever was not recognized as typhoid for some time, but towards the close of the summer it was practically decided that the fever which prevailed was not malarial, but enteric. During that summer the medical journals and the newspapers contained a number of communications from contract surgeons and others advancing the theory that flies were largely responsible for the spread of the disease, owing to the fact that in many of these camps the sinks or latrines were placed near the kitchens and dining tents, and that the enormous quantity of excrement in the sinks was not properly cared for. One of the most forcible writers on this topic was Dr. H. A. Veeder, whose paper, entitled 'Flies as Spreaders of Disease in Camps,' published in the 'New York Medical Record' of September 17, 1898, brought together a series of observations and strong arguments in favor of his conclusion that flies are prolific conveyors of typhoid under improper camp conditions.

This idea was not a new one. Following the proof of the agency of flies in the transmission of Asiatic cholera by Tizzoni and Cattani, Sawtchanko, Simmonds, Uffelmann, Flugge and Macrae, it was shown by Celli as early as 1888 that flies fed on the pure cultures of *Bacillus typhi abdominalis* are able to transmit virulent bacilli in their excrement. Dr. George M. Kober, of Washington, in his lectures before the Medical College of Georgetown University, had for some years been insisting upon the agency of flies in the transmission of typhoid, and in the report of the health officer of the District of Columbia for the year ending June 30, 1895, referred to the probable transferrence of typhoid germs from the privies and other receptacles for typhoid stools to the food supply of the house by the agency of flies.

Moreover, the Surgeon-General of the Army, Dr. George M. Sternberg, was fully alive to the great importance of the isolation and disinfection of excrement, as evidenced in his prize essay on 'Disinfection and Personal Prophylaxis in Infectious Diseases,' published by the American Public Health Association in 1885, and in the first circular issued from his office in the spring of 1898 (April) careful instructions were given regarding the preparation of sinks and their care, with a direct indication of the danger of transfer of typhoid fever by flies. These instructions were not followed, and the result was that over 21 per cent. of the troops in the national encampments in this country during the summer of 1898 had typhoid fever, and over 80 per cent. of the total number of deaths during that year were from this one cause.*

This condition of affairs was not confined to the United States. An epidemic occurred in the camp of the Eighth Cavalry at Puerto Principe, Cuba, in which two hundred and fifty cases of the fever occurred. The disease was imported by the regiment into its Cuban camp, and Dr. Walter Reed, U. S. A., upon investigation, reported to the Surgeon-General that the epidemic "was clearly not due to water infection, but was transferred from the infected stools of the patients to the food by means of flies, the conditions being especially favorable for this manner of dissemination. . . . "†

In all the published accounts, and in all literature of closely allied subjects, the expression used in connection with the insects has been

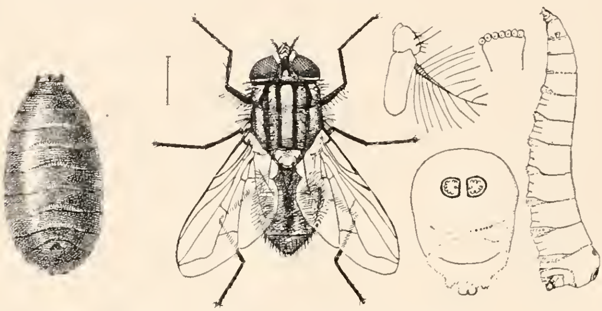

FIG. 1. MUSCA DOMESTICA—ENLARGED.

simply the word 'flies.' Nothing could be more unsatisfactory to the entomologist than such a general word as this, except it were taken for granted that the house-fly *(Musca domestica)* was always meant. It has not apparently been realized that there are many species of flies which are attracted to intestinal discharges, nor does it seem to have been realized that, while certain of these species may visit, and do visit, food supplies in dining rooms, kitchens and elsewhere, many others are not likely to be attracted.

In 1895, the writer made a study of the house-fly, not from this

* Conclusions reached after a study of typhoid fever among American soldiers in 1898, by Dr. Victor C. Vaughan, a member of the Army Typhoid Commission, read before the annual meeting of the American Medical Association at Atlantic City, N. J., June 6, 1900. 'Philadelphia Medical Journal,' June 9, 1900, pages 1315 to 1325.

† 'Sanitary Lessons of the War,' by George M. Sternberg, Surgeon-General, U. S. A., read at the meeting of the American Medical Association, at Columbus, O., June 6 to 9, 1899. 'Phila. Med. Jour.,' June 10 and 17, 1899.

standpoint, but from a desire to learn the principal source from which our houses are supplied with this eternal nuisance, with a view to being able to suggest remedial measures. Experimental work in this direction was continued for some years. In the course of this work he early decided that an overwhelming majority of the house-flies found in domiciles breed in horse manure. This substance is its favored larval food, and experimental work showed that by the semi-weekly treatment of the horse manure in one large stable, the house-fly supply of the neighborhood was very greatly reduced. In confined breeding cages he had been unable to breed house-flies in any other substance than horse-dung, and consequently when the camp typhoid question and the agency of flies became a matter of such general comment in 1898, he saw the desirability of a careful study of the insects which frequent or breed in human excrement, in order to give exact data from which reliable state-

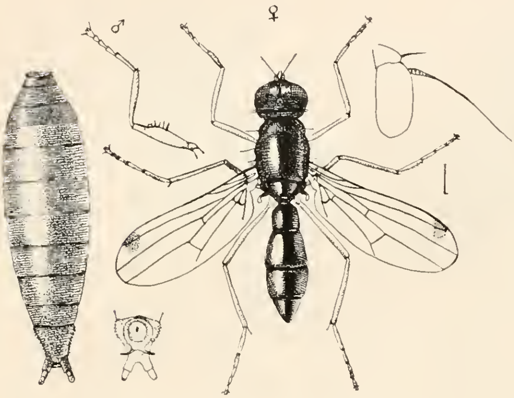

FIG. 2. SEPSIS VIOLACEA—ENLARGED.

FIG. 3. NEMOPODA MINUTA—ENLARGED.

ments could be made and upon which reliable conclusions could be based. This work was begun and carried on through the summer of 1899 and to some extent in the summer of 1900, with results which will be briefly summarized in the following paragraphs. The exact details, somewhat too technical, altogether too long and certainly too unpleasant for publication in a journal of this character, will be published in the Proceedings of the Washington Academy of Sciences.

In all seventy-seven distinct species of flies, belonging to twenty-one different families, were found by actual observation, either by rearing or by captures, to be coprophagous; thirty-six species were found to breed in human fæces under more or less normal conditions, while forty-one were captured upon such material. All have been studied with more or less care, and their other habits ascertained. The most abundant of the flies reared were *Helicobia quadrisetosa, Sepsis violacea, Nemopoda minuta, Limosina albipennis, Limosina fontinalis, Sphærocera subsultans* and *Scatophaga furcata,* while the most abundant forms captured were *Phormia terrænovæ* and *Borborus equinus.* In a second class, not including the most abundant forms reared and captured, but including species which were rather abundantly found, were *Sarcophaga sarraceniæ, Sarcophaga assidua, Sarcophaga trivialis, Musca domestica* (the common house-fly), *Morellia micans, Muscina stabulans, Myospila meditabunda, Ophyra leucostoma, Phorbia cinerella,* and *Sphærocera pusilla,* of the reared series, and *Pseudopyrellia cornicina* and *Limosina crassimana* among the captured series. All the others of the seventy-seven species were either scarce or not abundant.

The results so far stated and the observations made in the investigation as a whole have a distinct entomological interest, as showing the exact food habits of a large number of species, many of the obser-

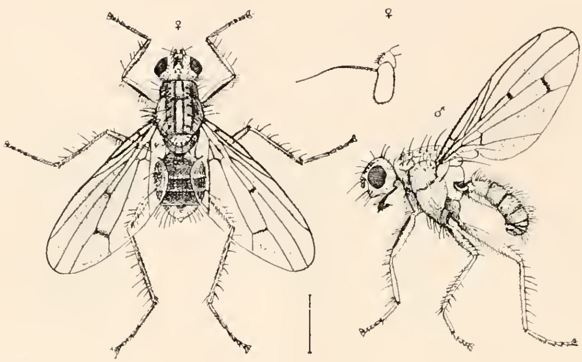

FIG. 4. SCATOPHAGA FURCATA—ENLARGED.

vations being novel contributions to the previous knowledge of these forms. But the principal bearings of the work are only brought out when we consider which of these forms are likely, from their habits, actually to convey disease germs from the substance in which they have bred or which they have frequented to substances upon which people feed. Therefore, collections of the Dipterous insects (flies) occurring in kitchens, pantries and dining rooms were made, with the assistance of correspondents and observers in different parts of the country, through the summer of 1899, and also in the summer and autumn of 1900. Such collections were made in the States of Massachusetts, New York, Pennsylvania, District of Columbia, Florida, Georgia, Louisiana, Nebraska and California. Nearly all of the flies thus captured were caught upon sheets of the ordinary sticky fly-paper, which, while ruining them as cabinet specimens, did not disfigure them beyond the point of specific recognition.

In all 23,087 flies were examined.* They were caught in rooms in which food supplies are ordinarily exposed, and may safely be said to have been attracted by the presence of these food supplies. Of these 23,087 flies, 22,808 were *Musca domestica;* that is to say, 98.8 per cent. of the whole number captured belonged to the species known as the common house-fly. The remainder, consisting of 1.2 per cent. of the whole, comprised various species, the most significant ones being *Homalomyia canicularis* (the species ordinarily known as the 'little house-fly'), of which 81 specimens were captured; the stable-fly *(Muscina stabulans)*, 37 specimens; *Phora femorata*, 33; *Lucilia cæsar* (screw-worm fly), 8; *Drosophila amelophila*, 15; *Sarcophaga trivialis*, 10; and *Calliphora erythrocephala* (the common blow-fly), 7.

Musca domestica is, therefore, the species of greatest importance from

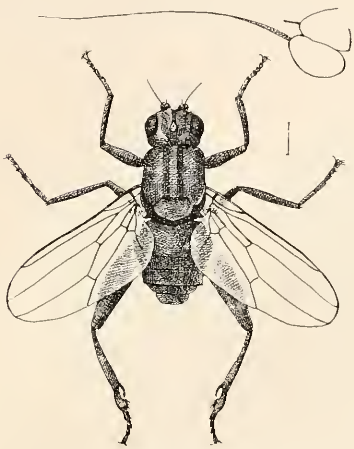

FIG. 5. SPHÆROCERA SUBSULTANS—ENLARGED.

FIG. 6. PHORMIA TERRÆNOVÆ—ENLARGED.

the food-infesting standpoint; *Homalomyia canicularis* is important and *Muscina stabulans* is of somewhat lesser importance. *Drosophila amelophila*, although not occurring in the former list of abundant species, does rarely breed in excreta and is an important form; it would have been much more abundant in the records of house captures had more of these been made in the autumn, after fruit makes its appearance upon the dining tables and sideboards, since this species is the commonest of the little fruit-flies which are seen flying about ripe fruit in the fall of the year. The Calliphora and the Lucilia are of slight importance, not only on account of their rarity in houses, but because they are not, strictly speaking, true excrement insects. They

* The determination work in the Diptera was all done by the writer's assistant, Mr. D. W. Coquillett, who is an authority on this group of insects.

are rather carrion species. Other forms were taken, but either their household occurrence was probably accidental or from their habits they have no significance in the disease-transfer function.

It appears plainly that the most abundant species breeding in or attracted to dejecta do not occur in kitchens and dining rooms, but it is none the less obvious that while the common house-fly, under ordinary city and town conditions as they exist at the present day, and more especially in such cities and towns, or in such portions of cities as are well cared for and inhabited by a cleanly and respectable population, may not be considered an imminent source of danger, it is, nevertheless, under other conditions a factor of the greatest importance in the spreading of enteric fever.

The house-fly undoubtedly prefers horse manure as a breeding place. We have shown that it is not one of the most abundant species of flies breeding in or attached to human fæces, but, in the course of the observations made in the summer of 1899, we have definitely proved

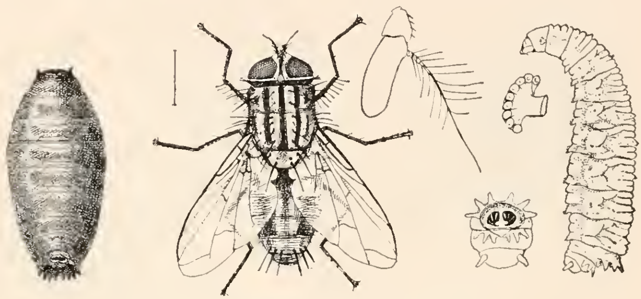

Fig. 7. Sarcophaga assidua—enlarged.

the following facts relative to the house-fly, and in the statement of these facts it must be remembered that every specimen has been carefully examined by an expert dipterologist, so that there can be no mistake:

(1.) In the army camps the latrines are not properly cared for and where their contents are left exposed, *Musca domestica* will, and does, breed in these contents in large numbers, and is attracted to them without necessary oviposition.

Such observations were not made by the writer at the concentration camps of 1898, but were made at the summer camps of the District of Columbia Militia, during the summers of 1899 and 1900.

The contrast between the conditions here observed and those which existed at the great army camp at the Presidio, San Francisco, California, as observed by the writer through the courtesy of Surgeon-General Sternberg and Colonel W. H. Forwood, surgeon in charge of the Department of California, in the late autumn of 1899, was most striking. At the Presidio camp, the chance for the transfer of typhoid by flies had by intelligent care been reduced to zero. This, however, was, of course, a more or less permanent camp and opportunities were better, but indicated in a beautiful way what might be done and what should be done even in a temporary camp.

(2) In towns where the box privy nuisance is still in existence the house-fly is attracted to such places to a certain extent, though not as abundantly as other flies, which, however, are not found in houses. Observations to this effect were made by the writer and his assistants in many parts of the United States.

(3.) In the filthy regions of a city, where sanitary supervision is lax, and where in low alleys and corners and vacant lots deposits are made by dirty people, the house-fly is attracted to the stools, may breed in them, and is thus a constant source of danger. The writer has seen a deposit made over night in South Washington in an alleyway swarm-

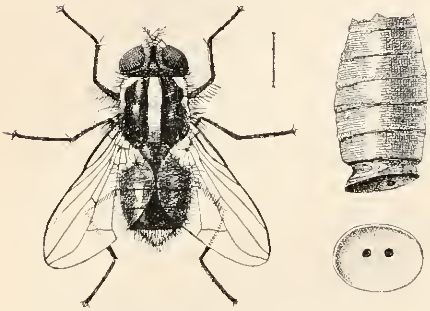

Fig. 8. Morellia micans—enlarged.

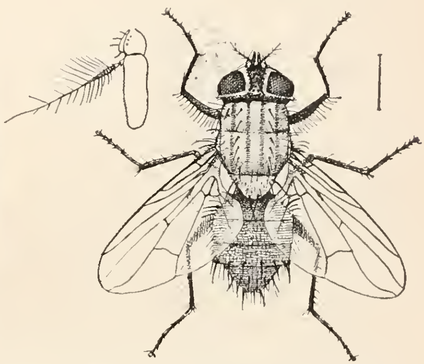

Fig. 9. Myospila meditabunda—enlarged.

ing with flies, in the bright sunlight of a June morning, temperature 92° F., and within thirty feet of this substance were the open doors and windows of the kitchens of two houses occupied by poor people, these two houses being only elements in a long row.

The conclusions which the writer has reached after two years of this experimental work are:

(1) Of the seventy-seven species of flies found under such conditions that their bodies, especially their feet and their proboscides, may become covered with virulent typhoid germs, only eight are likely to carry them to objects from which they can enter the alimentary canal of man.

(2) Of these eight species, two, namely, *Lucilia cæsar* and *Calliphora erythrocephala*, can very rarely carry such germs, though they may carry the germs of putrefaction and cause blood-poisoning, in alighting upon abrasions of the skin or open wounds.

(3) Four of these specimens, namely, *Homaloymia canicularis*, *Muscina stabulans*, *Phora femorata* and *Sarcophaga trivialis*, possess some degree of importance, but their comparative scarcity in houses renders them by no means of prime importance.

(4) The common little fruit-fly, *Drosophila ampelophila*, is a dangerous species.

(5) The house-fly is a constant source of danger, and wherever the least carelessness in the disposal of or the disinfection of dejecta exists, it becomes an imminent source of danger.

When we consider the prevalence of typhoid fever and the fact that virulent typhoid bacilli may occur in the excrement of an individual for some time before the disease is recognized in him, and that virulent germs may be found in the excrement for a long time after the apparent recovery of a patient, the wonder is not that typhoid is so prevalent, but that it does not prevail to a much greater extent.

Fig. 10. Muscina stabulans—Enlarged.

Fig. 11. Phorbia cinerella—Enlarged.

Box privies should be abolished in every community, or they should be disinfected daily. The depositing of excrement in the open within the town or city limits should be considered a punishable misdemeanor in cities which have not already such regulations, and the law should be enforced more vigorously in towns in which it is already prohibited. Such offenses are generally committed after dark, and it is often difficult, or even impossible, to trace the offender; therefore, the regulations should be carried even further, and should require the first responsible person who notices the deposit to immediately inform the police, so that it may be removed or covered up. Dead animals are so reported, but human excrement is much more dangerous. Boards of health in all communities should look after the proper treatment or disposal of horse manure, primarily in order to reduce the number of house-flies to a minimum, and all regulations regarding the disposal of garbage and foul matter should be made more stringent and should be more stringently enforced.

GEOMETRY: ANCIENT AND MODERN.

By Professor EDWIN S. CRAWLEY,
UNIVERSITY OF PENNSYLVANIA.

AMONGST the records of the most remote antiquity we find little to lead to the conclusion that geometry was known or studied as a branch of mathematics. The Babylonians had a remarkably well-developed number system and were expert astronomers; but, so far as we know, their knowledge of geometry did not go beyond the construction of certain more or less regular figures for necromantic purposes. The Egyptians did better than this, and Egypt is commonly acknowledged to be the birthplace of geometry. It was a poor kind of geometry, however, from our point of view, and should rather be designated as a system of mensuration. Nevertheless it served as a beginning, and probably was the means of setting the Greek mind at work upon this subject. Our knowledge of Egyptian geometry is obtained from a papyrus in the British Museum known as the Ahmes Mathematical Papyrus. It dates from about the eighteenth century B. C., and purports to be a copy of a document some four or five centuries older. It is the counterpart of what to-day is called an engineer's hand-book. It contains arithmetical tables, examples in the solution of simple equations, and rules for determining the areas of figures and the capacity of certain solids. There is no hint of anything in the nature of demonstrational geometry, nor any evidence of how the rules were derived. In fact, they could not have been obtained as the result of demonstration, for they are generally wrong. For example, the area of an isosceles triangle is given as the product of the base and half the side, and that of a trapezoid as the product of the half-sums of the opposite sides. These rules give results which are approximately correct so long as they are applied to triangles whose altitude is large compared with the base, and to trapezoids which do not depart very far from a rectangular shape. Whether the Egyptians ever came to realize that these rules were erroneous we cannot say, but it is known that long after the Greeks had discovered the correct ones they were still in use. Thus Cajori, 'History of Mathematics,' page 12, says: "On the walls of the celebrated temple of Horus at Edfu have been found hieroglyphics written about 100 B. C., which enumerate the pieces of land owned by the priesthood and give their areas. The area of any quadrilateral, however irregular, is there found by the formula $\frac{a+b}{2} \times \frac{c+d}{2}$." [$a$ and b stand for one pair of opposite sides and c and d for the others.] It is plausibly argued that a superstitious traditionalism made it an act of sacrilege to alter what had become part of the sacred writings.

When we consider the conditions of life in Egypt we can easily see why this particular kind of geometric knowledge so early gained currency. The annual inundation of the Nile was continually altering the minor features of the country along its course, and washing away landmarks between adjacent properties. Some means of re-establishing these marks and of determining the areas of fields was therefore essential. To meet this demand the surveyors devised the rules which Ahmes has given us. The further necessity of ascertaining the contents of a barn of given shape and dimensions likewise gave rise to the rules for determining volumes.

We learn also that the Egyptians were acquainted with the truth of the Pythagorean theorem, that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides, for they applied this knowledge practically by means of a triangle whose sides were 3, 4 and 5 respectively, in laying down right angles. This general truth was derived in all probability by deduction from a large number of individual cases. The Egyptian rule for the area of a circle was remarkably accurate for such an early date. It consisted in squaring eight-ninths of the diameter. This gives to π the value 3.1605.

It is generally supposed that the Greeks had their attention drawn to geometry through intercourse with the Egyptians. It was but a step, however, for them to pass beyond the latter, and with them we find the birth of the true mathematical spirit which refuses to accept anything upon authority, but requires a logical demonstration. It is well known what an important place was held by geometry in Greek philosophy. The Pythagorean school contributed much that was important along with a great deal that was fanciful and of little value. Pythagoras himself was the first to prove the theorem referred to above, which goes by his name. The Greeks for the most part pursued the study of geometry as a purely intellectual exercise. Anything in the nature of practical applications of the subject was repugnant to them, and hence but little attention was paid to theorems of mensuration. This reminds one of the story told of a professor of mathematics in modern times who, in beginning a course of lectures, made the remark: "Gentlemen, to my mind the most interesting thing about this subject is that I do not see how under any circumstances it can ever be put to any practical use." Euclid in his 'Elements' does not mention the theorem that the area of a triangle is equal to half the product of its base and altitude, nor does he enter into any discussion of the ratio of the circumference to the diameter of a circle. This last, however, was a problem which as early as the time of Pythagoras had attracted much attention. 'Squaring the circle' was a stumbling block to the Greeks and has been ever since.

The pursuit of the impossible seems to have an irresistible attraction for some minds. This remark applies only to the modern devotees of the subject, however. The Greeks did not know that the thing they sought was an impossibility. To square the circle, to trisect an angle and to duplicate the cube were three problems upon which the Greeks lavished more attention probably than upon any others. It was not labor wasted, because it led incidentally to many theorems, which otherwise might have remained unknown, but the principal object sought was not attained. To make matters clear it should be stated that to meet the requirements of Greek geometry the instruments used in the solution must be only the compasses and the unmarked straight edge. So that to square the circle meant to construct by these means the side of a square whose area should equal that of a given circle. The Greeks eventually succeeded in solving the last two problems by the aid of curves other than the circle, but this, of course, was unsatisfactory. As we know now they were pursuing *ignes fatui*. Nevertheless it is brought to the knowledge of mathematicians with painful frequency that a vast amount of energy is still wasted upon these problems, especially the first. Let me, therefore, take the space here to repeat that squaring the circle is not simply one of the unsolved problems of mathematics which is awaiting the happy inspiration of some genius, but that it has been ably demonstrated to be incapable of solution in the manner proposed.

When Euclid compiled his 'Elements' the knowledge of geometry current amongst the Greeks was about the same as that which we have to-day under the name of elementary geometry. The term Euclidean geometry has a somewhat different signification, which will be explained below.

About a century before Euclid's time the Greeks discovered the conic sections, and Apollonius of Perga, who lived about a century after Euclid, brought the geometry of these curves to a high degree of perfection. Archimedes, whose time was intermediate between that of Euclid and of Apollonius, had a more practical turn of mind and applied his mathematical knowledge to useful purposes. Amongst other things he showed that the value of π lies between $3\frac{1}{7}$ and $3\frac{10}{71}$ that is, between 3.1429 and 3.1408, a closer approximation than the Egyptian.

We see, therefore, that in the few centuries during which the Greeks occupied themselves with the study of geometry the knowledge of the right line, circle and conic sections reached about as high a state of development as it was possible to attain until the invention of more powerful methods of research, and many centuries were destined to elapse before this was to occur. I do not overlook the fact that the beautiful and extensive modern geometry of the triangle and the systems of remarkable points and circles associated with it, which has been developed by Brocard, Lemoine, Emmerich, Vigarié and others, was within the reach of the Greeks; but this does not destroy the force of the remark above.

The operations of mathematics are divided fundamentally into two kinds, analytic, which employ the symbolism and methods of algebra (in its broadest sense), and geometric, which consists of the operation of pure reason upon geometric figure. The two are now only partially exclusive, however, for analysis is frequently assisted by geometry, and geometric results are frequently obtained by analytic methods.

With the Greeks, Hindoos and Arabs, the only peoples who concerned themselves to any extent with mathematics until comparatively modern times, the operations of algebra and geometry were entirely distinct. With the Hindoos and Arabs algebra received more attention than geometry and with the Greeks the reverse was true. Many of the theorems of Euclid are capable of an algebraic interpretation, and this fact was probably well known, but nevertheless the theorems themselves are expressed in geometric terms and are proved by purely geometric means; and they do not, therefore, constitute a union of analysis with geometry in the modern sense.

The seventeenth century brought the invention of analytic geometry by Descartes and that of the calculus by Newton and Leibnitz. These methods opened hitherto undreamed-of possibilities in geometric research and led to the systematic study of curves of all descriptions and to a generalization of view in connection with the geometry of the right line, circle and conics, as well as of the higher curves, which has been of the greatest value to the modern mathematician. To point out by a very simple illustration the nature of this work of generalization let us consider the case of a circle and straight line in the same plane, the line being supposed to be of indefinite extent. According to the relative position of this line and circle the Greek geometer would say that the line either meets the circle, or is tangent to the circle, or that the line does not meet the circle at all. We say now, however, that the line always meets the circle in two points, which may be real and distinct, real and coincident or imaginary. Thus a condition of things which the Greek was obliged to consider under three different cases we can deal with now as a single case. This generalized view is a direct consequence of the analytic treatment of the question.

It will be seen from the illustration used above that two very important conceptions are introduced into geometry by the use of the analytic method. One of these is the conception of coincident or consecutive points of intersection, as in the case of a tangent, and the other is that of imaginary elements, as in the case of the imaginary points of intersection of a line and circle which are co-planar and non-intersecting in the ordinary sense. It is impossible to exaggerate the importance of these conceptions. Without them the beautiful fabric of modern geometry would not stand a moment. It will be seen to many readers, no doubt, that a fabric built upon such a foundation will have very much the same stability as a 'castle in Spain.' Such, however, is far from the case. The analysis by which our operations proceed is a thoroughly well founded and trustworthy instrument, and when we give to it the geometric interpretation which we are entirely justified in doing, we find frequently that it reveals to us facts which our senses unaided by its finer powers of interpretation could not have discovered. These facts require for their adequate explanation the recognition of the so-called imaginary elements of the figure. Let us take one more illustration. If from a point outside of, but in the same plane with, a circle we draw two tangents to the circle and connect the points of tangency with a straight line, the original point and the line last mentioned stand in an important relation to each other and are called respectively pole and polar with regard to the circle. Now suppose the point is inside the circle. The whole construction just described becomes then geometrically impossible, but analytically we can draw from a point within a circle two imaginary tangents to the circle, and similarly we can connect the imaginary points of tangency by a straight line, and this straight line is found to be a real line. Moreover, in its relations to the point and circle it exhibits precisely the same properties which are found in the case of the pole and polar first described. Hence this point and line are also included in the general definition of pole and polar. Such examples might be multiplied indefinitely, but they would all go to emphasize the fact of the great power of generalization which resides in the methods of analytic geometry.

While the power of the analytic method as an instrument of research is far greater than that of the older pure geometric method, yet to many minds it lacks somewhat the beauty and elegance of that method as an intellectual exercise. This is due to the fact that its operations, like all algebraic operations, are largely mechanical. Given the equations representing a certain geometric condition, we subject these equations to definite transformations and the results obtained denote certain new geometric conditions. We have been whisked from the data to the result very much as we are hurried over the country in a railroad train. We may have noted the features of the country as we passed through it or we may not; we arrive at our destination just the same. Pure geometric research, on the other hand, resembles travel on foot or horseback. We must scrutinize the landmarks and keep a careful watch on the direction in which we are traveling, lest we take a wrong turn and fail to reach our destination. The result is that we acquire a thorough familiarity with the country through which we pass. The analytical method, however, affords abundant opportunity for mental activity, although of a different kind from that required in the other. First, the most advantageous analytic expression for the given geometric conditions must be sought; then the proper line of analytic transformation must be determined upon; and finally the result must be interpreted geometrically. This last step requires keen insight in order to ensure the full value of the result, for it is here that we often find far more than we anticipated, or than a casual glance will reveal.

The obligation thus incurred by geometry to analysis has been largely repaid by the aid which analysis has derived from geometry. The study of pure analysis is unquestionably the most abstruse branch of mathematics, but it is now advancing with rapid strides and demands less and less the aid of geometry. The results of the analytic method in geometry, however, are too fruitful for it to be either desirable or possible for us to go back to a condition of complete separation of these two methods.

Amongst the distinctly modern developments of geometry is what is known as hyper-geometry, the geometry of space of more than three dimensions. The fact that the product of two linear dimensions is representable by an area, and the product of three linear dimensions by a volume, naturally leads us to ask what is the geometric representative of the product of four or more linear dimensions. The answer to this question leads to the ideal conception of space of four or more dimensions. Just as in space of three dimensions, the space of our every-day experience, we can draw three concurrent straight lines such that each one is perpendicular to each of the other two, so in space of four dimensions it must be possible to draw four concurrent straight lines such that each one is perpendicular to each of the other three. It is needless to say it transcends the power of the human mind to form such a conception, nevertheless it is possible to study the geometry of such a space, and much has been done in this way both analytically and by the methods of pure geometry. If our space has a fourth dimension (not to speak of any higher dimension) as some mathematicians seem disposed seriously to maintain, a body moved from any position in the direction of the fourth dimension will disappear from view. In fact, it will be annihilated so far as we are concerned. Again, a body placed in an inclosed space can be removed therefrom while the walls of the envelope remain intact; or the envelope itself can be turned inside out without rupturing the walls. For example, it would be possible to extract the meat from an egg and leave the shell unbroken. For most persons, however, the geometry of four-dimensional space is likely to remain a mathematical curiosity, serving no useful purpose except to furnish an opportunity for acute logical reasoning, for in-studying the geometry of such space we have only our reasoning powers to guide us and cannot fall back upon experience, as we so often do more or less unconsciously, perhaps, in ordinary geometry.

Geometry of three-dimensional space is often studied by projecting the solid in question upon two or more planes and working with these plane projections instead of with the solid itself. This is done exclusively in descriptive geometry, the geometry of the engineer and builder with their plan and elevation, so called. The geometry of four-dimensional figures has been studied in an analogous way. A four-dimensional figure, it should be remarked, is a figure whose bounding parts are three dimensional figures, just as a three-dimensional figure is one whose bounding parts are surfaces or two-dimensional figures. A four-dimensional figure can be projected on a three-dimensional space and its properties studied from such projections made from different points of view, corresponding to the plan and elevation of ordinary geometry. The mathematical department of the University of Pennsylvania has in its possession wire models of solid projections of all the possible regular four-dimensional hyper-solids, the number of which is limited in the same way as is the number of regular three-dimensional solids. These models were constructed, after a careful study of the question, by Dr. Paul R. Heyl, a recent student and graduate of the University.

Amongst the subjects of most profound interest to mathematicians of recent years has been an investigation into the foundations of geometry and analysis. It was found, as the growth of the science proceeded, that much of fundamental importance, which hitherto had been accepted without question, would not bear searching scrutiny, and it began to be feared that the foundation might collapse in places altogether. We are concerned here with this only so far as it relates to geometry. Whatever may be said of geometry as a science which proceeds by pure reason from certain axioms, postulates and definitions, it is undoubtedly true that for at least the most fundamental conceptions we are thrown back upon experience; and that in the matter of axioms or postulates there is some latitude as to what we shall accept. Amongst the axioms or postulates given by Euclid is one known as the parallel-postulate, which states that if two coplanar straight lines are intersected by a third straight line (transversal) and if the interior angles on one side of the transversal are together less than two right angles, the two straight lines, if produced far enough, will meet on the same side of the transversal on which the sum of the interior angles is less than two right angles. This is, in fact, a theorem, and it is hardly possible to suppose that Euclid did not adopt it as a postulate only after finding that he could neither prove it nor do without it. It belongs to a set of theorems which are so connected that if the truth of any one of them be assumed the others are readily proved. The theorem that the sum of the three angles of a triangle is equal to two right angles belong to this set. Ptolemy (Claudius Ptolemæus, second century A. D.) seems to have been the first to publish an attempted proof of this postulate of Euclid. Almost all mathematicians down to the beginning of the nineteenth century have given more or less attention to this question, and the account of their efforts to prove the postulate forms one of the most interesting chapters in the history of mathematics. Cajori, in his 'History of Elementary Mathematics,' says, page 270: "They all fail, either because an equivalent assumption is implicitly or explicitly made, or because the reasoning is otherwise fallacious. On this slippery ground good and bad mathematicians alike have fallen. We are told that the great Lagrange, noticing that the formulas of spherical trigonometry are not dependent upon the parallel-postulate, hoped to frame a proof on this fact. Toward the close of his life he wrote a paper on parallel lines and began to read it before the Academy, but suddenly stopped and said: 'Il faut que j'y songe encore' (I must think it over again); he put the paper in his pocket and never afterwards publicly recurred to it."

About the time to which I have referred, the end of the eighteenth and beginning of the nineteenth century, the idea began to force itself upon mathematicians that perhaps there was more in the question than appeared on the surface. It was one of the many instances which have occurred in all branches of human knowledge where some truth of fundamental importance has begun to force itself simultaneously on a number of minds. We leave the significance of this aspect of the question to the psychologists. Another curious fact to be noted in connection with the writings which have finally shown us the true meaning of the parallel-postulate is that either they attracted little or no general attention when they first appeared, or else they remained unpublished. The names of Lobatchewsky and the Bolyais have been made immortal by their writings on this subject, but it was not until long after they were published that their vast importance was recognized. The inimitable Gauss wrote on the same subject, but left his work unpublished, and Cajori (ibid., p. 274) mentions two writers of much earlier date who anticipated in part the theories of Lobatchewsky and the Bolyais. These are Geronimo Saccheri (1667-1733), a Jesuit father of Milan, and Johann Heinrich Lambert (1728-1777), of Mühlhausen, Alsace.

Lobatchewsky (Nicholaus Ivanovitch Lobatchewsky, 1793-1856) conceived the brilliant idea of cutting loose from the parallel-postulate altogether and succeeded in building up a system of geometry without its aid. The result is startling to one who has been taught to look upon the facts of geometry (that is, of the Euclidean geometry) as incontrovertible. The denial of the parallel-postulate leaves Lobatchewsky to face the fact that under the conditions given in the postulate the two lines, if continually produced, may never meet on that side of the transversal on which the sum of the interior angles is less than two right angles. In other words, through a given point we may draw in a plane any number of distinct lines which will never meet a given line in the same plane. A result of this is that the sum of the angles of a triangle is variable (depending on the size of the triangle), but is always less than two right angles. Notwithstanding the shock to our preconceived notions which such a statement gives, the geometry of Lobatchewsky is thoroughly logical and consistent. What, then, does it mean? Simply this: We must seek the true explanation of the parallel-postulate in the characteristics of the space with which we are dealing. The Euclidean geometry remains just as true as it ever was, but it is seen to be limited to a particular kind of space, space of zero-curvature the mathematicians call it; that is, for two dimensions, space which conforms to our common notion of a plane. Lobatchewsky's geometry, on the other hand, is the geometry of a surface of uniform negative curvature, while ordinary spherical geometry is geometry of a surface of uniform positive curvature. The Lobatchewskian geometry is sometimes spoken of as geometry on the pseudo-sphere.

The 'absolute geometry' of the Bolyais (Wolfgang Bolyai de Bolya, 1775-1856, and his son, Johann Bolyai, 1802-1860) is similar to that of Lobatchewsky. 'The Science Absolute of Space,' by the younger Bolyai, published as an appendix to the first volume of his father's work, has immortalized his name.

The work of Lobatchewsky and the Bolyais has been rendered accessible to English readers by the translations and contributions of Prof. George Bruce Halsted, of the University of Texas.

If we proceed beyond the domain of two-dimensional geometry we merge the ideas of non-Euclidean and hyper-space. The ordinary triply-extended space of our experience is purely Euclidean; and if we approach the conception of curvature in such a space it must be curvature in a fourth dimension, and here the mind refuses to follow, although by pure reasoning we can show what must take place in such a space.

H. Grassman, Riemann and Beltrami have written profoundly on these questions, and it is to the last that is due the discovery that the theorems of the non-Euclidean or Lobatchewskian geometry find their realization in a space of constant negative curvature.

We naturally ask the question: Is there any reason to suppose that the space which we inhabit is other than Euclidean? To this a negative reply must be returned. We may have suspicions, but we have no evidence. If we could discover a triangle the sum of whose angles by actual measurement departs from two right angles, the fact of the non-Euclidean character of our space would be established at once. But no such triangle has been discovered. Even the largest, which are concerned in the measurement of stellar parallax, do not help us, and it does not seem possible to get larger ones. Nevertheless Clifford and others have shown that some physical phenomena, which require the conception of elaborate and complex machinery for their explanation, are capable of very simple explanation upon the hypothesis of a fourth dimension. Then, too, in the domain of pure mathematics several phenomena find a ready explanation upon the basis of such an assumption. In the theory of curves we constantly make use of the assumption that a curve may return into itself after passing through infinity, which is only another aspect of the same hypothesis. In fact, without this aid our processes of generalization, so important to the development of modern geometry, would be sadly hampered. Professor Newcomb has carried this matter to its logical conclusion and has deduced the actual dimensions of the visible universe in terms of the measurement of curvature in the fourth dimension. In such a space it becomes actually possible for a curve with infinite branches to pass through infinity (so-called) and return into itself. Upon this hypothesis our universe is unbounded in the sense that however far we travel we can never reach its limits, for it has none, but it is not infinite. Just as we can travel forever on the surface of the earth without reaching any limits, but that surface is not infinite. But even supposing that all this is true, the question still presses home: What is beyond?

AN ADDRESS GIVEN BEFORE THE DEPARTMENT OF ANTHROPOLOGY OF THE BRITISH ASSOCIATION, 1878.

By T. H. HUXLEY.

[Huxley's address at the Dublin meeting of the British Association gives an admirable account of the condition of anthropological science twenty-two years ago. It has not been republished in the 'Collected Essays,' but like everything that Huxley wrote it is worth reading at the present time.]

WHEN I undertook, with the greatest possible pleasure, to act as a lieutenant of my friend, the president of this section, I steadfastly purposed to confine myself to the modest and useful duties of that position. For reasons, with which it is not worth while to trouble you, I did not propose to follow the custom which has grown up in the Association of delivering an address upon the occasion of taking the chair of a section or department. In clear memory of the admirable addresses which you have had the privilege of hearing from Professor Flower, and just now from Dr. McDonnell, I can not doubt that that practice is a very good one; though I would venture to say, to use a term of philosophy, that it looks very much better from an objective than from a subjective point of view. But I found that my resolution, like a great many good resolutions that I have made in the course of my life, came to very little, and that it was thought desirable that I should address you in some way. But I must beg of you to understand that this is no formal address. I have simply announced it as a few introductory remarks, and I must ask you to forgive whatever of crudity and imperfection there may be in the mode of expression of what I have to say, although naturally I shall do my best to take care that there is neither crudity nor inaccuracy in the substance of it. It has occurred to me that I might address myself to a point in connection with the business of this department which forces itself more or less upon the attention of everybody, and which, unless the bellicose instincts of human nature are less marked on this side of St. George's Channel than on the other, may possibly have something to do with the large audiences we are always accustomed to see in the anthropological department. In the geological section I have no doubt it will be pointed out to you, or, at any rate, such knowledge may crop up incidentally, that there are on the earth's surface what are called *loci* of disturbance, where, for long ages, cataclysms and outbursts of lava and the like take place. Then everything subsides into quietude;

but a similar disturbance is set up elsewhere. In Antrim, at the middle of the tertiary epoch, there was a great center of physical disturbance. We all know that at the present time the earth's crust, at any rate, is quiet in Antrim, while the great centers of local disturbance are in Sicily, in Southern Italy, in the Andes and elsewhere. My experience of the British Association does not extend quite over a geological epoch, but it does go back rather longer than I care to think about; and when I first knew the British Association, the *locus* of disturbance in it was the geological section. All sorts of terrible things about the antiquity of the earth, and I know not what else, were being said there, which gave rise to terrible apprehensions. The whole world, it was thought, was coming to an end, just as I have no doubt that, if there were any human inhabitants of Antrim in the middle of the tertiary epoch, when those great lava streams burst out, they would not have had the smallest question that the whole universe was going to pieces. Well, the universe has not gone to pieces. Antrim is, geologically speaking, a very quiet place now, as well cultivated a place as one need see, and yielding abundance of excellent produce; and so, if we turn to the geological section, nothing can be milder than the proceedings of that admirable body. All the difficulties that they seemed to have encountered at first have died away, and statements that were the horrible paradoxes of that generation are now the commonplaces of school boys. At present the *locus* of disturbance is to be found in the biological section, and more particularly in the anthropological department of that section. History repeats itself, and precisely the same apprehensions which were expressed by the aborigines of the geological section, in long far back time, are at present expressed by those who attend our deliberations. The world is coming to an end, the basis of morality is being shaken, and I don't know what is not to happen if certain conclusions which appear probable are to be verified. Well, now, whoever may be here thirty years hence—I certainly shall not be—but, depend upon it, whoever may be speaking at the meeting of this department of the British Association thirty years hence will find, exactly as the members of the geological section have found, on looking back thirty years, that the very paradoxes and horrible conclusions, things that are now thought to be going to shake the foundations of the world, will by that time have become parts of every-day knowledge and will be taught in our schools as accepted truth, and nobody will be one whit the worse.

The considerations which I think it desirable to put before you, in order to show the foundations of this conviction at which I have very confidently arrived, are of two kinds. The first is a reason based entirely upon philosophical considerations, namely, this—that the region of pure physical science, and the region of those questions which specially interest ordinary humanity, are apart, and that the conclusions reached in the one have no direct effect in the other. If you acquaint yourself with the history of philosophy, and with the endless variations of human opinion therein recorded, you will find that there is not a single one of those speculative difficulties which at the present time torment many minds as being the direct product of scientific thought, which is not as old as the times of Greek philosophy, and which did not then exist as strongly and as clearly as such difficulties exist now, though they arose out of arguments based upon merely philosophical ideas. Whoever admits these two things—as everybody who looks about him must do—whoever takes into account the existence of evil in this world and the law of causation—has before him all the difficulties that can be raised by any form of scientific speculation. And these two difficulties have been occupying the minds of men ever since man began to think. The other consideration I have to put before you is that, whatever may be the results at which physical science, as applied to man shall arrive, those results are inevitable—I mean that they arise out of the necessary progress of scientific thought as applied to man. You all, I hope, had the opportunity of hearing the excellent address which was given by our president yesterday, in which he traced out the marvellous progress of our knowledge of the higher animals which has been effected since the time of Linnæus. It is no exaggeration to say that at this present time the merest tyro knows a thousand times as much on the subject as is contained in the work of Linnæus, which was then the standard authority. Now how has that been brought about? If you consider what zoology, or the study of animals, signifies, you will see that it means an endeavor to ascertain all that can be studied, all the answers that can be given respecting any animal under four possible points of view. The first of these embraces considerations of structure. An animal has a certain structure and a certain mode of development, which means that it passes through a series of stages to that structure. In the second place, every animal exhibits a great number of active powers, the knowledge of which constitutes its physiology; and under those active powers we have, as physiologists, not only to include such matters as have been referred to by Dr. McDonnell in his observations, but to take into account other kinds of activity. I see it announced that the zöological section of to-day is to have a highly interesting paper by Sir John Lubbock on the habits of ants. Ants have a policy, and exhibit a certain amount of intelligence, and all these matters are proper subjects for the study of the zoologist as far as he deals with the ant. There is yet a third point of view in which you may regard every animal. It has a distribution. Not only is it to be found somewhere on the earth's surface, but paleontology tells us, if we go back in time, that the great majority of animals have had a past history—that they occurred in epochs of the world's history far removed from the present. And when we have acquired all that knowledge which we may enumerate under the heads of anatomy, physiology and distribution, there remains still the problem of problems to the zoologist, which is the study of the causes of those phenomena, in order that we may know how they came about. All these different forms of knowledge and inquiry are legitimate subjects for science, there being no subject which is an illegitimate subject for scientific inquiry, except such as involves a contradiction in terms, or is itself absurd. Indeed, I don't know that I ought to go quite so far as this at present, for undoubtedly there are many benighted persons who have been in the habit of calling by no less hard names conceptions which the president of this meeting tells us must be regarded with much respect. If we have four dimensions of space we may have forty dimensions, and that would be a long way beyond that which is conceivable by ordinary powers of imagination. I should, therefore, not like to draw too closely the limits as to what may be contradiction to the best-established principles. Now, let us turn to a proposition which no one can possibly deny—namely, that there is a distinct sense in which man is an animal. There is not the smallest doubt of that proposition. If anybody entertains a misgiving on that point he has simply to walk through the museum close by, in order to see that man has a structure and a framework which may be compared, point for point and bone for bone, with those of the lower animals. There is not the smallest doubt, moreover, that, as to the manner of his becoming, man is developed, step by step, in exactly the same way as they are. There is not the smallest doubt that his activities—not only his mere bodily functions, but his other functions—are just as much the subjects of scientific study as are those of ants and bees. What we call the phenomena of intelligence, for example (as to what else there may be in them, the anthropologist makes no assertion)—are phenomena following a definite causal order just as capable of scientific examination, and of being reduced to definite law, as are all those phenomena which we call physical. Just as ants form a polity and a social state, and just as these are the proper and legitimate study of the zoologist, so far as he deals with ants, so do men organize themselves into a social state. And though the province of politics is of course outside that of anthropology, yet the consideration of a man, so far as his instincts lead him to construct a social economy, is a legitimate and proper part of anthropology, precisely in the same way as the study of the social state of ants is a legitimate object of zoology. So with regard to other and more subtle phenomena. It has often been disputed whether in animals there is any trace of the religious sentiment. That is a legitimate subject of dispute and of inquiry; and if it were possible for my friend, Sir John Lubbock, to point out to you that ants manifest such sentiments, he would have made a very great and interesting discovery, and no one could doubt that the ascertainment of such a fact was completely within the province of zoology. Anthropology has nothing to do with the truth or falsehood of religion—it holds itself absolutely and entirely aloof from such questions—but the natural history of religion, and the origin and the growth of the religions entertained by the different kinds of the human race, are within its proper and legitimate province. I now go a step farther, and pass to the distribution of man. Here, of course, the anthropologist is in his special region. He endeavors to ascertain how various modifications of the human stock are arranged upon the earth's surface. He looks back to the past, and inquires how far the remains of man can be traced. It is just as legitimate to ascertain how far the human race goes back in time as it is to ascertain how far the horse goes back in time; the kind of evidence that is good in the one case is good in the other; and the conclusions that are forced on us in the one case are forced on us in the other also. Finally, we come to the question of the causes of all these phenomena, which, if permissible in the case of other animals, is permissible in the animal man. Whatever evidence, whatever chain of reasoning justifies us in concluding that the horse, for example, has come into existence in a certain fashion in time, the same evidence and the same canons of logic justify us to precisely the same extent in drawing the same kind of conclusions with regard to man. And it is the business of the anthropologist to be as severe in his criticism of those matters in respect to the origin of man as it is the business of the paleontologist to be strict in regard to the origin of the horse; but for the scientific man there is neither more nor less reason for dealing critically with the one case than with the other. Whatever evidence is satisfactory in one case is satisfactory in the other; and if any one should travel outside the lines of scientific evidence and endeavor either to support or oppose conclusions which are based upon distinctly scientific grounds, by considerations which are not in any way based upon scientific logic or scientific truth—whether that mode of advocacy was in favor of a given position, or whether it was against it, I, occupying the chair of the section, should, most undoubtedly, feel myself called upon to call him to order, and tell him that he was introducing topics with which we had no concern whatever.

I have occupied your attention for a considerable time, yet there is still one other point respecting which I should like to say a few words, because some very striking reflections arise out of it. The British Association met in Dublin twenty-one years ago, and I have taken the pains to look up what was done in regard to our subject at that period.

At that time there was no anthropological department. That study had not yet differentiated itself from zoology, or anatomy, or physiology so as to claim for itself a distinct place. Moreover, without reverting needlessly to the remarks which I placed before you some time ago, it was a very volcanic subject, and people rather liked to leave it alone. It was not until a long time subsequently that the present organization of this section of the Association was brought about; but it is a curious fact that although truly anthropological subjects were at the time brought before the geographical section—with the proper subject of which they had nothing whatever to do—I find, that even then, more than half of the papers that were brought before that section were, more or less distinctly, of an anthropological cast. It is very curious to observe what that cast was. We had systems of language—we had descriptions of savage races—we had the great question, as it then was thought, of the unity or multiplicity of the human species. These were just touched upon, but there was not an allusion in the whole of the proceedings of the Association, at that time, to those questions which are now to be regarded as the burning questions of anthropology. The whole tendency in the present direction was given by the publication of a single book, and that not a very large one—namely, 'The Origin of Species.' It was only subsequent to the publication of the ideas contained in that book that one of the most powerful instruments for the advance of anthropological knowledge—namely, the Anthropological Society of Paris—was founded. Afterwards the Anthropological Institute of this country and the great Anthropological Society of Berlin came into existence, until it may be said that, at the present time, there is not a branch of science which is represented by a larger or more active body of workers than the science of anthropology. But the whole of these workers are engaged, more or less intentionally, in providing the data for attacking the ultimate great problem, whether the ideas which Darwin has put forward in regard to the animal world are capable of being applied in the same sense and to the same extent to man.

That question, I need not say, is not answered. It is a vast and difficult question, and one for which a complete answer may possibly be looked for in the next century; but the method of inquiry is understood, and the mode in which the materials bearing on that inquiry are now being accumulated, the processes by which results are now obtained, and the observation of new phenomena lead to the belief that the problem also, some day or other, will be solved. In what sense I can not tell you. I have my own notion about it, but the question for the future is the attainment, by scientific processes and methods, of the solution of that question. If you ask me what has been done within the last twenty-one years towards this object, or rather towards clearing the ground in the direction of obtaining a solution, I don't know that I could lay my hand upon much of a very definite character—except as to methods of investigation—save in regard to one point. I have some reason to know that about the year 1860, at any rate, there was nothing more volcanic, more shocking, more subversive of everything right and proper, than to put forward the proposition that as far as physical organization is concerned there is less difference between man and the highest apes than there is between the highest apes and the lowest. My memory carries me back sufficiently to remind me that in 1860 that question was not a pleasant one to handle. The other day I was reading a recently published valuable and interesting work, 'L'espèce humaine,' by a very eminent man, M. de Quatrefages. He is a gentleman who has made these questions his special study, and has written a great deal and very well about them. He has always maintained a temperate and fair position, and has been the opponent of evolutionary ideas, so that I turned with some interest to his work as giving me a record of what I could look on as the progress of opinion during the last twenty years. If he has any bias at all, it is one in the opposite direction to that in which my own studies would lead me. I can not quote his words, for I have not the book with me, but the substance of them is that the proposition which I have just put before you is one the truth of which no rational person acquainted with the facts could dispute. Such is the difference which twenty years has made in that respect, and speaking in the presence of a great number of anatomists, who are quite able to decide a question of this kind, I believe that the opinion of M. de Quatrefages on the subject is one they will all be prepared to endorse. Well, it is a comfort to have got that much out of the way. The second direction in which I think great progress has been made is with respect to the processes of anthropometry, in other words, in the modes of obtaining those data which are necessary for anthropologists to reason upon. Like all other persons who have to deal with physical science, we confine ourselves to matters which can be ascertained with precision, and nothing is more remarkable than the exactness which has been introduced into the mode of ascertaining the physical qualities of man within the last twenty-five years. One can not mention the name of Broca without the greatest gratitude; I am quite sure that, when Professor Flower brings forward his paper on cranial measurements on Monday next, you will be surprised to see what precision of method and what accuracy are now introduced, compared with what existed twenty-five years ago, into these methods of determining the facts of man's structure. If, further, we turn to those physiological matters bearing on anthropology which have been the subject of inquiry within the last score of years, we find that there has been a vast amount of progress. I would refer you to the very remarkable collection of the data of sociology by Mr. Herbert Spencer, which contains a mass of information useful on one side or the other, in getting towards the truth. Then I would refer you to the highly interesting contributions which have been made by Prof. Max Müller and by Mr. Tylor to the natural history of religions, which is one of the most interesting chapters of anthropology. In regard to another very important topic, the development of art and the use of tools and weapons, most remarkable contributions have been made by General Lane Fox, whose museum at Bethnal Green is one of the most extraordinary exemplifications that I know of the ingenuity, and, at the same time, of the stupidity of the human race. Their ingenuity appears in their invention of a given pattern or form of weapon, and their profound stupidity in this, that having done so, they kept in the old grooves, and were thus prevented from getting beyond the primitive type of these objects and of their ornamentation. One of the most singular things in that museum is the exemplification of the wonderful tendency of the human mind when once it has got into a groove to stick there. The great object of scientific investigation is to run counter to that tendency.

Great progress has been made in the last twenty years in the direction of the discovery of the indications of man in a fossil state. My memory goes back to the time when anybody who broached the notion of the existence of fossil man would have been simply laughed at. It was held to be a canon of paleontology that man could not exist in a fossil state. I don't know why, but it was so; and that fixed idea acted so strongly on men's minds that they shut their eyes to the plainest possible evidence. Within the last twenty years we have an astonishing accumulation of evidence of the existence of man in ages antecedent to those of which we have any historical record. What the actual date of those times was, and what their relation is to our known historical epochs, I don't think anybody is in a position to say. But it is beyond all question that man, and not only man, but what is more to the purpose intelligent man, existed at times when the whole physical conformation of the country was totally different from that which characterizes it now. Whether the evidence we now possess justifies us in going back further or not, that we can get back as far as the epoch of the drift is, I think, beyond any rational doubt, and may be regarded as something settled. But when it comes to a question as to the evidence of tracing back man further than that—and recollect the drift is only the scum of the earth's surface—I must confess that to my mind, the evidence is of a very dubious character.

Finally, we come to the very interesting question—as to whether, with such evidence of the existence of man in those times as we have before us, it is possible to trace in that brief history any evidence of the gradual modification from a human type somewhat different from that which now exists to that which is met with at present. I must confess that my opinion remains exactly what it was some eighteen years ago, when I published a little book which I was very sorry to hear my friend, Professor Flower, allude to yesterday, because I had hoped that it would have been forgotten amongst the greater scandals of subsequent times. I did there put forward the opinion that what is known as the Neanderthal skull is of human remains, that which presents the most marked and definite characteristics of a lower type—using the language in the same sense as we would use it in other branches of zoology. I believe it to belong to the lowest form of human being of which we have any knowledge, and we know from the remains accompanying that human being, that as far as all fundamental points of structure were concerned, he was as much a man—could wear boots just as easily—as any of us, so that I think the question remains pretty much where it was. I don't know that there is any reason for doubting that the men who existed at that day were in all essential respects similar to the men who exist now. But I must point out to you that this conviction is by no means inconsistent with the doctrine of evolution. The horse, which existed at that time, was in all essential respects identical with the horse which exists now. But we happen to know that going back further in time the horse presents us with a series of modifications by which it can be traced back from an earlier type. Therefore, it must be deemed possible that man is in the same position, although the facts we have before us with respect to him tell in neither one way nor the other. I have now nothing more to do than to thank you for the great kindness and attention with which you have listened to these informal remarks.

THE STORY OF AUTONOUS.

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IF any one in these days condescends to read that first favorite with the youth of bygone generations, 'Robinson Crusoe,' he will be aware that, disregarding its more subtle meanings and the allegorical intention upon which the author himself laid so much stress, we may consider the narrative as a detailed study of self-help. In our actual world, we depend to an extent which we seldom appreciate upon social environment, organization, the labors of others and the accumulated culture-capital of the past. Well, DeFoe takes a man of an eminently sturdy, courageous and practical type, casts him upon a desert island and there leaves him to shift for himself. Supplies which he manages to rescue from the ship give him a fund of materials to start with; but henceforth he has nothing to rely upon save his own head and hands. To follow this plain and simple hero in his successful struggle against seemingly overwhelming odds does not fall within our present plan. But the issue shows how, by his own unaided exertions, an individual may reconstruct for himself a great many of those conditions of comfortable living which we are apt to assume to be impossible without the cooperation of others; and thus the mastery of man over his fate is vindicated—though it would certainly go hard with most of us if we were thrown into Robinson Crusoe's position.

Rousseau, who was the first to point out the educational significance of DeFoe's book, desired that Emile, in studying it, should examine the mariner's behavior, "to try to find out whether he omitted anything, and whether anything could have been better done." Questions of this kind may often have been in the reader's mind and are useful in bringing out the admirable art exhibited in every episode and detail. But there is another question which will, perhaps, occur to some, and which at once carries us beyond DeFoe's own narrative into a very wide field of speculation. Robinson Crusoe was already a mature man when he was cast away; he was in full possession of the stored-up resources of civilization; his mental powers were well developed; he brought a man's strength and training to bear upon the problems of his life. The theme of his story is, therefore, on the philosophic side, after all, a relatively simple and narrow one. But now let us suppose for a moment that he had been cut adrift from all his social moorings before education began—before, even, consciousness had awakened to a sense of outward things. What would have happened to him then? Would he necessarily have perished? Or, if he survived, would he have grown into anything better than a brute? What would the course of his life have been? And can we conceive that, lacking all influence from without, all family and social intercourse, all idea of human traditions as embodied in manners, customs, institutions, books, he would ever, mentally and morally, have reached the full stature of a man?

I am not going to attempt to discuss these questions from the standpoint of modern science, or in connection with the recent controversies of the evolutionists. My purpose is simply to give some account of an extremely crude, but none the less quaint and interesting old book, in which, under the thin guise of a story, an effort is made to answer them. The little volume is exceedingly rare and is probably unknown, even by name, to most readers of these pages. An outline of its contents may, therefore, prove entertaining, if not exactly instructive.

I must first dismiss some details of a bibliographical character. Referring, in his Memoirs, to his one-time tutor, John Kirkby, the historian Gibbon speaks slightingly enough of a work of his which, aspiring 'to the honors of a philosophical romance,' had brought him a certain measure of fame. Gibbon cites it by a brief title only—'The History of Automathes'; but its full title, after the fashion of the time, set forth a regular programme, or summary, of the volume—"The Capacity and Extent of the Human Understanding, exemplified in the extraordinary case of Automathes, a young nobleman, who was accidentally left in his infancy upon a desert island and continued nineteen years in that solitary state, separate from all human society." The book, which bears date 1745, was thought by Gibbon to be a kind of compound of 'Robinson Crusoe' and an Arabian story, 'The History of Hai Ebn Yockdan.' On closer examination, however, it turns out to be a barefaced plagiarism from a much smaller work, issued anonymously nine years before—"The History of Autonous: Containing a Relation how that young Nobleman was accidentally left alone in his Infancy, upon a desolate Island, where he lived nineteen years, remote from all human Society, till taken up by his Father; with an Account of his Life, Reflections and Improvements in Knowledge during his Continuance in that Solitary State. The whole as taken from his own mouth." It is almost incredible that, even in an age when literary frauds were more frequent and less easily detected than at present, Kirkby should have dared to publish his own book as original; but he never appears to have been taken to task for his conduct, nor, indeed, do readers and critics of 'Automathes' seem to have known or cared anything about 'Autonous.' But, from a pretty minute comparison of the two works, in the library of the British

Museum, I am able to state that where Kirkby's dependence upon an earlier writer is referred to at all—as in the article in the 'Dictionary of National Biography'—the case for plagiarism is not put half strongly enough. Kirkby did not merely borrow hints, ideas, episodes; he stole the entire book, adding, expanding and slightly rearranging in places, but adhering to the plan of his predecessor and sometimes retaining his actual phraseology for paragraphs and pages together. To illustrate these statements would necessitate the reproduction of a number of lengthy passages, and space cannot here be spared for such an undertaking. I have said this much to make clear to any reader of Gibbon's Memoirs, or Scott's fragment of autobiography, why I now disregard Kirkby's work and confine myself to what was evidently its immediate source and model.*

The writer of the 'History of Autonous,' then, opens his narrative by telling us how he became acquainted with that young nobleman, at the University of Eumathema, in the Kingdom of Epinoia. He is invited to take a short pleasure trip with him in his barge up the river. It is on this occasion that Antonous entertains his guest with the story of his life.

His father, Eugenius, chief of one of the most ancient houses in the kingdom, had married Paramythia, a young lady of 'quality nothing inferior to himself.' About the time of Autonous's birth, a rebellion broke out in Epinoia. It was promptly quashed; but, through 'the underhand Dealing of some ill-designing Persons,' enemies of Eugenius, he was arrested, tried and found guilty of treason. He was, therefore, condemned to banishment and the forfeiture of his estates.

With his wife, child and a couple of servants, the unfortunate nobleman sets sail for a distant land; the ship goes to pieces in a storm, and all on board perish, except Eugenius, Paramythia and the baby, who are cast upon an uninhabited island. The father manages, like Robinson Crusoe, to save some necessaries and a number of miscellaneous articles from the wreck, and, with these, a little dog, which afterwards plays an important part in the story.

On examination of the island, it is found that, most fortunately, there are no 'noxious animals' or venomous creatures there, 'but multitudes of goats, deer and fowls of every kind,' furnishing abundance of provision. Eugenius hunts with bow and arrow and presently builds a cottage, in a grove of trees and within view of the sea, in the hope, like Enoch Arden, of sooner or later sighting a chance sail. But the

* 'Autonous' occupies 117 pages; 'Automathes,' 284. The difference is due partly to Kirkby' tendency to amplification, and partly to a long critical introduction containing a good deal of political disquisition, not at all to the point, and incorporating the machinery of a manuscript discovered in a cylinder, which adds neither to the clearness nor to the interest of the subsequent narrative. (Of course, as we do not know who wrote 'Autonous' there is the chance that this was a first draft of the later and longer book, by Kirkby himself. But this does not seem likely.)

island lies out of the ordinary course of vessels; wherefore, but for a merciful Providence, the little party would have perished one by one—a catastrophe which, says Autonous with refreshing simplicity, 'wou'd have depriv'd me of the Opportunity of thus telling my Story.'

Herbs, roots and 'limpid water,' with the produce of the chase, therefore constitute their fare; and their greatest pleasure, animal wants being satisfied, is found in 'the usual Resort of Persons in affliction'—namely, 'Devotions and Spiritual Exercises.' Incidentally, we are here treated, in the characteristic style of the eighteenth century, to a brief disquisition on 'Nature' and 'Luxury'; but this may be skipped as having nothing directly to do with our narrative. By-and-by, poor Paramythia, unable to endure the hardships of the new life, falls sick and dies. For a time Eugenius is heart-broken. Then he returns to the care of the helpless baby, and, to obtain milk for him, domesticates a hind. By mere power of imitation, Autonous learns from the fawn to take nourishment directly from the animal, while by watching his constant companion, the dog, he soon begins to dig up edible roots.

Things in this way are prepared for the real commencement of Autonous's story. The death of his wife preys upon the mind of Eugenius; he grows restless and spends his time in vain attempts to devise some means of escape. One unusually clear day, he fancies that he can detect a faint streak of land upon the far horizon. Upon this, he patches up the ship's boat, which had been cast ashore, to start out by himself upon a voyage of discovery. Once more Fate shows herself against him. The boat, drawn into a swift current, is carried to another island and afterwards washed away. Eugenius saves himself, but father and son are now separated.

Autonous is not quite two years old when this happens. For nineteen years he lives entirely alone; at the expiration of which time both he and Eugenius are picked up by a stray ship of war and carried back to Epinoia. The latter's innocence is forthwith made clear to the world, and all ends happily. But, it may well be asked, in what condition is Autonous himself, after this long period of isolation? The good people of Epinoia are surprised, as we in our time are surprised, to find him acting more like 'a Philosopher than a Savage.' How had such an amazing result been brought about?

Looking back into the obscurity of his strange past, Autonous declares his first consciousness to have consisted in the simple sense of being in the cottage his father had built. He had, of course, no recollection of anything before his arrival on the island, or of his father and mother; but he remembered, vaguely, taking 'little journeys' from the cottage, the guidance or barking of the dog keeping him from going altogether astray. But he retained no image of the hind by which he had been suckled, for that portion of his experience belonged to the life of instinct and sensation merely. When he awoke to a realization of himself and the outer world, he found himself living, as a matter of simple habit, on roots and fruit, to which he had gone, apparently, in imitation of the animals and birds. "During this Part of my Life," he says, "my Rational Faculty laid [*sic*], as it were, dormant within me. I never made the least Reflection upon my Condition, nor turned my Thoughts to the Contemplation of anything about me." Such, Autonous conceives to be "the thoughtless State of all Persons for the greatest Part of the Childhood, while the Mind is furnishing itself with Instruments to work with."

With Autonous, however, this condition naturally lasts longer than with ordinary children, who from the beginning are associated with older people and have the advantage of the education directly and indirectly given by such intercourse. But it happens that, while all children are more or less inquisitive, Autonous is particularly so; and endowed, moreover, with unusual power of response to the stimuli of surroundings, he soon begins to gather in, from all sides, the rough materials of thought.

Happy accident first stirs him to 'serious Reflection.' One exceedingly hot day he strays 'something further than ordinary' from his cottage; and going to a small lake to quench his thirst, he is surprised 'with the appearance of a creature in the Lake' of a shape very different from anything he 'ever had seen,' which, as he stoops to the water, seems to leap upward to him, as if with a design to seize him. He flies in terror to a neighboring wood; but after a time, his thirst returning, he takes courage again, goes back to the lake and repeats the experiment; but only with the same dreadful result. This, Autonous explains, was the first time he had ever seen his reflection in smooth, still water, having previously drunk from fountains, or from shallow and rapid streams. He is so terribly frightened that for some weeks he hardly dares to leave the cottage, while his sleep is broken by 'fearful Starts and Dreams.' Little by little, the horror wears off, but other effects do not. He has been aroused to a 'sense of myself,' and begins to ask—a trifle prematurely, we fancy—'What am I? How came I Here?' These questions are rather too definitely put, but the incident and its consequences certainly foreshadow in an interesting way some of the speculations of recent anthropologists on the part played by shadows and reflections in the growth of the idea of the other self, or soul. Autonous's thoughts, however, take a somewhat different turn. He later discovers a 'crystal Brook,' in which, to his astonishment, he observes another sky, another dog, another world. By examination, he finds that there is, none the less, a real bottom to this brook; and thus he learns the secret of 'natural Reflection.' Remembering his former fright, he also studies himself very carefully in the water, and concludes that he had been alarmed by his 'own Image and Resemblance.' From this, he makes a sudden leap into theories concerning himself and the manner in which he and the dog had got to be where they are; and recalling what he had already noted of the 'usual method by which all other living creatures propagated their likes,' he sapiently infers that their own coming into the world must have been after the same fashion. All this must have happened, he believed, when he was about ten years of age.

The notion that he must have had a beginning somewhere, and that, though he was now living entirely alone, he was really in some inscrutable way linked to his kind, is now confirmed by an examination of his cottage, which up to the present he has accepted uninquiringly and as a mere matter of course. Comparing it with the dwellings of the beavers on the lake-shore, he guessed that it must have been built by predecessors of his own and arranged for their comfort and protection. The remains of one of the ship's boats, decaying on the strand, are, moreover, caught up in his speculation, suggesting transportation, and hinting, if at first rather vaguely, at a great human world out of which he has been cast. "But what," exclaims Autonous, "is the Beginning of Reason but the Beginning of Sorrow to creatures whose Reason can only serve to discover their Wants and Imperfections to them?" His tranquillity—the tranquillity of mere animal existence—is at an end. His mind broods continually over the 'Thoughts of Human Society,' without which he feels there can be no happiness for him, or even peace. He watches the birds and beasts, and envies their social lot. Had the boat been in sufficient repair, he feels that he might even have started off in the wild hope of finding somebody somewhere. "So strong an Inclination has Nature implanted in us for the Conversation of our Fellow-Creatures, in order to communicate our joys and griefs and sympathize under one another's sufferings."

Despite this heart-hunger, Autonous now enters on the high-road of intellectual progress. He begins to observe with close attention the growth of trees, grass and flowers, and the dependence of all animal life upon the fertility of the soil. Thus far we can without much difficulty keep up with him. But from this point he goes forward with such leaps and bounds that we are left almost breathless in our efforts to follow. For now he notes how the 'successive Renewals of Nature' exactly correspond with 'the Motions of the Sun,' and the agreement between the phases of the moon and the tides. The revolutions of 'the lesser heavenly luminaries' also become the subject of his 'nocturnal Contemplations'; moreover, he studies the rainbow, and discovers the 'necessity of Rain and the solar Heat' to 'ripen the Fruits of the Earth.'

Nor are these the only, or the most astonishing, results of his solitary cogitations. He considers 'the admirable Structure of the Bodies of every Species of Animal' within his reach; is struck by the detailed adaptations of their faculties to the various conditions of their lives; and soon learns to appreciate their 'Art and Foresight' in the preservation of self and young. "In fine," he declares—and by this time we are, of course, fully aware of the drift of his thought, "I beheld the marks of Wisdom wherever I cast my Eyes. An universal Harmony and Dependence appeared through all the Parts of Creation, and the most neglected Things, when duly examined, were not without their manifest use; and I was everywhere surprised with an apparently wise Design, where the least Design was expected."

Had our young Natural Philosopher, we ask, been reading the 'Essay on Man' on the sly? His 'universal Harmony and Dependence' is only the 'great chain of being' over again, and when he further informs us that 'from the works of Nature and Providence' he was inevitably 'led to the knowledge of the First Mover,' he is simply explaining how he looked 'through Nature up to Nature's God.' In fact, the religious development of Autonous, solitary and untaught, furnishes us with an interesting illustration of the early eighteenth-century argument from design. The familiar discussion follows of 'beauty' and 'fitness' as evidences of 'some intelligent Agent,' who is easily shown to be at once all-wise, all-powerful and all-good. All this, indeed, belongs to the 'mere Light of Nature.' But we have only to remember the common eighteenth-century view of the relation of natural and revealed religion to appreciate the importance of the step which the lonely youth had now taken.

We may observe, in passing, that the conditions of life on the island are highly favorable to an optimistic philosophy. Dwelling in a veritable little Garden of Eden, where general peace prevails and the red tooth and claw of nature are seldom shown, Autonous has no difficulty in believing in a Providence both omnipotent and benign. This is surely the best of all possible worlds, he might have said, with Leibnitz and Dr. Pangloss; and there is no rude fact to meet him at the first turning of the eye and shake his whole scheme to its foundations. But what if Autonous had been thrown among birds and beasts of prey? Our author has simplified his task by not raising that question.

Meanwhile the youth is gaining ground in other directions. From what, in the true style of his time, he calls 'the harmonious Chanting of the feathered Tribes,' he infers that speech is the 'method used among men to communicate their minds in conversing one with another'; and from the *ignis fatuus* and the glow-worm he learns something, though not as yet much, of fire and light. He also gets a little practical experience well worth recording. A couple of bottles, saved by his father from the wreck, have been standing all these years untouched on a shelf in the cottage. By accident one is broken and Autonous tastes the contents, which prove to be 'a most delicious and heady sort of Wine.' He is delighted, straightway opens the other bottle, and, sad to relate, gets drunk. Having quite by himself discovered the nature of God, he now, quite by himself, discovers the nature of intoxication. It is by this time apparent, I think, that Autonous is an unusually wise young fellow. Finding how ill the potations make him, he very properly throws 'the remainder of this beautiful Liquor, Bottle and all, into the Sea.'

During the feverish affection brought on by his bout, he walks a good deal at night, and is lucky enough (for thus, in the order of Providence, does good grow out of evil) to see the moon in eclipse. This phenomenon fills him with 'exceeding Amazement,' and for a time he does not know 'what to make of it.' But he is not the youth to be long puzzled over a little thing like an eclipse. Presently an eclipse of the sun occurs—seemingly for his personal benefit. Upon this, he sets to work in earnest, and soon clears up all the difficulty. Considering how long it took for the race at large to learn the real nature of an eclipse, we may regard this as one of our philosopher's most remarkable performances.

His continued study of animals—'some of which,' as he sagely remarks, 'afforded an excellent Pattern of Prudence and Industry, for the Imitation of Men'—leads to no less important results. Observing the beavers, in particular, he remarks 'with what true Policy every distinct Community' is 'governed under its peculiar Monarch'—the only wonder being that he did not infer from his investigations the principles of the Hanoverian Succession. Their methods of building houses and dams, of laying up supplies for the winter and of gnawing down trees with their teeth, specially delight him; and from their example, and that of the dog, he learns to swim; thus becoming acquainted with 'fresh matter for wonder' in the shape of fish. He now devotes a good deal of time to the contents of the cottage, and takes note of 'two or three knives and forks,' and a hatchet, the sharpness of which suggests a use similar to that which the beavers made of their teeth in cutting trees. Hammer and a bag of nails, a rusty sword, a bow, a silver tankard and some other utensils are also discovered by him, but these he confesses that he was never 'so ingenious' as to turn to account. But he learns the color and malleability of several metals, and as, by hacking at various articles with the chopper, he deprives them 'of the forms in which he found them,' so he concludes, by one of his rapid processes of reasoning, that 'they must by some like Operation'—by some human power and effort, he presumably means—'have been first wrought into the same.'

In this part of his story, Autonous of course depends a good deal on the then familiar theory that all art arose from observation and imitation of nature—a theory which often appears in the literature of the time and which will be at once recognized by readers of Dryden and Pope.*

A large chest and a couple of boxes, hitherto neglected, are now ransacked by our inquiring young friend. Much of their contents merely puzzles him; but he is highly pleased to discover books, white paper, some lead-pencils, pens, an inkstand, a magnifying glass, a case of mathematical instruments, a fan, a small looking-glass, a gold watch and a snuff-box. These form his playthings for some time and, little by little, he gets to understand the properties of glass and of the magnifier, the peculiar properties of which he finds to be due 'to convexity.' But, above all, he is enraptured by the fan, on which is painted a landscape, with several figures in his 'own shape.' Two in particular rivet his attention—'a comely Pair,' who seem 'wholly taken up with the Contemplation of each other.' They are 'seated under the Umbrage of a spreading Beech,' and he notes that 'their whole Bodies, save their Faces and Hands,' are 'hid from Sight under much the same sort of Coverings' as he had found 'in the Chest and Boxes.' One of these figures he concludes to be the male, the other the female; and upon the latter he gazes 'with more than common delight,' very gallantly, as well as very properly, concluding 'that the sex to which she belongs must be a masterpiece of nature's workmanship.' But the growth of tender sentiment does not here interfere (as it is occasionally known to do) with severer studies. Autonous—though he confesses that this may be judged 'quite above my capacity'—becomes 'in some Degree' acquainted with the pencils and paper, the books and instruments; and by dint of pothering over a volume of mathematics he gleans 'the Principles of that Science,' becoming quite familiar with the use and form of figures. All this happens about his fifteenth or sixteenth year, about which time he begins to make various improvements in and about the cottage, laying out the garden in imitation of the landscape on the fan, repairing the fences, clearing bushes and shrubs, and generally substituting order for confusion.

All this while Autonous is busy with the 'Contemplation of himself' and ripens apace into a metaphysician. He soon distinguishes between mind and matter, the former of which he recognizes as the 'only and proper self,' and by watching closely the procedure of the mind, actually reaches some notion of the doctrine of the association of ideas. Sleep, with its phenomenon of unconsciousness and dreams, also engages his attention, and while he is occupied with these mysterious matters, it happens that his dog is killed by a beaver. This was Autonous's first

* See 'Annus Mirabilis,' Sec. 155; 'Essay on Man,' Epistle III.

introduction to death. Reasoning over this occurrence, he advances step by step to the thought of dissolution and the immortality of the soul. We may suppose that he is really grieved over the loss of his faithful companion, but of this he says very little. And we have heard of other philosophers who, preoccupied with such questions as God, freedom and immortality, have had small energy to spare for ordinary mundane affairs.

Having followed Autonous in some detail up to this point, we shall probably express no great surprise when we learn of his further achievements, practical and intellectual. Passing over such feats as the invention of a sun-dial and the fashioning of a quadrant, we come at length to an important discovery which is made by simple accident. One day, while he is chopping down a tree, his hatchet strikes fire, some chips are ignited and he burns his fingers. Of course, he goes to work to experiment on this new element, fire, and in his pursuit of knowledge under difficulties, not only nearly burns down his cottage, but does, in fact, destroy a good deal of property and a number of animals. In this way he learns very effectually that fire, though a good servant, is a bad master. Indirectly, another consequence follows. His alarming adventure rather oddly gives him 'the first sad experience of the severe Lashes of a self-condemning Conscience'; a trouble compared with which he finds that all his other sorrows were as nothing. With such a youth as Autonous, the remote results of this discovery may be easily anticipated. An 'inward Sense of guilt and shame' arises; he begins to realize the 'natural Depravity and Perverseness' of his temper; and a new idea—the idea of Duty—takes shape in his mind. He begins to reflect on the 'great Disorders of the Soul,' of which other creatures on the island seem to know nothing, and comes slowly to feel that the world is 'nothing else but a black scene' of 'wickedness and impiety.' Having thought out for himself the principles of natural religion, our young theologian is, as we see, on the high-road to Christianity. Man by nature, he concludes, is in an 'indigent and imperfect State,' and is evidently so placed that he may be kept in a due sense of dependence on God. Hence the need of 'some Supernatural means' by which God must have made known His will to men; hence the inevitableness of prayer and supplication; and hence the necessity of a future life, with rewards and punishments, as the logical completion of the scheme of salvation.

The long course of Autonous's education* is now complete, and there is nothing left for him but to be rescued and brought into human

* It will be observed that by a striking oversight (whether intentional or not I cannot say) not a word is said about the question of language. Autonous clearly did not evolve this by himself, though, as we have seen, he had arrived at the idea of intercourse through speech. He must, therefore, on his return to civilization, have been in the condition of a dumb philosopher unable, till taught, to put his thoughts into language.

society. He is now, we remember, at the end of his twenty-first year, and our obvious comment is that he is well advanced for his age. With his return to civilized life, the story properly closes; but the author of the second work—the 'History of Automathes'—adds something on his own account to clinch the moral. The immense progress which the youth was able, by himself, to make was not, we are asked to recollect, due to inward natural capacity. Had he been thrown entirely on his own resources after his father's departure—had he, that is, been deprived of the various aids his father left behind him—he would inevitably have perished, or, surviving, have sunk to the level of the brutes. In such a condition the race at large would have remained in default of assistance from without. Hence, argues the author, civilization must have depended, at the first, upon supernatural revelation. Particularly must this have been the case, he further insists—though the history of Autonous (or Automathes) hardly sustains the contention—with all religious knowledge. We must, therefore, assume a primeval revelation to all men, shadows and survivals of which are to be found in heathen mythologies and extra-Christian speculations.*

It is almost a pity, we are tempted to say, as we lay the strange little book aside, that Autonous was rescued just when he was. Having on his own account discovered so many things which it has taken humanity thousands of years to find out, he might, had he been left alone, have pushed his researches into who knows what fresh domains of science, theoretical and applied. Or perhaps, it may be suggested, his achievements were, after all, due to his peculiar conditions—to abandon a child on an uninhabited island may, in other words, be the very best way of developing his faculties. In an age which has already gone wild over educational theories, some one may be glad to take this idea under consideration.

More serious comment is unnecessary. Our brief outline will have sufficed to show the extravagance of Autonous's story, the clumsiness of its machinery and its general lack of plausibility. Its further weakness as a culture-study—the introduction of too many human aids to mental growth—will also be equally apparent; though this is probably referable to the author's realization of the impossibility of getting on without such assistance, as testified in the actual case of the then famous Wild Boy of Germany. But the little book does open up a number of fascinating questions, and, in closing it, we may well ask why, in these days of scientific and psychological fiction, some novelist in search of fresh material does not try his hand on what is surely a not uninteresting or unfruitful theme.

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* Compare Dryden, 'Introduction to Religio Laici.'

THE ECONOMIC LIFE OF FRANCE.

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THE country of France, by reason of its position, has been forced into prominence in the life of Western Europe. The nation is surrounded by powerful peoples of diverse types, and because of its central location has perhaps developed a more cosmopolitan culture than its neighbors. The French people are separated most completely by the natural features of their boundaries from those races most closely resembling them. The road is open where the antagonism of types is greatest. The continental position of France has involved her in the troubles as well as in the reforms of her neighbors, and has opened the door to conquest, but left it open to invaders.

The internal geography of France shows no such extensive mountainous regions, or other sharp geographical divisions, as exist in the British Islands. The vanquished races of France have therefore not been able to retain their separate nationalities as completely as have the Scotch, Welsh and Irish. The British Islands are open on all sides to the sea, and with their abundant harbors have trained up a nation of sailors and colonists to carry Anglo-Saxon culture around the world. France is compact in outline, and though she has much coast, lacks good harbors. The activity of the national mind has been turned inward. This betrays itself in the intense patriotism of the people, in the influence exerted by the national capital and in the failure of France as a colonial power.

The region included in European France comprises about one two-hundred-and-fiftieth of the land of the earth, and about one eighteenth of Europe. The area is 204,150 square miles, or about twice that of the British Islands. The water boundaries are as follows: Mediterranean Sea coast, 395 miles; North Sea, Straits of Dover and English Channel, 572 miles; Atlantic Ocean, 584 miles.

The boundary between France and Spain coincides, for the most part, with the crest of the Pyrenees Mountains. It is, from the economic point of view, a veritable 'wall of separation.' Indeed, it is a well-nigh impassable boundary, as may be seen from the Spanish proverb describing the passes of these mountains—"A son would not wait there for his father." Communication between France and Spain is carried on by means of railways, near the Mediterranean and Atlantic coasts, and by water. The French slope of the Pyrenees is a pastoral country. Because of the regularity of the mountain chain this region affords an unrivaled opportunity to study social structure as influenced by altitude. In the upper mountain valleys the shepherds group their homes into clusters of houses. From them the flocks are led out to pasture, for weeks at a time, on the highest slopes that support vegetation. In these altitudes there are no true villages except where a military station and a custom house draw a few troops and officers together, or where springs have given rise to water-cures. No minerals have drawn thither a mining population. There is nothing but water, forest and pasture. Ten or twelve miles down the mountains the upper valleys open into larger ones. At these outlets are the mountain market towns. These mark the ends of the railway spurs, and from them the shepherds procure their supplies. Another twelve miles down, and the level plains are reached. Close to the openings of the lower valleys the railway branches join to form railway centers, and towns of considerable size have grown up to transact the business between the mountain and the plain.

Between Italy and France the highest portion of the Alpine range intervenes. Over these mountains the Roman legions and the soldiers of Hannibal toiled. But here has been achieved one of the most striking of the conquests of man over nature. The Mount Cenis railway tunnel route, which pierces these mountains, carries the modern tourist from the Rhône to the cities of the upper Po Valley in a few hours. The French slopes of the Alps support only a scant population of mountaineers. Many of these migrate in winter to the plains in search of work, or, housed for long months in their frozen valleys, devote themselves to household industries or to reading and self-education. It is a matter of general remark in the towns of the Rhône Valley that the schoolmasters come from the mountains.

Switzerland and France are divided by the Jura Mountains, but through the Pass of Belfort a large commerce finds passageway. The Jura present a semi-Swiss character, though, compared with the Alps, they are less lofty, differ in geological structure, and receive a greater rainfall. They are noted for luxuriant pastures and dense forests. The chief industries are cattle raising and the manufacture of butter and cheese. In the latter business the co-operative form of industry largely prevails. The rivulets of the mountains afford numerous small water-powers, which are employed in wood-working and the manufacture of watches. Besançon is the watch market of the region. From the timber are made casks for the wine merchants of Champagne.

North of the Jura lie the Vosges Mountains, along the crest of which the Germans have placed their boundary for some distance. The slopes of the Vosges toward Alsace are steep; those toward France are gradual. The rains which water the region come from the west.

The French slopes are, therefore, forest-covered, while in Alsace the lower hills are devoted to the vine, and the upper to grain.

North of the Vosges the boundary line across the plateau of Lorraine before plunging into the rugged forests of the Ardennes. From the latter it finally emerges upon the coast plains to form the Belgian frontier. Between Belgium and France the political boundary is purely arbitrary. There is not an economic boundary, but rather a hive of industry between the two peoples. The political grouping does not correspond with that of race or language.

This hasty review of the land boundaries of France has embraced the consideration of five distinct mountain regions. The general relief of France is less uniform than that of Prussia or Russia, but more uniform than that of Spain or Italy. Forty-six per cent. of French territory is classed as mountainous. Nevertheless, variations in altitude are softened, and there is in France a great deal of what might be called transitional country. The highest mountains are fortunately upon the borders, and but two other regions of broken country need to be considered.

Let us, then, turn from the boundaries to the internal geography of France, and first of all complete our enumeration of mountain areas by considering the Central Highlands and Brittany.

In the south central part of the country there exists an extensive semi-barren plateau of highly fractured, crystalline, eruptive and volcanic rocks. It slopes sharply to the Rhône on the east, more gently to the Garonne River on the southwest, and to the Loire River on the north. The rocks of this region are so fractured that the rains which fall upon them sink almost immediately out of sight. The country is graced by no transparent mountain lakes or sparkling rivulets. Water must be carefully collected in cisterns or laboriously transported from lower levels. Lack of moisture and the forbidding character of the rock make the pastures so meagre that only sheep and goats can be supported. From them is won the wool which supports a household industry, and from their milk cheese is made. In the eleventh century the cheese of the little village of Roquefort was put away in a rock cave to 'ripen'. It was soon found that this cheese possessed remarkable excellence of flavor. Its fame spread widely, and a new use was from that time found for the caverns which abound in the Cévennes Mountains. The demand was so great that 'bastard caverns' were excavated in the hope of securing the coveted flavor, but the cheese in them has never acquired the properties of real Roquefort. The western slopes of the Central Highlands receive a greater rainfall and possess a more durable pasturage and a more dense population than the eastern. Auvergne is celebrated as the home of sharp cattle merchants, as well as of the peddlers of France. The central plateau has been aptly termed, by the French, a 'pole of divergence,' from which the population migrate in all directions, but especially toward the northern plains, within which lies the pole of attraction.

The peninsula of Brittany, with its backbone of crystalline rock, may be counted as a semi-mountainous region. It much resembles the English peninsula of Cornwall. But Britanny contains no attractive mineral deposits, so it has longer remained a world apart than has Cornwall, and it still shields many ancient prejudices and practices. The interior districts are, in analogy with Cornwall, of inferior, unattractive character, but agriculture and the dairy industry are profitably carried on along the coast. This region is the only one in France abounding in good harbors. The sea is the mainstay of a large part of the population. The fisheries yield herring, sardines, mackerel, lobsters and oysters. The four departments which compose Brittany furnish the merchant marine of France with one-fifth of its sailors, while eighty-two other departments supply the remainder.

The portions of France still remaining to be treated may be grouped into river-valley and coast regions. Beginning with the southeast, we have, along the Mediterranean coast, the sea of ancient Phœnician, Greek and Roman colonies. This coast is divided into two very distinct portions, separated by the mouths of the Rhône River. The eastern section comprises the Mediterranean foot-hills of the Alpine system. It is a region of bold cliffs and promontories. It contains several excellent harbors, among which are Marseilles, Nice and Toulon, the last being the first naval station of France. This high, well-drained, romantic coast-land, forming part of the Riviera, is the most popular resort of Europe. Here are Cannes, Nice, Menton and the little principality of Monaco, possessing independence to no better purpose than to license the gaming tables of Monte Carlo. A little distance from the coast are the romantic islands called by the ancients the Islands of the Hesperides. To the west of the Rhône are to be found low, sandy plains, which stretch away to the foot of the Pyrenees. Toward the coast these give way to malarial swamps. Over these extensive marshes roam herds of half-wild cattle and horses, pastured in the mountains in summer, and brought to the coast in winter, just as are the wild bulls that inhabit the swamps about the mouth of the Guadalquivir in Spain. The inhabitants of the region have to contend with an unhealthy climate. Agriculture implies an expensive system of drainage. The wind-mills used for pumping give to the landscape a striking resemblance to Holland. Along the coast bay salt is evaporated by solar heat. The cities, because they require firm ground for their location, are of necessity situated a long distance inland. This fact has prevented Languedoc from being a commercial country.

Between the Alps and the Central Highlands intervenes the valley of the Rhône, which forms the highway across western Europe from the Mediterranean to the northern plains. The Rhône Valley is a narrow one. In the south the culture of silk-worms forms a special industry. At Lyons the manufacture of silk is located. Between these two regions there are detached areas suitable for agriculture. The Rhône is a beautiful stream of transparent blue water and swift current. The Saône Valley forms the northern continuation of the Rhône. It is transitional in character, having in the east the characteristics of the wooded Jura, in the west those of the parched Côte d'Or, and of the vineyards where Burgundy and Champagne are produced. Here also are blended the races and dialects of the north and south of France.

In the southwestern corner of the Republic spreads out the valley of the Garonne. The winds from the Atlantic which blow up this valley are caught as in a sack, and a rainfall is precipitated, which reaches each of the tributaries of the Garonne. Because of this, the river is subject to great variations of depth. It is not amenable to commercial uses, and has been paralleled by a canal. The region about the lower course of the river is devoted to wine producing, the product being named after the market 'Bordeaux.' South of the Garonne extends the level barren moor of the Landes, reaching as far as the foot-hills of the Pyrenees. This region is, in summer, a baked steppe; in winter, an almost endless morass. Steps are now being taken to reclaim the soil by drainage and by planting forests of cork oak. The chances are good that it will soon be converted into a habitable country.

From the northern slopes of the Central Highlands flow the waters which form the Loire River. This river flows first north, and then westward, through a long, narrow fertile valley, emptying into the Atlantic south of the peninsula of Brittany. Its course, at Orleans, lies through the grain fields of France. At Angers are extensive nurseries and market gardens, while hemp-growing and manufacture are prominent. On the lower course of the Loire is the port of Nantes, the traditional receiving station for such groceries as are called 'colonial wares' on the Continent.

Preeminent among the rivers of France is the Seine, which gathers the streams of the gently sloping northern plains of France and flows with even tide into the English Channel. Early in its course it passes the centers of manufacture, and is cut up to afford water power. From Paris to Havre the banks are so closely built up that the Seine has been called a river-street. The largest river basin of France is that of the Loire; the most diversified that of the Rhône. The most fertile is the Garonne Valley, and the most densely populated the Valley of the Seine. The Seine has those qualities in a river which render it useful to man. As Michelet says: "It has not the capricious, perfidious softness of the Loire, nor the rough ways of the Garonne, nor the terrible impetuosity of the Rhône, which comes down like a bull escaped from the Alps, traverses a lake fifty miles long, and rushes to the sea, biting at its shores as it goes."

Having thus reviewed some of the characteristics of the chief regions of France, let us consider the distribution of the population, and the location and character of the chief industries, agricultural, manufacturing and commercial, which are carried on by the French people. The population of France amounts to thirty-eight and one-half million souls. The rate of increase has been, for a number of years, less than that of surrounding nations. Because of this fact it may be observed that foreign nationalities are encroaching upon French territory from various sides. The Spaniards are flowing in around the eastern and western ends of the Pyrenees. The Italians invade Provence, and the Belgians and Germans the northeastern portion of the country, while there are large colonies of foreigners in Paris itself. Within the last forty years the internal movements of the population show that the valleys have gained at the expense of the mountains. The north has increased more rapidly than the south. The coal regions have amassed dense populations. The city portion of the population has risen from 24.42 per cent. in 1846 to 35.95 per cent. in 1886. Aggregate figures show that in that time the city population has been increased by five millions, while the country population has decreased two millions. The occupational statistics still show, however, that France is to be classed as preeminently an agricultural nation. Agriculture and industry are, however, not increasing as rapidly as commerce.

The peasantry of France are the foundation strata of the industrial pyramid upon which the superstructure of manufactures and commerce rests. They are a frugal and industrious class. Holdings of land are small in the fertile valleys, larger in the pasture country and communal in the mountains, where the land remains in a state of nature and where the shepherd must needs range widely with his flocks. The higher portions of the Pyrenees, Alps and Central Highlands are the sheep walks of France. Between these and the valleys stretches the belt of heavy pastures devoted to cattle-raising. As in England one hears of Scotch and Welsh cattle, so in France one hears of the cattle of Auvergne and Brittany. The stock are grown to full size in the pastures, and are then (such at least as are designed for Paris) shipped to the fertile plains around Paris, to be stall-fed and fattened. In like manner, the cattle sent to London from the north of England are 'finished,' to use the trade phrase, in a semicircle of country to the north of that city. The dairy industry must be sharply distinguished from cattle-raising. The economic problems presented by the two are quite different. In France the dairy industry flourishes, especially in the low-lying, moist plains which border the English Channel. France has been divided into four agricultural regions. The first is the land of the olive, bordering the Mediterranean; the second, to the north of the other, is the corn belt, extending in the west to the island of Oléron; in the east, to the middle of the Vosges Mountains. The third is the vine country, limited on the north by a line drawn from the mouth of the Loire to the middle of the Ardennes. The vine is grown throughout central and southern France in detached areas, wherever the soil and exposure especially favor it. The northern plains compose the fourth agricultural region. They are devoted to grain, flax, potatoes, apples, small fruits and garden produce. Southwest of Paris lies the fertile plain of Beauce, the 'Granary of France,' described by Zola in 'La Terre,' and pictured by Millet. Agricultural methods are in the main clumsy and imperfect, and their defects are made up only by grinding toil. This condition of things has been explained as due to the conservatism of the peasant. There is an absence of newspapers and farmers' organizations to spread scientific knowledge concerning the processes of agriculture. The prevalence of small holdings prevents the profitable use of expensive agricultural machinery on private account. While the price of land is high, foreign competition keeps the price of staple products low.

As to mineral resources, France is generally accounted under, rather than over, supplied. There is everywhere an abundance of building-stone. Paris has exhaustless supplies within the municipal area. This has had not a little to do with the splendor and durability of Parisian architecture, which contrasts favorably with the brick of London and the stucco of Berlin. In the northwestern portion of the Central Highlands the mountains of Limonsin afford unexcelled porcelain clays, from which the famous Limoges china is made. The Jura Mountains produce mill-stones and lithographic stones. Brittany has a little tin. The Pyrenees offer nothing but mineral waters, except some iron in the extreme east. At Baccarat, in the Vosges, the ingredients for glass are found, and St. Gobain and St. Quirin manufacture plate glass. Nevertheless, France has perhaps less mineral wealth than any other well-known country of like extent. The chief defect is in connection with the supplies of iron and coal. Iron ore must always be transported to coal, for in producing iron two tons of coal are required to one ton of ore. It is to be desired, therefore, that coal should exist in large beds, accessible to the miner, and of proper quality for coking. Iron, though it may be in small deposits, should be free from certain impurities and not far distant from fuel and flux. France has no large beds of fine coal, and her iron ore is not of high grade; neither is it advantageously located with reference to coal. The largest collieries are in the extreme northeast, and extend across the border into Belgium.

Other important beds are southwest of Lyons at St. Etienne, and northwest of Lyons near Creuzot. Some anthracite is found in the Alps; some lignite near Marseilles.

The manufactures of France depend more largely upon skill and artistic ability, and less upon cheap coal and raw materials, than do those of England or Germany. The use of the 'factory system' secures the advantage of cheap motive power and the economy of machines, but it does not so much further the utilization of skill. This accounts, in part, for the persistence of household industries in France. The distribution of industrial skill depends upon the location of trade centers, where the traditions of craft have been handed down from generation to generation of workers. Here and there one finds an industry that grew up under royal patronage, often carried on for a time, as an exotic by Italian workmen, as was the case with the silk manufactures of Lyons. The industries of many towns are the survivals of those founded when the place was one of the privileged cities in which the Protestants were allowed to live and carry on trade. In other places industries are still carried on where they were attracted by mediæval church fairs, or royal courts, or by water powers no longer utilized, or harbors now silted up. Skill is a relatively immobile economic factor. The supplies of raw silk are either imported at or grown close to Marseilles, but to be manufactured they must be taken as far north as Lyons to secure a healthy and temperate climate. The manufacture of woolens is located at five points in France, each being midway between sheep-raising highlands and the populated valleys where markets are found. The supplies of raw cotton come chiefly from America, and are landed at Le Havre. Cotton manufacturing requires exactly such a moist climate as there prevails. It is, therefore, carried on in the lower valley of the Seine, or, at most, is removed but a short distance to the east to secure coal and a labor market. The linen manufactories are naturally in a flax-growing country, and center at Amiens and Lille. The Liverpool of France is Le Havre. Its Birmingham is St. Etienne. The French Manchester is said to be Montluçon. The bank center and city of diversified industries, corresponding to London, is Paris. There a vast variety of art goods, conveniences and luxuries, such as Gobelin's tapestry and *articles de vertu*, collectively known to the trade as 'Articles of Paris,' are manufactured.

The commercial routes of France have been remarkably distinct from the earliest historical times. The railways of France have opened fewer new arteries of trade, and have destroyed less of the old equilibrium of industry than it has been their fate to do in most other countries. The distribution of large cities serves well to show where these commercial highways are located. The southern trade moves from Marseilles to the Rhône Valley, and across the plains to Paris, or it passes to the west down the Garonne Valley to Bordeaux From Bordeaux a route passes northward, to the west of the highlands, and along the coast to the city of Tours. At Tours this stream of trade is joined by that from the southern and western seas, and is carried inland to Paris. The great capital receives these streams from the south and feeds, and is in turn fed, from the fan-shaped network of commercial highways which branch out in every direction over the plains of the north. The chief of these bring Paris into close communication with Belgium and the coast.

Paris is situated in the center of the largest habitable plain of France. It is at the place where the road from the Mediterranean crosses the overland route from Spain to the low countries. The capital is near enough to the most important disputed boundaries to be able to throw the power of the nation into their protection, yet it is far enough inland from the channel to be safe from naval attack. The latitude gives Paris a climate which permits of continuous labor, and does not unduly complicate municipal sanitary problems. The metropolis is surrounded by regions which supplement one another in a beautiful manner in ministering to her necessities. On the northeast is a group of large cities devoted to the textile industries. In the southeast are the chalk plains, famous for wine. From the southwest comes grain. Due west are the Percheron and Norman hills furnishing their celebrated breeds of horses, while from further away, Brittany sends butter and eggs, honey and fish. Along the shores in the north and west are the ports of Dunkerque, Calais, Dieppe and Le Havre, for communication, while the lover of surf bathing finds the beach of Trouville not far away. The immediate environs have had not a little to do with the prosperity of the city. The merits of these are abundant artesian water and fine building-stone, a fertile surrounding soil able to assist in provisioning a metropolis, and romantic beauty of landscape, able, in the days of a monarchy, to attract a king to erect palaces and, in those of a republic, to stimulate a matter-of-fact *bourgeois*, and refresh an exhausted *ouvrier* on a holiday outing.

PEARSON'S GRAMMAR OF SCIENCE.

ANNOTATIONS ON THE FIRST THREE CHAPTERS.

By C. S. PEIRCE.

IF any follower of Dr. Pearson thinks that in the observations I am about to make I am not sufficiently respectful to his master, I can assure him that without a high opinion of his powers I should not have taken the trouble to make these annotations, and without a higher opinion still, I should not have used the bluntness which becomes the impersonal discussions of mathematicians.

An introductory chapter of ethical content sounds the dominant note of the book. The author opens with the declaration that our conduct ought to be regulated by the Darwinian theory. Since that theory is an attempt to show how natural causes tend to impart to stocks of animals and plants characters which, in the long run, promote reproduction and thus insure the continuance of those stocks, it would seem that making Darwinism the guide of conduct ought to mean that the continuance of the race is to be taken as the *summum bonum,* and '*Multiplicamini*' as the epitome of the moral law. Professor Pearson, however, understands the matter a little differently, expressing himself thus: "The sole reason [for encouraging] any form of human activity . . . lies in this: [its] existence tends to promote the welfare of human society, to increase social happiness, or to strengthen social stability. In the spirit of the age we are bound to question the value of science; to ask in what way it increases the happiness of mankind or promotes social efficiency."

The second of these two statements omits the phrase, 'the welfare of human society,' which conveys no definite meaning; and we may, therefore, regard it as a mere diluent, adding nothing to the essence of what is laid down. Strict adhesion to Darwinian principles would preclude the admission of the 'happiness of mankind' as an ultimate aim. For on those principles everything is directed to the continuance of the stock, and the individual is utterly of no account, except in so far as he is an agent of reproduction. Now there is no other happiness of mankind than the happiness of individual men. We must, therefore, regard this clause as logically deleterious to the purity of the doctrine. As to 'social stability,' we all know very well what ideas this phrase is intended to convey to English apprehensions; and it must be admitted that Darwinism, generalized in due measure, may apply to English society the same principles that Darwin applied to breeds. A family in which the standards of that society are not traditional will go under and die out, and thus 'social stability' tends to be maintained.

But against the doctrine that social stability is the sole justification of scientific research, whether this doctrine be adulterated or not with the utilitarian clause, I have to object, first, that it is historically false, in that it does not accord with the predominant sentiment of scientific men; second, that it is bad ethics; and, third, that its propagation would retard the progress of science.

Professor Pearson does not, indeed, pretend that that which effectually animates the labors of scientific men is any desire 'to strengthen social stability.' Such a proposition would be too grotesque. Yet if it was his business, in treating of the grammar of science, to set forth the legitimate motive to research—as he has deemed it to be—it was certainly also his business, especially in view of the splendid successes of science, to show what has, in fact, moved such men. They have, at all events, not been inspired by a wish either to 'support social stability' or, in the main, to increase the sum of men's pleasures. The man of science has received a deep impression of the majesty of truth, as that to which, sooner or later, every knee must bow. He has further found that his own mind is sufficiently akin to that truth, to enable him, on condition of submissive observation, to interpret it in some measure. As he gradually becomes better and better acquainted with the character of cosmical truth, and learns that human reason is its issue and can be brought step by step into accord with it, he conceives a passion for its fuller revelation. He is keenly aware of his own ignorance, and knows that personally he can make but small steps in discovery. Yet, small as they are, he deems them precious; and he hopes that by conscientiously pursuing the methods of science he may erect a foundation upon which his successors may climb higher. This, for him, is what makes life worth living and what makes the human race worth perpetuation. The very being of law, general truth, reason—call it what you will—consists in its expressing itself in a cosmos and in intellects which reflect it, and in doing this progressively; and that which makes progressive creation worth doing—so the researcher comes to feel—is precisely the reason, the law, the general truth for the sake of which it takes place.

Such, I believe, as a matter of fact, is the motive which effectually works in the man of science. That granted, we have next to inquire which motive is the more rational, the one just described or that which Professor Pearson recommends. The ethical text-books offer us classifications of human motives. But for our present purpose it will suffice to pass in rapid review some of the more prominent ethical classes of motives.

A man may act with reference only to the momentary occasion, either from unrestrained desire, or from preference for one desideratum over another, or from provision against future desires, or from persuasion, or from imitative instinct, or from dread of blame, or in awed obedience to an instant command; or he may act according to some general rule restricted to his own wishes, such as the pursuit of pleasure, or self-preservation, or good-will toward an acquaintance, or attachment to home and surroundings, or conformity to the customs of his tribe, or reverence for a law; or, becoming a moralist, he may aim at bringing about an ideal state of things definitely conceived, such as one in which everybody attends exclusively to his own business and interest (individualism), or in which the maximum total pleasure of all beings capable of pleasure is attained (utilitarianism), or in which altruistic sentiments universally prevail (altruism), or in which his community is placed out of all danger (patriotism), or in which the ways of nature are as little modified as possible (naturalism); or he may aim at hastening some result not otherwise known in advance than as that, whatever it may turn out to be, to which some process seeming to him good must inevitably lead, such as whatever the dictates of the human heart may approve (sentimentalism), or whatever would result from every man's duly weighing, before action, the advantages of his every purpose (to which I will attach the nonce-name *entelism*, distinguishing it and others below by italics), or whatever the historical evolution of public sentiment may decree (*historicism*), or whatever the operation of cosmical causes may be destined to bring about (evolutionism); or he may be devoted to truth, and may be determined to do nothing not pronounced reasonable, either by his own cogitations (rationalism), or by public discussion (dialecticism), or by crucial experiment; or he may feel that the only thing really worth striving for is the generalizing or assimilating elements in truth, and that either as the sole object in which the mind can ultimately recognize its veritable aim (educationalism), or that which alone is destined to gain universal sway (pancratism); or, finally, he may be filled with the idea that the only reason that can reasonably be admitted as ultimate is that living reason for the sake of which the psychical and physical universe is in process of creation (*religionism*).

This list of ethical classes of motives may, it is hoped, serve as a tolerable sample upon which to base reflections upon the acceptability as ultimate of different kinds of human motives; and it makes no pretension to any higher value. The enumeration has been so ordered as to bring into view the various degrees of generality of motives. It would conduce to our purpose, however, to compare them in other respects. Thus, we might arrange them in reference to the degree to which an impulse of dependence enters into them, from express obedience, generalized obedience, conformity to an external exemplar, action for the sake of an object regarded as external, the adoption of a motive centering on something which is partially opposed to what is present, the balancing of one consideration against another, until we reach such motives as unrestrained desire, the pursuit of pleasure, individualism, sentimentalism, rationalism, educationalism, religionism, in which the element of otherness is reduced to a minimum. Again, we might arrange the classes of motives according to the degree in which immediate qualities of feeling appear in them, from unrestrained desire, through desire present but restrained, action for self, action for pleasure generalized beyond self, motives involving a retro-consciousness of self in outward things, the personification of the community, to such motives as direct obedience, reverence, naturalism, evolutionism, experimentalism, pancratism, religionism, in which the element of self-feeling is reduced to a minimum. But the important thing is to make ourselves thoroughly acquainted, as far as possible from the inside, with a variety of human motives ranging over the whole field of ethics.

I will not go further into ethics than simply to remark that all motives that are directed toward pleasure or self-satisfaction, of however high a type, will be pronounced by every experienced person to be inevitably destined to miss the satisfaction at which they aim. This is true even of the highest of such motives, that which Josiah Royce develops in his 'World and Individual.' On the other hand, every motive involving dependence on some other leads us to ask for some ulterior reason. The only desirable object which is quite satisfactory in itself without any ulterior reason for desiring it, is the reasonable itself. I do not mean to put this forward as a demonstration; because, like all demonstrations about such matters, it would be a mere quibble, a sheaf of fallacies. I maintain simply that it is an experiential truth.

The only ethically sound motive is the most general one; and the motive that actually inspires the man of science, if not quite that, is very near to it—nearer, I venture to believe, than that of any other equally common type of humanity. On the other hand, Professor Pearson's aim, 'the stability of society,' which is nothing but a narrow British patriotism, prompts the *cui bono* at once. I am willing to grant that England has been for two or three centuries a most precious factor of human development. But there were and are *reasons* for this. To demand that man should aim at the stability of British society, or of society at large, or the perpetuation of the race, as an *ultimate* end, is too much. The human species will be extirpated sometime; and when the time comes the universe will, no doubt, be well rid of it. Professor Pearson's ethics are not at all improved by being adulterated with utilitarianism, which is a lower motive still. Utilitarianism is one of the few theoretical motives which has unquestionably had an extremely beneficial influence. But the greatest happiness of the greatest number, as expounded by Bentham, resolves itself into merely superinducing the quality of pleasure upon men's immediate feelings. Now, if the pursuit of pleasure is not a satisfactory ultimate motive for me, why should I enslave myself to procuring it for others? Leslie Stephen's book was far from uttering the last word upon ethics; but it is difficult to comprehend how anybody who has read it reflectively can continue to hold the mixed doctrine that no action is to be encouraged for any other reason than that it either tends to the stability of society or to general happiness.

Ethics, as such, is extraneous to a Grammar of Science; but it is a serious fault in such a book to inculcate reasons for scientific research the acceptance of which must tend to lower the character of such research. Science is, upon the whole, at present in a very healthy condition. It would not remain so if the motives of scientific men were lowered. The worst feature of the present state of things is that the great majority of the members of many scientific societies, and a large part of others, are men whose chief interest in science is as a means of gaining money, and who have a contempt, or half-contempt, for pure science. Now, to declare that the sole reason for scientific research is the good of society is to encourage those pseudo-scientists to claim, and the general public to admit, that they, who deal with the applications of knowledge, are the true men of science, and that the theoreticians are little better than idlers.

In Chapter II., entitled 'The Facts of Science,' we find that the 'stability of society' is not only to regulate our conduct, but, also, that our opinions have to be squared to it. In section 10 we are told that we must not believe a certain purely theoretical proposition because it is 'anti-social' to do so, and because to do so 'is opposed to the interests of society.' As to the 'canons of legitimate inference' themselves, that are laid down by Professor Pearson, I have no great objection to them. They certainly involve important truths. They are excessively vague and capable of being twisted to support illogical opinions, as they are twisted by their author, and they leave much ground uncovered. But I will not pursue these objections. I do say, however, that truth is truth, whether it is opposed to the interests of society to admit it or not—and that the notion that we must deny what it is not conducive to the stability of British society to affirm is the mainspring of the mendacity and hypocrisy which Englishmen so commonly regard as virtues. I must confess that I belong to that class of scallawags who purpose, with God's help, to look the truth in the face, whether doing so be conducive to the interests of society or not. Moreover, if I should ever attack that excessively difficult problem, 'What is for the true interest of society?' I should feel that I stood in need of a great deal of help from the science of legitimate inference; and, therefore, to avoid running round a circle, I will endeavor to base my theory of legitimate inference upon something less questionable—as well as more germane to the subject—than the true interest of society.

The remainder of this chapter on the 'Facts of Science' is taken up with a theory of cognition, in which the author falls into the too common error of confounding psychology with logic. He will have it that knowledge is built up out of sense-impressions—a correct enough statement of a conclusion of psychology. Understood, however, as Professor Pearson understands and applies it, as a statement of the nature of our logical data, of 'the facts of science,' it is altogether incorrect. He tells us that each of us is like the operator at a central telephone office, shut out from the external world, of which he is informed only by sense-impressions. Not at all! Few things are more completely hidden from my observation than those hypothetical elements of thought which the psychologist finds reason to pronounce 'immediate,' in his sense. But the starting point of all our reasoning is not in those sense-impressions, but in our percepts. When we first wake up to the fact that we are thinking beings and can exercise some control over our reasonings, we have to set out upon our intellectual travels from the home where we already find ourselves. Now, this home is the parish of percepts. It is not inside our skulls, either, but out in the open. It is the external world that we directly observe. What passes within we only know as it is mirrored in external objects. In a certain sense, there is such a thing as introspection; but it consists in an interpretation of phenomena presenting themselves as external percepts. We first see blue and red things. It is quite a discovery when we find the eye has anything to do with them, and a discovery still more recondite when we learn that there is an *ego* behind the eye, to which these qualities properly belong. Our logically initial data are percepts. Those percepts are undoubtedly purely psychical, altogether of the nature of thought. They involve three kinds of psychical elements, their qualities of feelings, their reaction against my will, and their generalizing or associating element. But all that we find out afterward. I see an inkstand on the table: that is a percept. Moving my head, I get a different percept of the inkstand. It coalesces with the other. What I call the inkstand is a generalized percept, a quasi-inference from percepts, perhaps I might say a composite-photograph of percepts. In this psychical product is involved an element of resistance to me, which I am obscurely conscious of from the first. Subsequently, when I accept the hypothesis of an inward subject for my thoughts, I yield to that consciousness of resistance and admit the inkstand to the standing of an external object. Still later, I may call this in question. But as soon as I do that, I find that the inkstand appears there in spite of me. If I turn away my eyes, other witnesses will tell me that it still remains. If we all leave the room and dismiss the matter from our thoughts, still a photographic camera would show the inkstand still there, with the same roundness, polish and transparency, and with the same opaque liquid within. Thus, or otherwise, I confirm myself in the opinion that its characters are what they are, and persist at every opportunity in revealing themselves, regardless of what you, or I, or any man, or generation of men, may think that they are. That conclusion to which I find myself driven, struggle against it as I may, I briefly express by saying that the inkstand is a *real* thing. Of course, in being real and external, it does not in the least cease to be a purely psychical product, a generalized percept, like everything of which I can take any sort of cognizance.

It might not be a very serious error to say that the facts of science are sense-impressions, did it not lead to dire confusion upon other points. We see this in Chapter III., in whose long meanderings through irrelevant subjects, in the endeavor to make out that there is no rational element in nature, and that the rational element of natural laws is imported into them by the minds of their discoverers, it would be impossible for the author to lose sight entirely of the bearing of the question which he himself has distinctly formulated, if he were not laboring with the confusing effects of his notion that the data of science are the sense-impressions. It does not occur to him that he is laboring to prove that the mind has a marvelous power of creating an element absolutely supernatural—a power that would go far toward establishing a dualism quite antagonistic to the spirit of his philosophy. He evidently imagines that those who believe in the reality of law, or the rational element in nature, fail to apprehend that the data of science are of a psychical nature. He even devotes a section to proving that natural law does not belong to things-in-themselves, as if it were possible to find any philosopher who ever thought it did. Certainly, Kant, who first decked out philosophy with these chaste ornaments of things-in-themselves, was not of that opinion; nor could anybody well hold it after what he wrote. In point of fact, it is not Professor Pearson's opponents but he himself who has not thoroughly assimilated the truth that everything we can in any way take cognizance of is purely mental. This is betrayed in many little ways, as, for instance, when he makes his answer to the question, whether the law of gravitation ruled the motion of the planets before Newton was born, to turn upon the circumstance that the law of gravitation is a formula expressive of the motion of the planets 'in terms of a purely mental conception,' as if there could be a conception of anything not purely mental. Repeatedly, when he has proved the content of an idea to be mental, he seems to think he has proved its object to be of human origin. He goes to no end of trouble to prove in various ways, what his opponent would have granted with the utmost cheerfulness at the outset, that laws of nature are rational; and, having got so far, he seems to think nothing more is requisite than to seize a logical maxim as a leaping pole and lightly skip to the conclusion that the laws of nature are of human provenance. If he had thoroughly accepted the truth that all realities, as well as all figments, are alike of purely mental composition, he would have seen that the question was, not whether natural law is of an intellectual nature or not, but whether it is of the number of those intellectual objects that are destined ultimately to be exploded from the spectacle of our universe, or whether, as far as we can judge, it has the stuff to stand its ground in spite of all attacks. In other words, is there anything that is really and truly a law of nature, or are all pretended laws of nature figments, in which latter case, all natural science is a delusion, and the writing of a grammar of science a very idle pastime?

Professor Pearson's theory of natural law is characterized by a singular vagueness and by a defect so glaring as to remind one of the second book of the *Novum Organum* or of some strong chess-player whose attention has been so riveted upon a part of the board that a fatal danger has, as it were, been held upon the blind-spot of his mental retina. The manner in which the current of thought passes from the woods into the open plain and back again into the woods, over and over again, betrays the amount of labor that has been expended upon the chapter. The author calls attention to the sifting action both of our perceptive and of our reflective faculties. I think that I myself extracted from that vein of thought pretty much all that is valuable in reference to the regularity of nature in the POPULAR SCIENCE MONTHLY for June, 1878, (p. 208). I there remarked that the degree to which nature seems to present a general regularity depends upon the fact that the regularities in it are of interest and importance to us, while the irregularities are without practical use or significance; and in the same article I endeavored to show that it is impossible to conceive of nature's being markedly less regular, taking it, 'by and large,' than it actually is. But I am confident, from having repeatedly returned to that line of thought that it is impossible legitimately to deduce from any such considerations the unreality of natural law. 'As a pure suggestion and nothing more,' toward the end of the chapter, after his whole plea has been put in, Dr. Pearson brings forward the idea that a transcendental operation of the perceptive faculty may reject a mass of sensation altogether and arrange the rest in place and time, and that to this the laws in nature may be attributable—a notion to which Kant undoubtedly leaned at one time. The mere emission of such a theory, after his argument has been fully set forth, almost amounts to a confession of failure to prove his proposition. Granting, by way of waiver, that such a theory is intelligible and is more than a nonsensical juxtaposition of terms, so far from helping Professor Pearson's contention at all, the acceptance of it would at once decide the case against him, as every student of the *Critic of the Pure Reason* will at once perceive. For the theory sets the rationality in nature upon a rock perfectly impregnable by you, me or any company of men.

Although that theory is only problematically put forth by Professor Pearson, yet at the very outset of his argumentation he insists upon the relativity of regularity to our faculties, as if that were in some way pertinent to the question. "Our law of tides," he says, "could have no meaning for a blind worm on the shore, for whom the moon had no existence." Quite so; but would that truism in any manner help to prove that the moon was a figment and no reality? On the contrary, it could only help to show that there may be more things in heaven and earth than your philosophy has dreamed of. Now the *moon*, on the one hand, and the *law of the tides*, on the other, stand in entirely analogous positions relatively to the remark, which can no more help to prove the unreality of the one than of the other. So, too, the final decisive stroke of the whole argumentation consists in urging substantially the same idea in the terrible shape of a syllogism, which the reader may examine in section 11. I will make no comment upon it.

Professor Pearson's argumentation rests upon three legs. The first is the fact that both our perceptive and our reflective faculties reject part of what is presented to them, and 'sort out' the rest. Upon that, I remark that our minds are not, and cannot be, positively mendacious. To suppose them so is to misunderstand what we all mean by truth and reality. Our eyes tell us that some things in nature are red and others blue; and so they really are. For the real world is the world of insistent generalized percepts. It is true that the best physical idea which we can at present fit to the real world, has nothing but longer and shorter waves to correspond to red and blue. But this is evidently owing to the acknowledged circumstance that the physical theory is to the last degree incomplete, if not to its being, no doubt, in some measure, erroneous. For surely the completed theory will have to account for the extraordinary contrast between red and blue. In a word, it is the business of a physical theory to account for the percepts; and it would be absurd to accuse the percepts—that is to say, the facts—of mendacity because they do not square with the theory.

The second leg of the argumentation is that the mind projects its worked-over impressions into an object, and then projects into that object the comparisons, etc., that are the results of its own work. I admit, of course, that errors and delusions are everyday phenomena, and hallucinations not rare. We have just three means at our command for detecting any unreality, that is, lack of insistency, in a notion. First, many ideas yield at once to a direct effort of the will. We call them *fancies*. Secondly, we can call in other witnesses, including ourselves under new conditions. Sometimes dialectic disputation will dispel an error. At any rate, it may be voted down so overwhelmingly as to convince even the person whom it affects. Thirdly, the last resort is prediction and experimentation. Note that these two are equally essential parts of this method, which Professor Pearson keeps—I had almost said sedulously—out of sight in his discussion of the rationality of nature. He only alludes to it when he comes to his transcendental 'pure suggestion.' Nothing is more notorious than that this method of prediction and experimentation has proved the master-key to science; and yet, in Chapter IV., Professor Pearson tries to persuade us that prediction is no part of science, which must only describe sense-impressions. [A sense-impression cannot be described.] He does not say that he would permit generalization of the facts. He ought not to do so, since generalization inevitably involves prediction.

The third leg of the argumentation is that human beings are so much alike that what one man perceives and infers another man will be likely to perceive and infer. This is a recognized weakness of the second of the above methods. It is by no means sufficient to destroy that method, but along with other defects it does render resort to the third method imperative. When I see Dr. Pearson passing over without notice the first and third of the only three possible ways of distinguishing whether the rationality of nature is real or not, and giving a lame excuse for reversing the verdict of the second, so that his decision seems to spring from antecedent predilection, I cannot recommend his procedure as affording such an exemplar of the logic of science as one might expect to find in a grammar of science.

An ignorant sailor on a desert island lights in some way upon the idea of the parallelogram of forces, and sets to work making experiments to see whether the actions of bodies conform to that formula. He finds that they do so, as nearly as he can observe, in many trials invariably. He wonders why inanimate things should thus conform to a widely general intellectual formula. Just then, a disciple of Professor Pearson lands on the island and the sailor asks him what he thinks about it. "It is very simple," says the disciple, "you see you made the formula and then you projected it into the phenomena." *Sailor:* What are the phenomena? *Pearsonist:* The motions of the stones you experimented with. *Sailor:* But I could not tell until afterward whether the stones had acted according to the rule or not. *Pearsonist:* That makes no difference. You made the rule by looking at some stones, and all stones are alike. *Sailor:* But those I used were very unlike, and I want to know what made them all move exactly according to one rule. *Pear-*

sonist: Well, maybe your mind is not in time, and so you made all the things behave the same way at all times. Mind, I don't say it is so; but it may be. *Sailor:* Is that all you know about it? Why not say the stones are made to move as they do by something *like* my mind?

When the disciple gets home, he consults Dr. Pearson. "Why," says Dr. Pearson, "you must not deny that the facts are really concatenated; only there is no rationality about that." "Dear me," says the disciple, "then there really is a concatenation that makes all the component accelerations of all the bodies scattered through space conform to the formula that Newton, or Lami, or Varignon invented?" "Well, the formula is the device of one of those men, and it conforms to the facts." "To the facts its inventor knew, and also to those he only predicted?" "As for prediction, it is unscientific business." "Still the prediction and the facts predicted agree." "Yes." "Then," says the disciple, "it appears to me that there really is in nature something extremely like action in conformity with a highly general intellectual principle." "Perhaps so," I suppose Dr. Pearson would say, "but nothing in the least like rationality." "Oh," says the disciple, "I thought rationality was conformity to a widely general principle."

CHAPTERS ON THE STARS.

By Professor SIMON NEWCOMB, U. S. N.

THE STRUCTURE OF THE HEAVENS.

THE problem of the structure and duration of the universe is the most far-reaching with which the mind has to deal. Its solution may be regarded as the ultimate object of stellar astronomy, the possibility of reaching which has occupied the minds of thinkers since the beginning of civilization. Before our time the problem could be considered only from the imaginative or the speculative point of view. Although we can to-day attack it by scientific methods, to a limited extent, it must be admitted that we have scarcely taken more than the first step toward the actual solution. We can do little more than state the questions involved, and show what light, if any, science is able to throw upon the possible answers.

Firstly, we may inquire as to the extent of the universe of stars. Are the latter scattered through infinite space, so that those we see are merely that portion of an infinite collection which happens to be within reach of our telescopes, or are all the stars contained within a certain limited space? In the latter case, have our telescopes yet penetrated to the boundary in any direction? In other words, as, by the aid of increasing telescopic power, we see fainter and fainter stars, are these fainter stars at greater distances than those before known, or are they smaller stars contained within the same limits as those we already know? Otherwise stated, do we see stars on the boundary of the universe?

Secondly, granting the universe to be finite, what is the arrangement of the stars in space? Especially, what is the relation of the galaxy to the other stars? In what sense, if any, can the stars be said to form a permanent system? Do the stars which form the Milky Way belong to a different system from the other stars, or are the latter a part of one universal system?

Thirdly, what is the duration of the universe in time? Is it fitted to last forever in its present form, or does it contain within itself the seeds of dissolution? Must it, in the course of time, in we know not how many millions of ages, be transformed into something very different from what it now is? This question is intimately associated with the question whether the stars form a system. If they do, we may suppose that system to be permanent in its general features; if not, we must look further for our conclusion.

The first and third of these questions will be recognized by students of Kant as substantially those raised by the great philosopher in the form of antinomies. Kant attempted to show that both the propositions and their opposites could be proved or disproved by reasoning equally valid in either case. The doctrine that the universe is infinite in duration and that it is finite in duration are both, according to him, equally susceptible of disproof. To his reasoning on both points the scientific philosopher of to-day will object that it seeks to prove or disprove, *à priori*, propositions which are matters of fact, of which the truth can be therefore settled only by an appeal to observation. The more correct view is that afterward set forth by Sir William Hamilton, that it is equally impossible for us to conceive of infinite space (or time), or of space (or time) coming to an end. But this inability merely grows out of the limitations of our mental power, and gives us no clue to the actual universe. So far as the questions are concerned with the latter, no answer is valid unless based on careful observation. Our reasoning must have facts to go upon before a valid conclusion can be reached.

The first question we have to attack is that of the extent of the universe. In its immediate and practical form, it is whether the smallest stars that we see are at the boundary of a system, or whether more and more lie beyond, to an infinite extent. This question we are not yet ready to answer with any approach to certainty. Indeed, from the very nature of the case, the answer must remain somewhat indefinite. If the collection of stars which forms the Milky Way be really finite, we may not yet be able to see its limit. If we do see its limit, there may yet be, for aught we know, other systems and other galaxies, scattered through infinite space, which must forever elude our powers of vision. Quite likely the boundary of the system may be somewhat indefinite, the stars gradually thinning out as we go further and further, so that no definite limit can be assigned. If all stars are of the same average brightness as those we see, all that lie beyond a certain distance must evade observation, for the simple reason that they are too far off to be visible in our telescopes.

There is a law of optics which throws some light on the question. Suppose the stars to be scattered through infinite space in such a way that every great portion of space is, in the general average, about equally rich in stars.

Then imagine that, at some great distance, say that of the average stars of the sixth magnitude, we describe a sphere having its center in our system. Outside this sphere, describe another one, having a radius greater by a certain quantity, which we may call S. Outside that let there be another of a radius yet greater, and so on indefinitely. Thus we shall have an endless succession of concentric spherical shells, each of the same thickness, S. The volume of each of these regions will be proportional to the square of the diameters of the spheres which bound it. Hence, supposing an equal distribution of the stars, each of these regions will contain a number of stars increasing as the square of the radius of the region. Since the amount of light which we receive from each individual star is as the inverse square of its distance, it follows that the sum total of the light received from each of these spherical shells will be equal. Thus, as we include sphere after sphere, we add equal amount of light without limit. The result of the successive addition of these equal quantities, increasing without limit, would be that if the system of stars extended out indefinitely the whole heavens would be filled with a blaze of light as bright as the sun.

Now, as a matter of fact, such is very far from being the case. It follows that infinite space is not occupied by the stars. At best there can only be collections of stars at great distances apart.

The nearest approximation to such an appearance as that described is the faint, diffused light of the Milky Way. But so large a fraction of this illumination comes from the stars which we actually see in the telescope that it is impossible to say whether any visible illumination results from masses of stars too faint to be individually seen. Whether the cloud-like impressions, which Barnard has found in long-exposed photographs of the Milky Way, are produced by countless distant stars, too faint to impress themselves even upon the most sensitive photographic plate, is a question of extreme interest which cannot be answered. But even if we should answer it in the affirmative, the extreme faintness of light shows that the stars which produce it are not scattered through infinite space; but that, although they may extend much beyond the limits of the visible stars, they thin out very rapidly. The evidence, therefore, seems to be against the hypothesis that the stars we see form part of an infinitely extended universe.

But there are two limitations to this conclusion. It rests upon the hypothesis that light is never lost in its passage to any distance, however great. This hypothesis is in accordance with our modern theories of physics, yet it cannot be regarded as an established fact for all space, even if true for the distances of the visible stars. About half a century ago Struve propounded the contrary hypothesis that the light of the more distant stars suffers an extinction in its passage to us. But this had no other basis than the hypothesis that the stars were equally thick out to the farthest limits at which we could see them.

It might be said that he assumed the hypothesis of an infinite universe, and from the fact that he did not see the evidence of infinity, concluded that light was lost. The hypothesis of a limited universe and no extinction of light, while not absolutely proved, must be regarded as the one to be accepted until further investigation shall prove its unsoundness.

The second limitation has been the possible structure of an infinite universe. The mathematical reader will easily see that the conclusion that an infinite universe of stars would fill the heavens with a blaze of light, rests upon the hypothesis that every region of space of some great but finite extent is, on the average, occupied by at least one star. In other words, the hypothesis is that if we divide the total number of the stars by the number of cubic miles of space, we shall have a finite quotient. But an infinite universe can be imagined which does not fill this condition. Such will be the case with one constructed on the celebrated hypothesis of Lambert, propounded in the latter part of the last century. This author was an eminent mathematician, who seems to have been nearly unique in combining the mathematical and the speculative sides of astronomy. He assumed a universe constructed on an extension of the plan of the Solar System. The smallest system of bodies is composed of a planet with its satellites. We see a number of such systems, designated as the Terrestrial, the Martian (Mars and its satellites), the Jovian (Jupiter and its satellites), etc., all revolving round the Sun, and thus forming one greater system, the Solar System. Lambert extended the idea by supposing that a number of solar systems, each formed of a star with its revolving planets and satellites, were grouped into a yet greater system. A number of such groups form the great system which we call the galaxy, and which comprises all the stars we can see with the telescope. The more distant clusters may be other galaxies. All these systems again may revolve around some distant center, and so on to an indefinite extent. Such a universe, how far so ever it might extend, would fill the heavens with a blaze of light, and the more distant galaxies might remain forever invisible to us. But modern developments show that there is no scientific basis for this conception, attractive though it is by its grandeur.

So far as our present light goes, we must conclude that although we are unable to set absolute bounds to the universe, yet the great mass of stars is included within a limited space of whose extent we have as yet no evidence. Outside of this space there may be scattered stars or invisible systems. But if these systems exist, they are distinct from our own.

The second question, that of the arrangement of the stars in space, is one on which it is equally difficult to propound a definite general conclusion. So far, we have only a large mass of faint indications, based on researches which cannot be satisfactorily completed until great additions are made to our fund of knowledge.

A century ago Sir William Herschel reached the conclusion that our universe was composed of a comparatively thin but widely extended stratum of stars. To introduce a familiar object, its figure was that of a large thin grindstone, our Solar System being near the center. Considering only the general aspect of the heavens, this conclusion was plausible. Suppose a mass of a million of stars scattered through a space of this form. It is evident that an observer in the center, when he looks through the side of the stratum, would see few stars. The latter would become more and more numerous as he directed his vision toward the circumference of the stratum. In other words, assuming the universe to have this form, we should see a uniform, cloud-like arch spanning the heavens—a galaxy in fact.

This view of the figure of the universe was also adopted by Struve, who was, the writer believes, the first astronomer after Herschel to make investigations which can be regarded as constituting an important addition to thought on the subject. To a certain extent we may regard the hypothesis as incontestable. The great mass of the visible stars is undoubtedly contained within such a figure as is here supposed.

To show this let Fig. 1 represent a cross section of the heavens at

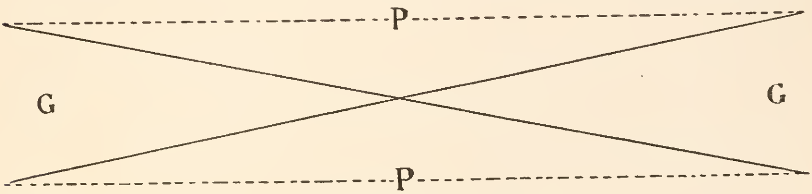

FIG. 1.

right angles to the Milky Way, the Solar System being at S. It is an observed fact that the stars are vastly more numerous in the galactic regions G G than in the regions P P. Hence, if we suppose the stars equally scattered, they must extend much farther out in G G than in P P. If they extend as far in the one direction as in the other, then they must be more crowded in the galactic belt. It will still remain true that the greater number of the stars are included in the flat region A B C D, those outside this stratum being comparatively few in number.*

But we cannot assume that this hypothesis of the form of the universe affords the basis for a satisfactory conception of its arrangement. Were it the whole truth, the stars would be uniformly dense along the whole length of the Milky Way. Now, it is a familiar fact that this is not the case. The Milky Way is not a uniformly illuminated belt, but a chain of irregular, cloud-like aggregations of stars. Starting from this fact as

* Regarding the galaxy as a belt spanning the heavens, the central line of which is a great circle, the poles of the galaxy are the two opposite points in the heavens everywhere 90° from this great circle. Their direction is that of the two ends of the axle of the grindstone, as seen by an observer in the center, while the galaxy would be the circumference of the stone.

a basis, our best course is to examine the most plausible hypotheses we can make as to the distribution of the stars which do not belong to the galaxy, and see which agrees best with observation.

Let Fig. 2 represent a section of the galactic ring or belt in its own plane, with the sun near the center S. To an observer at a vast distance in the direction of either pole of the galaxy, the latter would appear of this form. Let Fig. 3 represent a cross section as viewed by an observer in the plane of the galaxy at a great distance outside of it. How would the stars that do not belong to the galaxy be situated? We may make three hypotheses:

1. That they are situated in a sphere (A B) as large as the galaxy itself. Then the whole universe of stars would be spherical in outline, and the galaxy would be a dense belt of stars girdling the sphere.

2. The remaining stars may still be contained in a spherical space

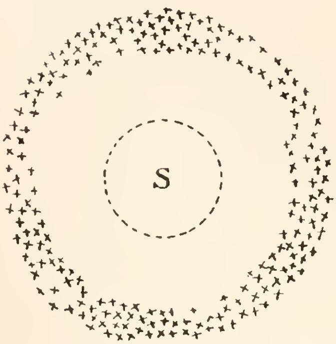

FIG. 2.

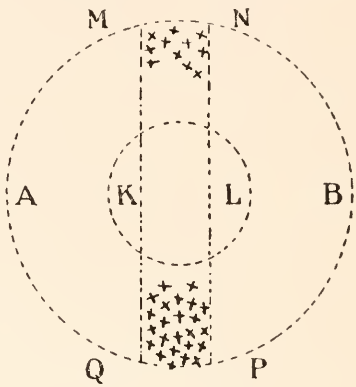

FIG. 3.

(K L), of which the diameter is much less than that of the galactic girdle. In this case our Sun would be one of a central agglomeration of stars, lying in or near the plane of the galaxy.

3. The non-galactic stars may be equally scattered throughout a flat region (M N P Q), of the grindstone form. This would correspond to the hypothesis of Herschel and Struve.

There is no likelihood that either of these hypotheses is true in all the geometric simplicity with which I have expressed them. Stars are doubtless scattered to some extent through the whole region M N P Q, and it is not likely that they are confined within limits defined by any geometrical figure. The most that can be done is to determine to which of the three figures the mutual arrangement most nearly corresponds.

The simplest test is that of the third hypothesis as compared with the other two. If the third hypothesis be true, then we should see the fewest stars in the direction of the poles of the galaxy; and the number in any given portion of the celestial sphere, say one square degree, should continually increase, slowly at first, more rapidly afterwards, as we went from the poles toward the circumference of the galaxy. At a distance of 60° from the poles and 30° from the central line or circumference we should see more than twice as many stars per square degree as near the poles.

The general question of determining the precise position of the galaxy naturally enters into our problem. There is no difficulty in mapping out its general course by unaided eye observations of the heavens or a study of maps of the stars. Looking at the heavens, we shall readily see that it crosses the equator at two opposite points; the one east of the constellation Orion, between 6h. and 7h. of right ascension; the other at the opposite point, in Aquila, between 18h. and 19h. It makes a considerable angle with the equator, somewhat more than 60°. Consequently it passes within 30° of either pole. The point nearest of approach to the north pole is in the constellation Cassiopeia. In consequence of this obliquity to the equator, its apparent position on the celestial sphere, as seen in our latitude, goes through a daily change with the diurnal rotation of the earth. In the language of technical astronomy, every day at 12h. of sidereal time, it makes so small an angle with the horizon as to be scarcely visible. If the air is very clear, we might see a portion of it skirting the northern horizon. This position occurs during the evenings of early summer. At 0h. of sidereal time, which during autumn and early winter fall in the evening, it passes nearly through our zenith, from east to west, and can, therefore, then best be seen.

Its position can readily be determined by noting the general course of its brighter portions on a map of the stars, and then determining by inspection, or otherwise, the circle which will run most nearly through those portions. It is thus found that the position is nearly always near a great circle of the sphere. From the very nature of the case the position of this circle will be a little indefinite, and probably the estimates made of it have been based more on inspection than on computation. The following numerical positions have been assigned to the pole of the galaxy:

Gould, ...	R. A. = 12h. 41m.	Dec. = + 27° 21′
Herschel, W.	12h. 29m.	31° 30′
Seeliger	12h. 49m.	27° 30′
Argelander	12h. 40m.	28° 5′

Were it possible to determine the distance of a star as readily as we do its direction, the problem of the distribution of the stars in space would be at once solved. This not being the case, we must first study the apparent arrangement of the stars with respect to the galaxy, with a view of afterward drawing such conclusions as we can in regard to their distance.

APPARENT DISTRIBUTION OF THE STARS IN THE SKY.

Distribution of the Lucid Stars: Our question now is how are the stars, as we see them, distributed over the sky? We know in a general way that there are vastly more stars round the belt of the Milky Way than in the remainder of the heavens. But we wish to know in detail what the law of increase is from the poles of the galaxy to the belt itself.

In considering any question of the number of stars in a particular region of the heavens, we are met by a fundamental difficulty. We can set no limit to the minuteness of stars, and the number will depend upon the magnitude of those which we include in our account. As already remarked, there are, at least up to a certain limit, three or four times as many stars of each magnitude as of the magnitude next brighter. Now, the smallest stars that can be seen, or that may be included in any count, vary greatly with the power of the instrument used in making the count. If we had any one catalogue, extending over the whole celestial sphere, and made on an absolutely uniform plan, so that we knew it included all the stars down to some given magnitude, and no others, it would answer our immediate purpose. If, however, one catalogue should extend only to the ninth magnitude, while another should extend to the tenth, we should be led quite astray in assuming that the number of stars in the two catalogues expressed the star density in the regions which they covered. The one would show three or four times as many stars as the other, even though the actual density in the two cases were the same.

If we could be certain, in any one case, just what the limit of magnitude was for any catalogue, or if the magnitudes in different catalogues always corresponded to absolutely the same brightness of the star, this difficulty would be obviated. But this is the case only with that limited number of stars whose brightness has been photometrically measured. In all other cases our count must be more or less uncertain. One illustration of this will suffice:

I have already remarked that in making the photographic census of the southern heavens, Gill and Kapteyn did not assume that stars of which the images were equally intense on different plates were actually of the same magnitude. Each plate was assumed to have a scale of its own, which was fixed by comparing the intensity of the photographic impressions of those stars whose magnitudes had been previously determined with these determinations, and thus forming as it were a separate scale for each plate. But, in forming the catalogue from the international photographic chart of the heavens, it is assumed that the photographs taken with telescopes of the same aperture, in which the plates are exposed for five minutes, will all correspond, and that the smallest stars found on the plates will be of the eleventh magnitude.

In the case of the lucid stars this difficulty does not arise, because the photometric estimates are on a sufficiently exact and uniform scale to enable us to make a count, which shall be nearly correct, of all the stars down to, say, magnitude 6.0 or some limit not differing greatly from this. Several studies of the distribution of these stars have been made; one by Gould in the *Uranometria Argentina,* one by Schiaparelli, and another by Pickering. The counts of Gould and Schiaparelli, having special reference to the Milky Way, are best adapted to our purpose. The most striking result of these studies is that the condensation in the Milky Way seems to commence with the brightest stars. A little consideration will show that we cannot, with any probability, look for such a condensation in the case of stars near to us. Whatever form we assign to the stellar universe, we shall expect the stars immediately around us to be equally distributed in every direction. Not until we approach the boundary of the universe in one direction, or some great masses like those of the galaxy in another direction, should we expect marked condensation round the galactic belt. Of course we might imagine that even the nearest stars are most numerous in the direction round the galactic circle. But this would imply an extremely unlikely arrangement, our system being as it were at the point of a cone. It is clear that if such were the case for one point, it could not be true if our Sun were placed anywhere except at this particular point. Such an arrangement of the stars round us is outside of all reasonable probability. Independent evidence of the equal distribution of the stars will hereafter be found in the proper motions. If then, the nearer stars are equally distributed round us, and only distant ones can show a condensation toward the Milky Way, it follows that among the distant stars are some of the brightest in the heavens, a fact which we have already shown to follow from other considerations.

Very remarkable is the fact, pointed out first by Sir J. Herschel and
heavens very nearly in a great circle, but not exactly in the Milky Way.
heavens very nearly in a great circle, but not exactly in the Milky Way.
In the northern heavens the brightest stars in Orion, Taurus, Cassiopeia,
being near the Southern Cross and the other in Cassiopeia. This belt includes the brightest stars in a number of constellations, from Canis Major through the southern region of the heavens and back to Scorpius.
In the northern heavens the brightest stars in Orion, Taurus, Cassiopeia,
Cygnus and Lyra belong to this belt. It would not be safe, however, to assume that the existence of this belt results from anything but the chance distribution of the few bright stars which form it. In order to reach a definite conclusion bearing on the structure of the heavens,

it is advisable to consider the distribution of the lucid stars as a whole.

Dr. Gould finds that the stars brighter than the fourth magnitude are arranged more symmetrically relatively to the bright stars we have just described than to the galactic circle. This and other facts suggested to him the existence of a small cluster within which our sun is eccentrically situated and which is itself not far from the middle plane of the galaxy. This cluster appears to be of a flattened shape and to consist of somewhat more than 400 stars of magnitudes ranging from

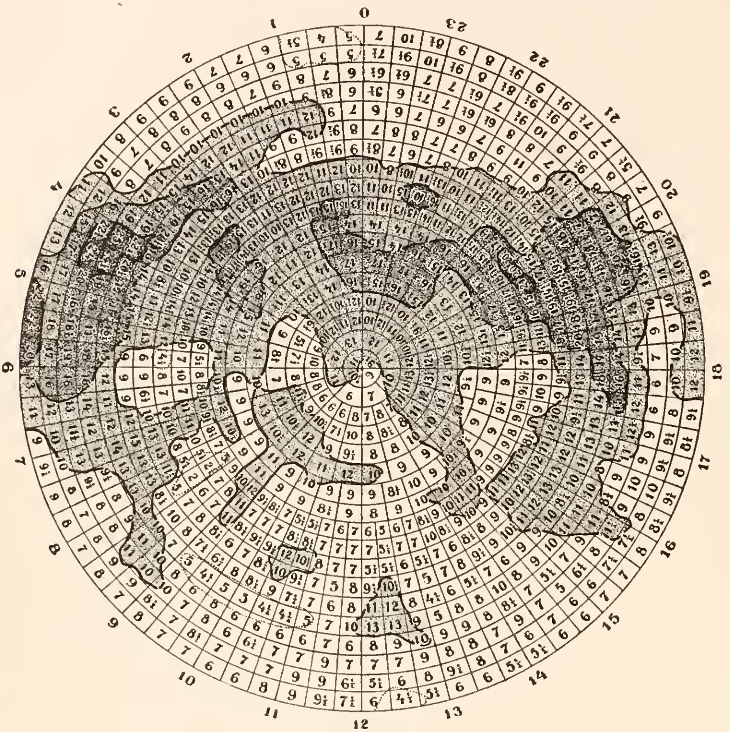

Fig. 4. Northern Hemisphere.

the first to the seventh. Since Gould wrote, the extreme inequality in the intrinsic brightness of the stars has been brought to light and seems to weaken the basis of his conclusion on this particular point.

A very thorough study of the subject, but without considering the galaxy, has also been made by Schiaparelli. The work is based on the photometric measures of Pickering and the *Uranometria Argentina* of Gould. One of its valuable features is a series of planispheres, showing in a visible form the star density in every region of the heavens for stars of various magnitudes. We reproduce in a condensed form two of these planispheres. They were constructed by Schiaparelli in the following way: The entire sky was divided into 36 zones by parallels of declination 5° apart. Each zone was divided into spherical trapezia by hour-circles taken at intervals of 5° from the equator up to 50° of north or south declination; of 10° from 50 to 60; of 15° from 60 to 80; of 45° from 80 to 85, while the circle within 5° of the pole was taken as a single region. In this way 1,800 areas, not excessively different from each other, were formed.

The star density, as it actually is, might be indicated by the number

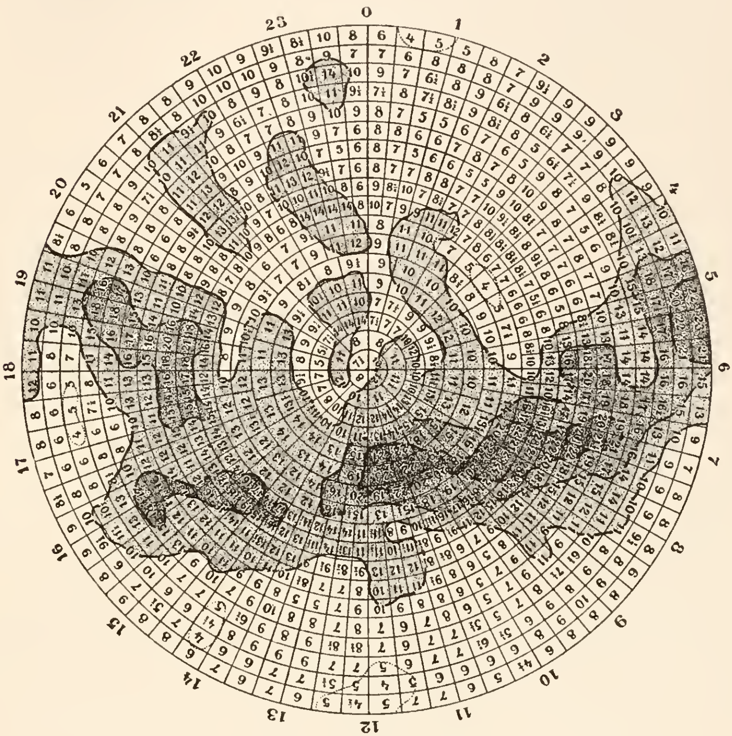

Fig. 5. Southern Hemisphere.

of stars of these regions. As a matter of fact, however, the density obtained in this way would vary too rapidly from one area to the adjoining one, owing to the accidental irregularities of distribution of the stars. An adjustment was, therefore, made by finding in the case of each area the number of stars contained in 1/200 of the entire sphere, including the region itself and those immediately round it. The number thus obtained was considered as giving the density for the central region. The total number of stars being 4,303, the mean number in 1/200 of the whole sphere is 21.5, and the mean in each area is 10.4.

The numbers on the planisphere given in each area thus express the star density of the region, or the number of stars per 100 square degrees, expressed generally to the nearest unit, the half unit being sometimes added.

A study of the reproduction which we give will show how fairly well the Milky Way may be traced out round the sky by the tendency of those stars visible to the naked eye to agglomerate near its course. In other words, were the cloud forms which make up the Milky Way invisible to us, we should still be able to mark out its course by the condensation of the stars. As a matter of interest, I have traced out the central line of the shaded portions of the planispheres as if they were the galaxy itself. The nearest great circle to the course of this line was then found to have its pole in the following position:

R. A.; 12h. 18m.

Dec. + 27°.

This estimate was made without having at the time any recollection of the position of the galaxy given by other authorities. Compared with the positions given in the last chapter by Gould and Seeliger, it will be seen that the deviation is only 5° in right ascension, while the declinations are almost exactly similar. We infer that the circle of condensation found in this way makes an angle with the galaxy of less than 5°.

DISTRIBUTION OF THE FAINTER STARS.

The most thorough study of the distribution of the great mass of stars relative to the galactic plane has been made by Seeliger in a series of papers presented to the Munich Academy from 1884 to 1898. The data on which they are based are the following:

1. The Bonner *Durchmusterung* of Argelander and Schönfeld, described in our third chapter. These two works included under this title are supposed to include all the stars to the ninth magnitude, from the north pole to 24° of south declination. But there are some inconsistencies in the limit of magnitude which we shall hereafter mention.

2. The 'star gauges' of the two Herschels. These consisted simply in counts of the number of stars visible in the field of view of the telescope when the latter was directed toward various regions of the sky. Sir William Herschel's gauges were partly published in the 'Philosophical Transactions.' A number of unpublished ones were found among his papers by Holden and printed in the publications of the Washburn Observatory, Vol. II. The younger Herschel, during his expedition to the Cape of Good Hope, continued the work in those southern regions of the sky which could not be seen in England.

3. A count of the stars by Celoria, of Milan, in a zone from the equator to 6° Dec., extended round the heavens.

From what has been said the question which will first occupy our attention is that of the distribution of the stars with reference to the galactic plane, or rather, the great circle forming the central line of the Milky Way.

The whole sky is divided by Seeliger into nine zones or regions, each 20° in breadth, by small circles parallel to the galactic circle. Region I. is a circle of 20° radius, whose center is the galactic pole. Round this central circle is a zone 20° in breadth, called Zone II. Continuing the division, it will be seen that Zone V. is the central one of the Milky Way, extending 10° on each side of the galactic circle.

The condensed result of the work is shown in the following table:

Column 'Area' shows the number of square degrees in each region, so far as included in the survey. It will be remarked that the catalogues in question do not include the whole sky, as they stop at 24° S. Dec.

Column 'Stars' shows the number of stars to magnitude 9.0 found in each area.

Column 'Density' is the quotient of the number of stars by the area, and is, therefore, the mean number of stars per square degree in each region. In column 'D' these numbers are corrected, for certain anomalies in the magnitudes given by the catalogues, so as to reduce them to a common standard.

Region.	Area. Degrees.	Stars.	Density.	D.
I.	1,398.7	4,277	3.06	2.78
II.	3,146.9	10,185	3.24	3.03
III.	5,126.6	19,488	3.80	3.54
IV.	4,589.8	24,492	5.34	5.32
V.	4,519.5	33,267	7.36	8.17
VI.	3,971.5	23,580	5.94	6.07
VII.	2,954.4	11,790	3.99	3.71
VIII.	1,790.6	6,375	3.56	3.21
IX.	468.2	1,644	3.51	3.14

A study of the last two columns is decisive of one of the fundamental questions already raised. The star density in the several regions increases continuously from each pole (regions I. and V.) to the galaxy itself. If the latter were a simple ring of stars surrounding a spherical system of stars, the star density would be about the same in regions I., II. and III., and also in VII., VIII. and IX., but would suddenly increase in IV. and VI. as the boundary of the ring was approached. Instead of such being the case, the numbers 2.78, 3.03 and 3.54 in the north, and 3.14, 3.21 and 3.71 in the south, show a progressive increase from the galactic pole to the galaxy itself.

The conclusion to be drawn is a fundamental one. The universe, or, at least, the denser portions of it, is really flattened between the galactic poles, as supposed by Herschel and Struve. In the language of Seeliger: "The Milky Way is no merely local phenomenon, but is closely connected with the entire constitution of our stellar system."

This conclusion is strengthened by a study of the data given by Celoria. It will be remarked that the zone counted by this astronomer cuts the Milky Way diagonally at an angle of about 62°, and, therefore, does not take in either of its poles. Consequently, regions I. and IX. are both left out. For the remaining seven regions the results are shown as follows: We show first the area, in square degrees, of each of the regions, II. to VII., included in Celoria's zone. Then follows in the next column the number of stars counted by Celoria, and, in the third, the number enumerated in the *Durchmusterung* in these portions of each region. The quotients show the star-density, or the mean number of stars per square degree, recorded by each authority:

Region.	Area. Degrees.	Number of Stars. Cel.	D. M.	Star-Density. Cel.	D. M.
II.	404.4	27,352	1,230	67.6	3.04
III.	284.6	22,551	932	79.3	3.28
IV.	254.6	29,469	1,488	115.7	5.83
V.	284.6	41,820	1,833	146.9	6.44
VI.	284.6	31,706	1,472	111.4	5.22
VII.	329.5	25,618	1,342	77.7	4.07
VIII.	314.5	22,264	1,184	70.8	3.77

It will be seen that the law of increasing star-density from near the galactic pole to the galaxy itself is of the same general character in the two cases. The number of stars counted by Celoria is generally between 18 and 25 times the number in the *Durchmusterung*.

An important point to be attended to hereafter is that the star-density of the Milky Way itself, as derived from each authority, is between two and three times that near the galactic poles. Very different is the result derived from the Herschelian gauges, which is this:

Region	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Density	107	154	281	560	2019	672	261	154	111

From the gauges of the Herschels it follows that the galactic star-density is nearly 20 times that of the galactic poles. At these poles the Herschels counted about 50 per cent. more stars than Celoria. In the galaxy itself they counted 14 for every one by Celoria. The principal cause of this discrepancy is the want of uniformity of the magnitudes.

The recent comparisons of the *Durchmusterung* with the heavens, mostly made since Seeliger worked out the results we have given, show that the limit of magnitude to which this list extends is far from uniform, and varies with the star-density. In regions poor in stars, all of the latter to the tenth magnitude are listed; in the richer regions of the galaxy the list stops, we may suppose, with the ninth magnitude, or even brighter. Yet, in all cases, the faintest stars listed are classed as of magnitude 9.5. Thus a ninth magnitude star in the galaxy, according to the *Durchmusterung*, is very different from one of this magnitude elsewhere.

DISTRIBUTION OF THE STARS HAVING A PROPER MOTION.

Having found that the stars of every magnitude show a tendency to crowd toward the region of the Milky Way, the question arises whether this is true of those stars which have a sensible proper motion. Kapteyn has examined this question in the case of the Bradley stars. His conclusion is that those having a considerable proper motion, say more than 10″ per century, are nearly equally distributed over the sky, but that when we include those having a small proper motion, we see a continually increasing tendency to crowd toward the galactic plane.

But the irregularity in the distribution of the stars observed by Bradley seems to me to render this result quite unreliable. For every such star Auwers derived a proper motion. And, if these proper motions are considered, their distribution will be the same as that of the stars. To reach a more definite conclusion, we must base our work on lists of proper motions, which are as nearly complete within their limits as it is possible to make them. Such lists have been made by Auwers and Boss, their work being based on their observations of zones of stars for the catalogue of the *Astronomische Gesellschaft*. The zone observed by Auwers was that between 15° and 20° in N. Dec.; while Boss's was between 1° and 5°. To speak more exactly, the limits were from 14° 50′ to 20° 10′ and 0° 50′ to 5° 10′, each zone of observation overlapping 10′ on the adjoining one. Thus the actual breadths were 5° 20′ and 4° 20′. Within these respective limits, Auwers, by a comparison with previous observations, found 1,300 stars having an appreciable proper motion, and Boss 295. But Boss's list is confined to stars having a motion of at least 10″; of such the list of Auwers contains 431. The number of square degrees in the two zones is 1,556 and 1,830, respectively. The corresponding number of stars with proper motions extending 10″ is, for each 100 square degrees:

In Boss's zone, 18.9.
In Auwers's zone, 23.9.

The question whether the greater richness of nearly 25 per cent. in Auwers's zone is real is one on which it is not easy to give a conclusive answer. The probability, however, seems to be that it is mainly due to the greater richness of the material on which Auwers's proper motions are based. The question is not, however, essential in the present discussion.

We now examine the question of the respective richness of proper motion stars in this way:

Each of these zones cuts the galaxy at a considerable angle. Each zone, as a matter of course, has a far larger richness of stars per unit of surface in the galactic region than in the remaining region. We, therefore, divide each zone in four strips, two including the galactic regions and two the intermediate region. The boundaries are somewhat indefinite; we have fixed them by the richness of the total number of stars. For the galactic strips we take in Boss's zone the strip between 5h. and 8h. of R. A. and that between 17h. and 20h. Each of these strips being 3h. in length, the two together comprise one-quarter the total surface of the zone. If the proper motion stars crowd towards the galaxy like others do, then the numbers in the galactic region should be proportional to the total number observed in the region. But if they are equally distributed then there should be only one-quarter as many in the galactic region as in the other regions.

In the case of Boss's zone, the total number of stars observed and of those having a proper motion found in the four regions described are as follows:

	Total Number Observed.	Proper Motions. Actual.	Prop.
Galactic strip, 5h. to 8h.	1,614	24	37
Galactic strip, 17h. to 20h.	1,340	36	37
Intermediate strip, 8h. to 17h.	2,458	124	111
Intermediate strip, 20h. to 5h.	2,831	111	111

The last column contains the number of proper motions we should find if the whole 295 were distributed proportionally to the areas of the several strips. There is evidently no excess of richness in the galactic strips, but rather a deficiency in the strip near 6h., which is accidental.

In the case of Auwers's zone, the galactic strips are those between 5h. and 8h., and again between 18h. and 21h. Here, as in the other case, the galactic strips include one-quarter of the whole area. But, owing to the greater richness of the sky, they include nearly 40 per cent. of the whole number of stars. Then, if the proper motion stars are equally distributed, one-quarter should be found in the region, and if they are proportional to the number of stars observed, 40 per cent. should be within this region. Grouping the regions outside the galaxy together, as we need not distinguish between them, the result is as follows:

	Stars Observed.	Proper Motions. Actual.	Prop.
Galactic strip, 5″ to 8″	1,797	155	157
Galactic strip, 18″ to 21″	1,984	202	157
Outside the galaxy	6,008	901	944

We see that in the strip from 5h. to 8h. there is contained almost exactly one-eighth the whole number of proper motion stars. That is, in this region the stars are no thicker than elsewhere. In the region from 18h. to 21h. there is an excess of 45 stars having proper motions. Whether this excess is real may well be doubted. It is scarcely, if at all, greater than might be the result of accidental inequalities of distribution. Were the proper motion stars proportional to the whole number, there ought to be 240 within the strip. The actual number is 38 less than this.

It is to be remembered that Auwers's proper motions are not limited to a definite magnitude, as were Boss's, but that he looked for all stars having a sensible proper motion. The question, what proper motion would be sensible, is a somewhat indefinite one, depending very largely on the data. It may, therefore, well be that the small excess of 45 found within this strip is due to the fact that more stars were observed and investigated, and, therefore, more proper motions found. Besides this, some uncertainty may exist as to the reality of the minuter proper motions.

The conclusion is interesting and important. If we should blot out from the sky all the stars having no proper motion large enough to be detected, we should find remaining stars of all magnitudes; but they would be scattered almost uniformly over the sky, and show no tendency toward the galaxy.

From this again it follows that the stars belonging to the galaxy lie farther away than those whose proper motions can be detected.

DISCUSSION AND CORRESPONDENCE.

NEEDLESS OBSCURITY IN SCIENTIFIC PUBLICATIONS.

After having called attention in a recent issue of the Monthly to certain circumstances leading to the retardation of science, we may now venture to discuss a few of the particular ways in which a scientific writer can perplex his brother workers. Nobody supposes that the ordinary author wishes his contribution to be regarded as a sort of 'puzzle-page,' but that is the effect often unintentionally produced. The causes of this are of diverse nature. In these days of ultra-specialization and of hurry, a specialist often inclines to address himself solely to his fellow-specialists, or to an even smaller circle—his fellow-specialists of the moment, forgetting those that may come at a later day. There may be in the whole world but two men who will take the trouble to read his paper, or who would really understand its bearings. Whether from modesty or from pride, from desire of brevity or from laziness, our specialist addresses his remarks solely to those two. The student who is not yet quite at the same level, the professor who tries to keep abreast of his subject in general, the worker who comes a few years later and sees things from an altered point of view; all these find themselves 'out of it,' and long investigations are often necessary before they can be sure of the author's meaning.

The same obscurity is achieved by those whose humility leads them to think other folk more learned than themselves, whereas, in writing scientific papers, as in lecturing, political speaking or leader-writing, one should remember the old request of the listener, 'Of course, I know; but speak to me as if I didn't know,' and the practical warning of the playwright, 'Never fog your audience.' Or it may be not so much humanity as the short-sighted egoism of the enthusiast, who assumes that his little corner must needs be known to all the world. But it is perhaps not so important for our present purpose to discuss the state of mind conducing to obscurity, as it is to point out instances.

Here is a common one. In stratigraphical geology everyone is supposed to know the names of the great systems; and if the names of their main subdivisions are less familiar, they can at all events be readily hunted up in a text-book. But there are an extraordinary number of names nowadays invented for quite small divisions, or for purely local rocks, and many of these names convey of themselves very little meaning. Is there a geologist living who can say offhand what is meant by all or even half of the following names, which are taken at random from some recent publications: Plaisancien, Schlier, Catadupa beds, Calder Limestone, Hornstein, Oberen Mergel-schichten, Feuerstein, Scaglia rosata, Knorrithone, Ferrugineus-schichten, Deer Creek Limestone, Semmeringkalke, Diceratien, Moscow shale, Lenneschiefer? The language or the locality may guide one to a rough determination, or a few names of fossils may be an indication to the expert; but when these names are introduced without further explanation, as is actually the case in many of the papers from which these instances are quoted, then perplexity followed by irritation is the natural result. The names just cited are of diverse nature. Calder Limestone and Lenneschiefer are terms of local application and perfectly justifiable; all that we ask is a hint, however guarded, as to the probable horizon of these restricted rocks in comparison with a better known geological series. Plaisancien and Diceratien are minor divisions on the time-scale, which are doubtless familiar enough to the students of Pliocene or of Middle Jurassic rocks, but which may cause the ordinary geologist a journey to the public library and prolonged search. Feuerstein and Oberen Mergel-schichten are terms the meaning of which is absolutely governed by the context, or by the place in which the author happens to live; stratigraphically considered, there can be no value in such words as firestone and upper marl-beds. As for Knorrithone, it is simply a vulgar barbarism, the offspring of specialism and illiteracy, which may do well enough for the notebook of a field-geologist, but is out of place in the official publication from which it is culled. A couple of friends may talk of the 'Bel. quad. beds' or the 'corang zone,' but a sense of respect for their science, no less than a feeling for foreign readers, should keep these colloquialisms out of their serious publications.

Akin to the instance last mentioned is the slovenly habit indulged in by many zoologists of referring to a species by its trivial name alone, without mentioning the generic name, which is an equally essential component of the name of the species. This is especially a custom with entomologists of the baser sort, who, in matters nomenclatorial, seem to be capable of anything. With them as with other classes of naturalists, this apparent familiarity is probably due to their ignorance that the same has been applied to species of, it may be, twenty other genera. They would be less prone to the habit if they knew that zoologists of wider knowledge regard it as the hall-mark of provincialism.

What is true of geological formations and of species applies also to genera. Until the reform proposed by Prof. A. L. Herrera is adopted, the scientific names of animals and plants will not be self-explanatory. How many scientific men, asks the ingenious Mexican, outside the systematists of the group, understand what is meant by *Spinolis zena?* Is it a mushroom, an ant, a rose, a spider or a monkey? Some names are intended to indicate the class to which the plant or animal belongs; thus a name ending in *crinus* is pretty sure to belong to a crinoid, one ending in *ceras* may be a fossil mollusc belonging to the Ammonoidea; *graptus* is fairly certain to be a graptolite, and *saurus* a fossil reptile. The principle might well be extended, and systematists should at least refrain from applying a termination tacitly ear-marked for a particular group to a new genus belonging to another group. If the name of an Echinoderm genus ends in *cystis*, the reader naturally supposes that the animal belongs to the extinct class Cystidea, and he is not a little disturbed if he discovers that it is a recent sea-urchin. However, these things are so, and will continue to be so, until people realize the responsibility that rests on the proposer of a new name. It is unnecessary to do more than recall the fact that, owing to inadvertence or ignorance, the same name has often been applied to more than one kind of organism, and may for years continue to be used in both senses, while many names well-known in zoology occur also in botanical nomenclature.

The point we would emphasize is this: Considering the difficulties that inevitably spring from such a state of affairs, it is the more incumbent on writers to explain the nature or systematic position of the organism about which they are writing. Merely to give the name, even if it chance to be correct and elsewhere unappropriated, is not enough. Still less is this satisfactory when the name has been used in more than one sense. How often does a zoologist spend time and trouble in looking up a paper on some genus in which he believes himself to be interested, only to find that the subject of the article is some different animal, or even a plant, bearing the same name. To show how real a grievance this may be, let us give an actual case. Last year two naturalists presented to the French Academy of Sciences an account of their investigations into the perivisceral fluid of *Phymosoma*. The mention of perivisceral fluid indicates that *Phymosoma* is an animal and that it possesses viscera; also that it is not a fossil. But neither the title nor the paper itself gives any further hint as to the zoological position of the creature. We must, therefore, have recourse to some work of reference, such as Scudder's 'Nomenclator,' and here we find *Phymosoma* given as the name of a sea-urchin, better known as *Cyphosoma*. This may be the reason why the paper in question has been indexed in a well-known bibliography under the head of Echinoderms. But on inquiring further into the matter we find, first, that the sea-urchin *Phymosoma* is only known as a fossil, or if it does occur in the recent state, it is by no means so common as readily to afford material for biological investigation; secondly, that the phenomena observed are not such as we have hitherto been taught to associate with the Echinoidea. These considerations, while not excluding the possibility that the *Phymosoma* of the paper is a sea-urchin, arouse our suspicion. But what is to be done? We ransack the works of reference in a great library, we appeal to our zoological friends, specialists in various branches, professors, bibliographers. In vain. The resources of civilization appear exhausted, and we . . . 'Why on earth don't you write to the authors?' says some superior practical person. My dear sir, are you not aware that the address of a scientific writer is never affixed to his publications, that if he is a Frenchman with a common name his initials are invariably replaced by M., and that, with all respect to Messrs. Cassino, Friedländer and other benefactors of scientific humanity, it is still as difficult to hunt down a budding author as to solve any other problem of scientific nomenclature? Before risking a letter that, even should it arrive, may elicit no reply, it occurs to us that the authors, being French, are likely to follow the names used by Prof. Edmond Perrier in his large 'Traité de zoologie.' Unfortunately this work, since it is still in progress, has as yet no index. However, by dint of wading through the probable groups of animals, we are at last rewarded by finding *Phymosoma* among the Gephyreans. No doubt a specialist on that small section of the worms will think all this fuss highly absurd, for the name *Phymosoma* is naturally quite familiar to him. So much the worse, since no Gephyrean has a right to it. True it is that A. de Quatrefages, in 1865, obscurely printed the name *Phymosomum* (not *Phymosoma*), as applicable to a subgenus of the Gephyrean *Sipunculus;* but the name *Phymosoma* was proposed for the sea-urchin by d'Archiac and Haime, in 1853. If both names be objected to on the score of etymology, and the more correct form *Phymatosoma* be suggested, confusion is certain to arise with a name given to a beetle in 1831 by Laporte and Brullé, viz., *Phymatisoma*, which is, in fact, though erroneously, frequently written *Phymatosoma*. At every turn, then, there is risk of that very confusion which it is the object of scientific nomenclature to eliminate.

Now it is distinctly to be understood that this narration has not exaggerated the facts one jot, and it is clear that the experience may have been shared by many others. All this loss of time, vexation of spirit and promulgation of actual error might have been spared by the insertion of the single word 'Gephyrêen' in the title, or, at least, by some intimation in the paper itself. Justly then do we stigmatize heedlessness in such matters as an agent in the retardation of science.

An Editor.

SCIENTIFIC LITERATURE.

BOTANY AND AGRICULTURE.

THE second volume of the 'Cyclopedia of American Horticulture,' edited by Prof. L. H. Bailey, has made its appearance from the press of the Macmillan Company and shows the same general excellence attributed to the first volume already noticed in this magazine. Subjects under the initials E. M. are treated in the last volume. Among the most notable topics of broader interest are Ferns, Horticulture, Greenhouses and the zonal regions in the various States discussed. A biographical sketch of Asa Gray, by Professor Bailey, carries with it a touch of interest due to the acquaintance of the editor with that eminent botanist. By the most recent census it has been shown that nearly 2,500 species of native American plants have been brought into cultivation. Dr. Wilhelm Miller gives a piquant description of the manner in which the Cyclopedia was written and edited in an article in the 'Asa Gray Bulletin' for August, 1900, of which the following paragraph is fairly characteristic: "The rest is hard work, and every man to his own method. Professor Bailey uses any or all methods, or no method; usually the latter. He is too busy getting done to think about the best way. Allamanda he wrote in sixty minutes by the clock. It is an article of about 640 words, with eight good species, and accounts for ten trade names. The plants are not merely described; they are distinguished. Eleven pictures were cited. Not less than twenty books were consulted. Four dried specimens were named. This was the first genus he tackled."

A MUCH-NEEDED introduction to vegetable physiology (J. & A. Churchill), by Dr. Reynolds Green, of the Pharmaceutical Society of Great Britain, has just appeared. The author discusses the general anatomy of the plant and takes up the general principles of physiology in a very attractive manner, although in certain sections the conciseness of the elementary text is not adhered to. It is a readable book, and the author is particularly apt in his sections dealing with respiration and fermentation. It is distracting, however, to find Professor Green in disagreement with himself concerning the dialysation of the enzymes, a group of substances which have been the subject of important investigations by Professor Green for a number of years. This book will undoubtedly find its way into every botanist's library in a few years.

THE annual report of the State Geologist of New Jersey, for 1899, upon Forests is a carefully indexed volume of 328 pages (State Printers), with 31 plates and some text figures. The report is in four principal divisions. C. C. Vermeule gives a general description of the forested area and the conditions of the timber in the several natural divisions of the State, which is well set forth by the aid of well-colored maps. Prof. Arthur Hollick treats the relation between forestry and geology in New Jersey and divides the State into three zones; that of deciduous trees, that of coniferous trees and an intermediate formation. Attention is also paid to the evolution of the species of trees as exhibited by fossil specimens. Prof. J. B. Smith discusses the rôle of insects in the forest. Dr. John Gifford reports on the forestal conditions and silvicultural prospects of the coastal plain of New Jersey. These, with other matter given by the State Geologist, John C. Smock, form a splendid volume of very great practical value as well as of scientific interest.

THREE important bulletins (Reports Nos. 5, 7 and 11) of the U. S. Dept. of Agriculture, dealing with the investigations upon vegetable fibers, have been recently mailed to correspondents. It is notable that comparatively slow progress has been made in the perfection of methods of cultivation and use of new fiber plants. The time seems at hand for the making of extended and serious attempts to utilize the fiber furnished by ramie and other plants, and the importance of adding a staple of this kind to the products of the country would justify any reasonable expenditure of time and experimentation.

THE indexes and bibliographies which are being issued by the United States Department of Agriculture are among the most complete and comprehensive in the fields which they cover, and will be found helpful to persons who are pursuing studies in the various branches of science related to agriculture. The latest contribution in this line is an 'Index to Literature relative to Animal Industry,' prepared by Mr. George F. Thompson. The volume covers the publications issued by the Department of Agriculture from its establishment in 1837 to 1898, and comprises 676 pages, with some 80,000 entries. It includes a wide range of subjects, relating to the care and management of domestic animals, diseases and their treatment, statistics of different kinds of live stock, and investigations upon animal products such as milk, butter, cheese, eggs, wool, meats, etc. In these lines it renders available for convenient reference a large amount of scientific investigation, much of it unsurpassed in its line, which is so scattered through various bulletins and reports as to be easily lost sight of, and difficult for one unfamiliar with the publications of the Department to bring together.

NEUROLOGY, PSYCHOLOGY AND EDUCATION.

THE eighth volume of the 'Science Series,' edited by Professor J. McKeen Cattell and published by the Putnams, is Professor Jacques Loeb's 'Comparative Physiology of the Brain and Comparative Psychology.' The author is known as an able investigator of the physiology of the invertebrates and a thinker of daring genius. His book is in no sense a mere compend; it has the life and vigor natural to a student's presentation of his own research and theories. Professor Loeb's aim is to analyze the behavior of animals, roughly attributed to the nervous system, into elements, and to seek the definite factors that account for these elementary reactions; to replace the various hypothetical accounts of the nervous mechanism by the theory that it is a complex of a number of largely independent segmental organs; and to pave the way for an explanation of nervous action by definite laws of physical and chemical change. The book is thus an important example of the present attempts of students of life-processes to reduce physiology to the more elementary sciences of matter.

IN 'Fact and Fable in Psychology' (Houghton, Mifflin & Co.), Professor Joseph Jastrow reprints with some alterations a number of essays. The author is eminent among psychologists for his original research, and his clearness and skill in exposition are already known to readers of the POPULAR SCIENCE MONTHLY, in which most of these essays originally appeared. His wide knowledge and clear judgment fit him admirably to treat the rather delicate subjects with which his book is concerned, namely, that group of facts which arise in our minds at the word 'occult,' matters which have received such diverse treatment by both psychologists and laymen. They are directly dealt with in the essays on 'The modern occult,' 'The problems of psychical research,' 'The logic of mental telegraphy' and 'The psychology of spiritualism,' while those entitled 'The psychology of deception,' 'Hypnotism and its antecedents,' 'The natural history of analogy,' 'The mind's eye' and 'A study of involuntary movements' throw light upon the general characteristics of the phenomena involved and the mental attitudes which people take toward them. The information given about the means taken by those whose interest it is to mislead observation, about the inevitable influence of our previous experiences, our temporary frame of mind and the 'unconscious logic of our hopes and fears' on our sensations and judgments, and about the tendency to make unconsciously expressive movements, is scientifically valuable, and is attractively set forth. The attitude taken toward Christian science, spiritualism, thought-transference and veridical hallucinations is, as would be expected, sane and consistent. There is, too, a pleasing courtesy and absence of any pharisaical air of superiority in the criticisms. It is Professor Jastrow's good fortune to possess, in addition to the knowledge of the criteria of evidence and inference in human phenomena proper to a scientific psychologist, an insight into the interests and motives of men outside his own class. This makes his comments on the types of interest in psychical research and the factors predisposing to belief in thought-transference or in spiritualism of especial value. There is a growing class, at least among psychologists, who have been so affected by the quantity of talk about psychical research and the quality of the work done in it, as to be fairly careless whether there be spirit communication or no, whether the adepts of spiritualism be knaves or fools or neither or both. Even to these Professor Jastrow's shrewd comments on the raison d'être of the belief will be interesting.

Barring some traces of a too Wordsworthian sentimentalism, nothing but praise can be bestowed upon Professor MacCunn's new volume, 'The Making of Character' (Macmillan). Pedagogy, even if it can be dignified by the name of science, has suffered sadly at the hands of its friends. Loose, unsystematic, fallacious and frothy books abound; screaming too often takes the place of close reasoning, wishy-washy guessing of sober investigation. A mere enumeration of MacCunn's main divisions shows how far he has advanced beyond this. His treatment falls into four principal parts, dealing with Congenital Endowment, its nature and treatment; Educative Influences; Sound Judgment; Self-development and Self-control. As is to be expected from one of British training and associations, the social aspects of the theme are reviewed most successfully. The English distaste for psychology in its modern developments limits the discussion of congenital endowment somewhat obviously. But, take it for all in all, a wiser handbook for parents and teachers, or a more inspiring and sensible *vade mecum* for the general reader would be hard to find. Incidentally, the discussion throws some little light on the old question as to the relative educational value of the 'humanities' and the 'sciences'; but only incidentally.

THE PROGRESS OF SCIENCE.

We again direct attention to the bills before Congress for the establishment of the National Standardizing Bureau, the functions of which shall consist in the custody of the standards used in scientific investigations, engineering and commerce; the construction, when necessary, of such standards, their multiples and submultiples; the testing and calibration of such standards and standard measuring apparatus; the solution of problems arising in connection with standards and the determination of physical constants and the properties of materials, when such data are of great importance and are not to be obtained of sufficient accuracy elsewhere. The establishment of a National Physical Laboratory has been under discussion in this country for almost twenty years, and although the urgent need of such an institution has been generally recognized, the spasmodic efforts in that direction have heretofore either lacked sufficient support from those most vitally concerned or have not taken into account existing conditions. The bill submitted last spring by the Secretary of the Treasury was evidently framed after most careful consideration of the question from its legislative as well as from its scientific and technical aspects. It is believed that its scope is as broad as could be reasonably expected at present, even by the scientific interests, and while the bureau is to be placed under a director having, as is proper, full control of its administration, there is also provided a board of visitors, consisting of five members prominent in the various interests involved, and not in the employ of the Government, the board serving thus in a supervisory capacity, and at the same time eliminating by its high standing, and by its close relationship to the technical and scientific bodies of the country, the effect of 'political influence' in the administration of the bureau.

The prospects for favorable action by Congress seem most promising owing to the hearty cooperation of all interested, the measure having received the indorsement of the National Academy of Sciences, the American Association for the Advancement of Science, the American Physical Society, the American Chemical Society, the American Institute of Electrical Engineers, the Congress of American Physicians and Surgeons, the National Electric Light Association and other prominent organizations. It has also been indorsed by the scientific and technical bureaus of the Government, by institutions of higher learning through members of their scientific and engineering faculties, and by manufacturers of scientific apparatus, and it has appealed especially to the electrical fraternity. Although introduced towards the close of the last session, the bill was favorably reported to the House by the unanimous vote of the Committee on Coinage, Weights and Measures. The Senate bill is now before the Committee on Commerce, which, it is hoped, will repeat the action of the House Committee. The immediate passage of the measure cannot be too strongly urged, even with due regard to the great volume of other important business awaiting action during the present short session, especially as the bill could be disposed of in a very short time, containing, as it does, nothing which could possibly provoke partisan discussion.

The importance of the National Physical Laboratory is now universally recognized. Germany attributes its wonderful strides in the manufacture and export of scientific apparatus principally to the splendid work of the Imperial Physico-Technical Institute. The recognition of this fact on the part of English manufacturers was one of the most potent influences which last year induced Parliament to provide for the establishment of a similar bureau. Russia, about to adopt the metric system, has also established a Central Chamber of Weights and Measures, with Professor Mendelejeff at its head. At the International Congress of Physicists, held at Paris last summer, Professor Pellat read a paper on the National Physical Laboratory as a factor in the industrial development of a country, which created such a strong impression that a motion was unanimously passed in favor of the establishment of such institutions in all countries not already provided therewith. The United States, far in the van in so many respects, cannot afford to lag behind in a matter of such vital and universally recognized importance.

THAT the United States is now ready to take a place beside Germany in the production of scientific instruments is demonstrated by what has already been accomplished in the case of astronomy. In proof of this statement we may refer to the recently-issued catalogue from the works of Messrs. Warner & Swasey, at Cleveland, Ohio. This is a tangible witness that the United States is, in respect of the making of astronomical instruments of all sorts, quite out of the leading strings of the Old World. The work here exhibited is strictly of the first class. The instruments are, in the first place, designed so as to fit the uses to which they are to be put, not only in their general form, but also in their details. The execution of the mechanical work is also of the very highest quality. Lastly, we note the very significant fact that the designs of the instruments are, in a high degree, elegant and artistic. It is a far cry from the stone-adze of the paleolithic man to the Ferrera blade; and the evolution carries a lesson with it. Weapons and tools must first of all be fitted to their uses. Their design must be appropriate to the desired end. After the end is plainly comprehended improvements are made in the mechanical processes of manufacture. Last of all it is the desire of the artisan to become an artist—to make his work beautiful. The evolution of the weapon and of the tool follows laws which govern that of the scientific instrument also. Long centuries elapsed between the quadrants of Alexandria, Samarkand and Uraniborg, and the elegant designs of the instruments of the great observatory of Pulkowa. It seemed that almost the last word had been said when Struve and Repsold installed their joint productions in the Imperial Observatory, lavishly endowed by the Russian Emperor. It is highly significant, then, to find their work surpassed in a distant country across the ocean—in the country that hardly possessed an astronomical establishment of any sort when Pulkowa was founded. And it is gratifying and startling to note that two New England mechanics without hereditary training, advised by our own astronomers, have excelled the work of the famous house of Repsold, now in its third generation, advised and counseled, as it has been, by the most skilled astronomers of Europe.

A STUDY of the catalogue in question will show that in all respects—in general design, in detail and in artistic beauty—instruments now made in this country are superior to any made in the world. The book referred to is entirely composed of plates, showing equatorial mountings, micrometers, chronographs, transits, zenith telescopes, alt-azimuths, meridian-circles and dividing-engines made at Cleveland; and of views of observatories in various parts of the world furnished with instruments or domes from the same works. The observations made by some of the instruments referred to at the United States Naval

Observatory, at the Lick, Yerkes, Flower, Dudley and other establishments, are the best evidence of success. This book marks an epoch in the history of practical astronomy in America and has more than a passing value. A country that has produced the object-glasses of the Clarks and of Brashear, the sextant of Godfray, the zenith-telescope of Talcott, the chronograph of the Bonds, the break-circuit chronometer of Winlock, the diffraction-gratings of Rutherfurd and of Rowland, the mountings of Warner and Swasey—to say nothing of many minor inventions and devices—has already taken the highest place in one important field. Who can doubt that the next century will see a corresponding progress in other branches of astronomy? The oldest science may yet find its chief center in the youngest country.

The annual report of the Secretary of Agriculture has come to be regarded as of special interest to men of science, inasmuch as it is devoted very largely to a résumé of the scientific investigation which is being carried on under his direction. The high appreciation which Secretary Wilson has of the economic value of investigation along lines related to agriculture is evidenced by his cordial support of such work, and the spirit of inquiry which he has inspired throughout the Department. His practical experience as a farmer and his active connection with experiment-station work before coming to the Department have made him quick to see the application of a new discovery and have enabled him in many instances to suggest new lines of inquiry. The result has been a wider appreciation of the department as an institution for research, and the securing of greatly increased financial support from Congress for its development along this line. It is now recognized by those familiar with it as being one of the largest and best equipped institutions for organized research in this country, and in the special lines in which it is engaged it occupies a leading position. Some of the newer features which Secretary Wilson mentions are experiments in plant breeding, directed toward the production of hardier orange hybrids for the Southern States and corn of earlier maturity and more resistant to drought and smut; studies of the true cause of the fermentation of tobacco in curing, which have suggested important modifications of the old method of handling; experiments in growing Sumatra tobacco in the Connecticut Valley, with the aid of shade, and the Cuban types of cigar-filler in Texas, the indications for the success of both of which are now considered very promising; the extensive preparation and testing of serums for combating hog cholera and tetanus or lockjaw, and of vaccine for the disease known as black-leg; field and laboratory studies of plants supposed to be poisonous to sheep on the Western ranges, to determine the actual causes of the heavy losses of stock, and to find remedies for poisoned animals; and the investigation of a number of the more troublesome plant diseases, among them diseases of the sugar beet, which are reported to have caused a loss of over two million dollars in California.

The Department's policy of sending explorers to various parts of the world to search out new plants or varieties likely to prove valuable in this country has already resulted in a long list of promising introductions, including especially the Kiushu rice from Japan, which, it is believed, will insure the success of the rice industry in this country, and varieties of wheat from Russia, Hungary and Australia, which are superior in milling qualities, resistance to rust and yield. The successful introduction into California of the insect which fertilizes the flowers of the Smyrna fig, resulting the past season in the production of six tons of these figs of the highest grade of excellence, promises the development of another important industry. Among the larger operations in the field the studies of the use and economy of irrigation waters have attracted widespread attention throughout the irrigated region, and have indicated that there is great opportunity for improvement in the methods and use of water. The result has been a great desire for an accurate and complete showing of facts, on which permanent improvement alone can be based; and wherever the investigations have been undertaken, private individuals and local authorities have lent their hearty cooperation. The preparation of 'working plans' for forest owners, to guide them in caring for and cutting off their forests in a more systematic manner, has proved so popular that the demands last year exceeded the resources of the Division of Forestry. Requests for these plans cover over fifty million acres of forest, and come from private owners, large consumers of timber for manufacturing purposes and public custodians. The Secretary points out the encouraging fact that public interest in forestry is at present not only keener and more widespread than at any time heretofore, but 'is growing with a rapidity altogether without precedent.' Quite large increases in appropriation for these irrigation investigations and lines of forestry work are recommended, as well as for soil surveys with reference to the distribution of alkali in the West, location of tobacco soils and other questions. Cooperation with the agricultural experiment stations has now become a prominent feature of the department work, and is heartily endorsed. Congress has recognized this in recent years by giving funds for special investigations to be carried on in cooperation with the stations. This has naturally brought the Department into much closer relations with the stations, and has tended to secure greater stability for the operations of the stations and an increased measure of influence with their own constituents. Not only is such cooperation in the interests of economy, but it strengthens the efficiency of both the Department and the stations as organizations for the improvement of agriculture. As a result of the investigations made the past year of the agricultural conditions in Hawaii and Porto Rico, the Secretary recommends the establishment of experiment stations in these islands.

The growing interest in the work of the National Department of Agriculture is evidenced by the rapidly increasing demand for its publications. Last year three hundred and twenty new publications were issued, and the number of copies printed was considerably over seven million. This was far in excess of any previous year, both in number of publications and total edition. Notwithstanding this fact, the Department was obliged to refuse many applicants for its bulletins and reports, the number of refusals being ten times more numerous than six years ago, when the total edition was only half that of the past year. In addition to these more technical publications, one hundred and eight farmers' bulletins, including reprints, were issued, aggregating two and a third million copies. This furnishes some idea of the enormous activity of the Department in the diffusion of knowledge. But with the growth of its investigations and the consequent increase of material for publication, Secretary Wilson shows that there has not been a commensurate increase in the appropriation for printing, which has now become inadequate to the prompt diffusion of the information acquired. He accordingly requests a material increase in the printing fund for another year, but he questions whether, without some change in the present system of distributing publications, it will be possible to maintain a supply equal to the demand. The distribution has been restricted in several ways within recent years, and mailing lists have been kept revised to prevent waste. In the interest of the greatest usefulness of the Department to applied science and to its constituents, the policy should, if possible, remain sufficiently liberal to provide copies to such persons as are especially interested in the publications, and make application for them. The problem is undoubtedly a perplexing one, and unless Congress makes liberal additions to the printing fund, is likely to prove more troublesome with succeeding years.

The present organization of the Department of Agriculture is for the most part one of divisions quite independent of each other in their operations. These are not generally grouped into bureaus, as is the case in other departments of the Government, but each is responsible directly to the Secretary of Agriculture. The lines of work of different divisions very naturally overlap, and as new lines are taken up, troublesome questions arise as to their assignment. The condition is one which calls for close coöperation along the broadest lines possible, but the segregation which has resulted from the multiplication of divisions has not conduced to this. The Secretary believes that the best interests of the Department now demand aggregation, rather than segregation, and that the time has come to bring together the related lines of work. In accordance with this policy he announces the affiliation of four divisions, closely allied by the nature of their work, under the title of Office of Plant Industry, with a director in charge. How far anything like a reorganization of the Department will be carried is at present uncertain, but it is felt that the movement is in the direction of progress, and will almost inevitably be extended sooner or later. In point of location, furthermore, the scientific divisions are widely separated, the laboratories being for the most part in separate rented buildings, removed some distance from the executive offices and the library. These buildings are regarded as temporary makeshifts, and are wholly inadequate to the present needs, several of them being dwelling houses, with small, poorly-lighted rooms. The Secretary makes a strong plea for a laboratory building, and submits plans for a fire-proof structure costing approximately $200,000. He points out that the items of rent and other expenses connected with the present laboratory quarters amount to about $10,000 a year, and that the Department is far behind many State institutions in its laboratory facilities. The excellent equipment which is being brought together in these laboratories, the extensive collections and the valuable records of investigation, are jeopardized by their present location. It seems eminently fitting that the National Department of Agriculture should be provided with the very best facilities for the important and far-reaching work which it is conducting.

The account of the extensive and varied operations of the United States Commission of Fish and Fisheries, as contained in the annual report of the Commissioner for 1900, shows a growth, as remarkable as it was unforeseen, during the three decades that have elapsed since Professor Baird was appointed "to prosecute investigations with a view of ascertaining what diminution in the number of food-fishes of the coast and the lakes of the United States has taken place, to what causes the same is due, and what protective, prohibitory or precautionary measures should be adopted." A summary by the Commissioner of the work of the different divisions of the service is followed by detailed accounts of the propagation and distribution of food-fishes, the biological investigations, the collection of statistics of the commercial fisheries, the study of the methods of the fisheries, the inspection of the fur-seal rookeries of the Pribilof Islands, and the operations of the vessels, including a narrative of the recent South Sea expedition of the *Albatross* under Mr. Agassiz. The scientific investigations conducted in the field, on the vessels and in the laboratories pertain to almost every phase of aquatic biology. Much of the biological work is naturally and necessarily addressed to practical questions connected with the economic fisheries and fish-culture, but facilities are freely afforded for the prosecution of purely scientific studies; and it may be noted that an unusually large number of able investigators have availed themselves of the advantages which the laboratories of the Commission afford. Among the recent acts of Congress pertaining to the scientific work have been the appropriation of a liberal sum for special experiments and investigations regarding the clam and lobster; the establishment of a new marine laboratory at Beaufort, North Carolina, and the creation of the position of fish pathologist.

The results of the early investigations by the Commission soon led to the institution of artificial propagation as the most feasible and effective form of aid that could be rendered by the Federal Government for the maintenance of the food-fish supply; and for many years fish-culture has been the leading branch of the Commission's work. Thirty-five hatching stations in twenty-five States were operated in 1900, and new hatcheries are established at nearly every session of Congress. The output of young and adult fishes reached the extraordinary number of 1,164,000,000, which represent practically all the important food and game fishes of our rivers and lakes, and several marine species, those receiving most attention being the shad, the salmons of both coasts, the various trouts, the whitefish, the wall-eyed pike, the black basses, the cod, the winter flounder and the lobster. The important feature of this work is that a very large proportion of the ova which are handled, being taken from fish that have been caught for market, would have been lost but for the Commission's efforts; in the year covered by the report, fully nine-tenths of the output were from this source. The Commission is one of the most popular of the Government bureaus, and its popularity will undoubtedly increase as the objects, methods, limitations and results of its work become more generally known.

Students of economics are familiar with the apparently far-fetched hypothesis that periods of economic crises or hard times may be related to the fluctuations of the sun-spots. There is now reason to believe that the hypothesis is not a rash guess based on some specious coincidences. Sir Norman Lockyer and Dr. W. J. S. Lockyer have investigated the connection between sun-spots and the weather, and claim, in a paper read before the Royal Society on November 22, that increased and decreased areas of the spots on the sun may be indicative of fluctuations in the heat it gives out and that the solar conditions they indicate are approximately contemporaneous with pulses of greater rainfall. The Lockyers found that when the area of spots was greatest the unknown lines of the spectra of the sun-spots were widened; when the area was least the known lines were widened. From this they infer that a maximum area of sun-spots goes with a great increase of temperature. They thus find periodic changes of solar temperature, a maximum being followed by a mean condition, and that by a minimum. The years 1881, 1886-7 and 1892, for instance, would be, according to these spectrum records, years of mean temperature condition. The fluctuations in rainfall in India, Mauritius, Egypt and elsewhere were then compared with the spectrum records. Heavy rains generally occurred in India in the year following the mean condition, that is in dates near but somewhat earlier than the maxima and minima for sun-spots. The fall of snow followed the same rule. Between these pulses of great rainfall there are periods of drought, which correspond to the intervals between the maxima and minima of solar temperature indicated by the fluctuations in the spots. All the Indian famines since 1836 have occurred in such intervals, if we assume that maxima have appeared every eleven years. The famines of 1836, 1847, 1860, 1868-69, 1880 and 1890-92 fit almost exactly with the central points or mean conditions between minima and maxima which occurred in 1836, 1847, 1858, 1869, 1880 and 1891. So also the mean conditions between maxima and minima which came in 1852-53, 1863-64, 1874-75 and 1885-86, are very close to the famine years 1854, 1865-66, 1876-77 and 1884-85. The possibility of predicting famines in India is too obvious for comment. The present famine is, according to the Lockyers, to be explained by abnormal solar temperature. A mean temperature would, acording to precedent, have been reached in 1897 or 1898, but observations of the spectrum show that it has not even yet been reached. To the absence of the minimum condition, which should have obtained in 1899 and caused rain from the southern ocean, the present famine is due.

AMONG recent events of scientific interest we note the following: Professor W. W. Campbell has been elected director of the Lick Observatory, in the room of the late Professor James E. Keeler.—Otto H. Tittman, assistant superintendent of the United States Coast and Geodetic Survey, has been promoted to the superintendency, vacant by the resignation of Dr. Henry S. Pritchett, to accept the presidency of the Massachusetts Institute of Technology.—The vacancy caused by the death of William Saunders, for the past thirty-eight years superintendent of Experimental Gardens and Grounds, United States Department of Agriculture, has been filled by the appointment of B. T. Galloway, who in turn has been succeeded by Albert F. Woods as chief of the Division of Vegetable Physiology and Pathology.—President D. C. Gilman, of the Johns Hopkins University, has privately intimated to the trustees his intention of resigning at the close of the present academic year, which will complete twenty-five years of service since the opening of the university in 1876.—Sir William Huggins, the eminent astronomer, has succeeded Lord Lister as president of the Royal Society. The medals of the Society have been presented as follows: The Copley Medal to M. Berthelot, For. Mem. R. S., for his services to chemical science; the Rumford Medal to M. Becquerel, for his discoveries in radiation proceeding from uranium; a Royal medal to Major MacMahon, for his contributions to mathematical science; a Royal Medal to Prof. Alfred Newton, for his contributions to ornithology; the Davy Medal to Prof. Guglielmo Koerner, for his investigations on the aromatic compounds; and the Darwin Medal to Prof. Ernst Haeckel, for his work in zoology.—Lord Avebury has given the first Huxley Memorial Lecture, which the Anthropological Institute of London has established to commemorate Huxley's anthropological work.—It is proposed to found two memorials in honor of the late Miss Mary Kingsley, one a small hospital at Liverpool for the treatment of tropical diseases and one a society for the study of the natives of West Africa.—The death is announced of Dr. John Gardiner, until recently professor of biology in the University of Colorado, and of Dr. Adolf Pichler, formerly professor of geology at the University at Innsbrück, and an eminent German poet and man of letters.—Mr. D. O. Mills, of New York, has promised the University of California about $24,000, to defray the expenses of a two years' astronomical expedition from the Lick Observatory to South America or Australia, the object of which is to study the movement of stars in the line of sight.—Surgeon Major Reed and a board of experts are continuing the investigation into the propagation of yellow fever by mosquitoes, and an experimental station will be established outside Havana.—Tufts College will open at South Harpswell, Me., next summer, a small marine biological laboratory under the direction of Prof, J. S. Kingsley.

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HUXLEY'S LIFE AND WORK.*

By the Right Honorable Lord AVEBURY, D. C. L., LL. D.

I ACCEPTED with pleasure the invitation of your Council to deliver the first Huxley lecture, not only on account of my affection and admiration for him and my long friendship, but it seemed also especially appropriate as I was associated with him in the foundation of this Society. He was President of the Ethnological Society, and when it was fused with the Anthropological we, many of us, felt that Huxley ought to be the first President of the new Institute. No one certainly did so more strongly than your first President, and I only accepted the honor when we found that it was impossible to secure him.

But the foundation of our Institute was only one of the occasions on which we worked together.

Like him, but, of course, far less effectively, from the date of the appearance of the 'Origin of Species,' I stood by Darwin and did my best to fight the battle of truth against the torrent of ignorance and abuse which was directed against him. Sir J. Hooker and I stood by Huxley's side and spoke up for Natural Selection in the great Oxford debate of 1860. In the same year we became co-editors of the 'Natural History Review.'

Another small society in which I was closely associated with Huxley for many years was the X Club. The other members were George Busk, secretary of the Linnean Society; Edward Frankland, president of the Chemical Society; T. A. Hirst, head of the Royal Naval College at Greenwich; Sir Joseph Hooker, Herbert Spencer, W. Spottiswoode,

* The first 'Huxley Memorial Lecture' of the Anthropological Institute, delivered on November 13, 1900.

president of the Royal Society, and Tyndall. It was started in 1864, and nearly nineteen years passed before we had a single loss—that of Spottiswoode; and Hooker, Spencer and I are now, alas! the only remaining members. We used to dine together once a month, except in July, August and September. There were no papers or formal discussions, but the idea was to secure more frequent meetings of a few friends who were bound together by common interests and aims, and strong feelings of personal affection. It has never been formally dissolved, but the last meeting was in 1893.

In 1869 the Metaphysical Society, of which I shall have something more to say later on, was started.

From 1870 to 1875 I was sitting with Huxley on the late Duke of Devonshire's Commission on Scientific Instruction; we had innumerable meetings, and we made many recommendations which are being by degrees adopted.

I had also the pleasure of spending some delightful holidays with him in Switzerland, in Brittany and in various parts of England. Lastly, I sat by his side in the Sheldonian Theater at the British Association meeting at Oxford, during Lord Salisbury's address, to which I listened with all the more interest knowing that he was to second the vote of thanks, and wondering how he would do it. At one passage we looked at one another, and he whispered to me, "Oh, my dear Lubbock, how I wish we were going to discuss the address in Section D instead of here!" Not, indeed, that he would have omitted any part of his speech, but there were other portions of the address which he would have been glad to have criticised. I was, therefore, for many years in close and intimate association with him.

Huxley showed from early youth a determination, in the words of Jean Paul Richter, 'to make the most that was possible out of the stuff,' and this was a great deal, for the material was excellent. He took the wise advice to consume more oil than wine, and, what is better even than midnight oil, he made the most of the sweet morning air.

In his youth he was a voracious reader and devoured everything he could lay his hand on, from the Bible to Hamilton's 'Essay on the Philosophy of the Unconditioned.' He tells us of himself that when he was a mere boy he had a perverse tendency to think when he ought to have been playing.

Considering how preeminent he was as a naturalist, it is rather surprising to hear, as he has himself told us, that his own desire was to be a mechanical engineer. "The only part," he said, "of my professional course which really and deeply interested me was physiology, which is the mechanical engineering of living machines; and, notwithstanding that natural science has been my proper business, I am afraid there is very little of the genuine naturalist in me; I never collected anything, and species work was a burden to me. What I cared for was the architectural and engineering part of the business; the working out the wonderful unity of plan in the thousands and thousands of diverse living constructions, and the modifications of similar apparatus to serve diverse ends."

In 1846 Huxley was appointed naturalist to the expedition which was sent to the East under Captain Owen Stanley in the *Rattlesnake*, and good use, indeed, he made of his opportunities. It is really wonderful, as Sir M. Foster remarks in his excellent obituary notice in the Royal Society's 'Proceedings,' how he could have accomplished so much under such difficulties.

"Working," says Sir Michael Foster, "amid a host of difficulties, in want of room, in want of light, seeking to unravel the intricacies of minute structure with a microscope lashed to secure steadiness, cramped within a tiny cabin, jostled by the tumult of a crowded ship's life, with the scantiest supply of books of reference, with no one at hand of whom he could take counsel on the problems opening up before him, he gathered for himself during those four years a large mass of accurate, important and, in most cases, novel observations, and illustrated them with skilful, pertinent drawings."

The truth is that Huxley was one of those all-round men who would have succeeded in almost any walk in life. In literature his wit, his power of clear description and his admirable style would certainly have placed him in the front rank.

He was as ready with his pencil as with his pen. Every one who attended his lectures will remember how admirably they were illustrated by his blackboard sketches, and how the diagrams seemed to grow line by line almost of themselves. Drawing was, indeed, a joy to him, and when I have been sitting with him at Royal Commissions or on committees, he was constantly making comical sketches on scraps of paper or on blotting-books which, though admirable, never seemed to distract his attention from the subject on hand.

Again, he was certainly one of the most effective speakers of the day. Eloquence is a great gift, although I am not sure that the country might not be better governed and more wisely led if the House of Commons and the country were less swayed by it. There is no doubt, however, that, to its fortunate possessor, eloquence is of great value, and if circumstances had thrown Huxley into political life, no one can doubt that he would have taken high rank among our statesmen. Indeed, I believe his presence in the House of Commons would have been of inestimable value to the country. Mr. Hutton, of the 'Spectator'—no mean judge—has told us that, in his judgment, 'an abler and more accomplished debater was not to be found even in the House of Commons.' His speeches had the same quality, the same luminous style of exposition, with which his printed books have made all readers in America and England familiar. Yet it had more than that. You could not listen to him without thinking more of the speaker than of his science, more of the solid, beautiful nature than of the intellectual gifts, more of his manly simplicity and sincerity than of all his knowledge and his long services. His Friday evening lectures at the Royal Institution rivaled those of Tyndall in their interest and brilliance, and were always keenly and justly popular. Yet, he has told us that at first he had almost every fault a speaker could have. After his first Royal Institution lecture he received an anonymous letter recommending him never to try again, as whatever else he might be fit for, it was certainly not for giving lectures. It is also said that after one of his first lectures, 'On the Relations of Animals and Plants,' at a suburban Athenæum, a general desire was expressed to the Council that they would never invite that young man to lecture again. Quite late in life he told me, and John Bright said the same thing, that he was always nervous when he rose to speak, though it soon wore off when he warmed up to his subject.

No doubt easy listening on the part of the audience means hard working and thinking on the part of the lecturer, and, whether for the cultivated audience at the Royal Institution or for one to workingmen, he spared himself no pains to make his lectures interesting and instructive. There used to be an impression that Science was something up in the clouds, too remote from ordinary life, too abstruse and too difficult to be interesting; or else, as Dickens ridiculed it in 'Pickwick,' too trivial to be worthy of the time of an intellectual being.

Huxley was one of the foremost of those who brought our people to realize that science is of vital importance in our life, that it is more fascinating than a fairy tale, more thrilling than a novel, and that any one who neglects to follow the triumphant march of discovery, so startling in its marvelous and unexpected surprises, so inspiring in its moral influence and its revelations of the beauties and wonders of the world in which we live and the universe of which we form an infinitesimal, but to ourselves at any rate, an all-important part, is deliberately rejecting one of the greatest comforts and interests of life, one of the greatest gifts with which we have been endowed by Providence.

But there is a time for all things under the sun, and we cannot fully realize the profound interest and serious responsibilities of life unless we refresh the mind and allow the bow to unbend. Huxley was full of humor, which burst out on most unexpected occasions. I remember one instance during a paper on the habits of spiders. The female spider appears to be one of the most unsociable, truculent and bloodthirsty of her sex. Even under the influence of love she does but temporarily suspend her general hatred of all living beings. The courtship varies in character in different species, and is excessively quaint and curious; but at the close the thirst for blood, which has been temporarily over-mastered by an even stronger passion, bursts out with irresistible fury, she attacks her lover and, if he be not on the watch and does not succeed in making his escape, ends by destroying and sucking him dry. In moving a vote of thanks to the author, Huxley ended some interesting remarks by the observation that this closing scene was the most extraordinary form of marriage settlements of which he had ever heard.

He seemed also to draw out the wit of others. At the York 'Jubilee' meeting of the British Association, he and I strolled down in the afternoon to the Minster. At the entrance we met Prof. H. J. Smith, who made a mock movement of surprise. Huxley said: "You seem surprised to see me here." "Well," said Smith hesitatingly, "not exactly, but it would have been on one of the pinnacles, you know."

His letters were full of fun. Speaking of Siena in one of his letters, contained in Mr. Leonard Huxley's excellent Life of his father, he says: "The town is the quaintest place imaginable, built of narrow streets on several hills to start with, and then apparently stirred up with a poker to prevent monotony of effect."

And again, writing from Florence:

"We had a morning at the Uffizi the other day, and came back minds enlarged and backs broken. To-morrow we contemplate attacking the Pitti, and doubt not the result will be similar. By the end of the week our minds will probably be so large, and the small of the back so small, that we should probably break if we stayed any longer, so think it prudent to be off to Venice."

By degrees public duties and honors accumulated on him more and more. He was Secretary, and afterwards President, of the Royal Society, President of the Geological and of the Ethnological Societies, Hunterian Professor from 1863 to 1870, a Trustee of the British Museum, Dean of the Royal College of Science, President of the British Association, Inspector of Fisheries, Member of Senate of the University of London, member of no less than ten Royal Commissions, in addition to which he gave many lectures at the Royal Institution and elsewhere, besides, of course, all those which formed a part of his official duties.

In 1892 he was made a member of the Privy Council, an unwonted but generally welcome recognition of the services which science renders to the community.

As already mentioned, he was elected a Fellow of the Royal Society in 1851. He received a Royal Medal in 1852, the Copley in 1888, and the Darwin Medal in 1894.

Apart from his professional and administrative duties, Huxley's work falls into three principal divisions—Science, Education and Metaphysics.

SCIENTIFIC WORK.

Huxley's early papers do not appear to have in all cases at first received the consideration they deserved. The only important one which was published before his return was the one 'On the Anatomy and Affinities of the Family of the Medusæ.'

After his return, however, there was a rapid succession of valuable Memoirs, the most important, probably, being those on Salpa and Pyrosoma, on Appendicularia and Doliolum and on the Morphology of the Cephalus Mollusca.

In recognition of the value of these Memoirs he was elected a Fellow of the Royal Society in 1851, and received a Royal Medal in 1852. Lord Rosse, in presenting it, said: "In these papers you have for the first time fully developed their (the Medusæ) structure and laid the foundation of a rational theory for their classification." "In your second paper, 'On the Anatomy of Salpa and Pyrosoma,' the phenomena, etc., have received the most ingenious and elaborate elucidation, and have given rise to a process of reasoning the results of which can scarcely yet be anticipated, but must bear, in a very important degree, upon some of the most abstruse points of what may be called transcendental physiology."

A very interesting result of his work on the Hydrozoa was the generalization that the two layers in the bodies of Hydrozoa (Polyps and Sea Anemones), the Ectoderm and the Entoderm correspond with the two primary germ layers of the higher animals. Again, though he did not discover or first define protoplasm, he took no small share in making its importance known, and in bringing naturalists to recognize it as the physical basis of life, and in demonstrating the unity of animal and plant protoplasm.

Among other important memoirs may be mentioned those 'On the Teeth and the Corpuscula Tactus,' 'On the Tegumentary Organs,' 'Review of the Cell Theory,' 'On Aphis,' and many others.

His paleontological work, for which he has told us that at first 'he did not care,' began in 1855. That 'On the Anatomy and Affinities of the Genus Pterygotus' is still a classic; in another, 'On the Structure of the Shields of Pteraspis,' and in one 'On Cephalaspis,' in 1858, he for the first time clearly established their vertebrate character; his work 'On Devonian Fishes' in 1861 threw quite a new light on their affinities; and amongst other later papers may be mentioned that 'On Hyperodapedon;' 'On the Characters of the Pelvis,' 'On the Crayfish,' and one botanical memoir, 'On the Gentians,' the outcome of one of his Swiss trips.

One of the most striking results of his paleontological work was the clear demonstration of the numerous and close affinities between reptiles and birds, the result of which is that they are regarded by many as forming together a separate group, the Sauropsida; while the Amphibia, long regarded as reptiles, were separated from them and united with fishes under the title of Ichthyopsida. At thc same time he showed that the Mammalia were not derived from the Sauropsida, but formed two diverging lines springing from a common ancestor. And besides this great generalization, says the Royal Society obituary notice, "the importance of which, both from a classificatory and from an evolutional point of view, nceds no comment, there came out of the same researches numerous lesser contributions to the advancement of morphological knowledge, including, among others, an attempt, in many respects successful, at a classification of birds."

In conjunction with Tyndall, he communicated to the 'Philosophical Transactions' a memoir on glaciers, and his interest in philosophical geography was also shown in his popular treatise on physiography.

But it would be impossible here to go through all his contributions to science. The Royal Society Catalogue enumerates more than a hundred, every one of which, in the words of Prof. S. Parker, "contains some brilliant generalization, some new and fruitful way of looking at the facts of science. The keenest morphological insight and inductive power are everywhere apparent; but the imagination is always kept well in hand, and there are none of those airy speculations—a liberal pound of theory to a bare ounce of fact—by which so many reputations have been made." Huxley never allowed his study of detail to prevent him from taking a wide general view.

I now come to his special work on Man.

In the 'Origin of Species,' Darwin did not directly apply his views to the case of Man. No doubt he assumed that the considerations which applied to the rest of the animal kingdom must apply to Man also, and I should have thought must have been clear to every one, had not Wallace been in some respects, much to my surprise, of a different opinion. At any rate, it required some courage to state this boldly, and much skill and knowledge to state it clearly.

He put it in a manner which was most conclusive, and showed, in Virchow's words, "that in respect of substance and structure Man and the lower animals are one. The fundamental correspondence of human organization with that of animals is at present universally accepted."

This, I think, is too sweeping a proposition. It may be true for Germany, but it certainly is not true here. Many of our countrymen and countrywomen not only do not accept, they do not even understand, Darwin's theory. They seem to suppose him to have held that Man was descended from one of the living Apes. This, of course, is not so. Man is not descended from a Gorilla or an Orang-utang, but Man, the Gorilla, the Orang-utang and other Anthropoid Apes are all descended from some far-away ancestor.

"A Pliocene Homo skeleton," Huxley said, "might analogically be expected to differ no more from that of modern men than the *Œningen* *canis* from modern Canes, or Pliocene horses from modern horses. If so, he would most undoubtedly be a man—genus Homo—even if you made him a distinct species. For my part, I should by no means be astonished to find the genus Homo represented in the Miocene, say, the Neanderthal man, with rather smaller brain capacity, longer arms and more movable great toe, but at most specifically different."

In his work 'On Man's Place in Nature,' while referring to the other higher Quadrumana, Huxley dwelt principally on the chimpanzee and the gorilla, because, he said, "It is quite certain that the ape, which most nearly approaches man in the totality of its organization, is either the chimpanzee or the gorilla."

This is no doubt the case at present; but the gibbons (Hylobates), while differing more in size, and modified in adaptation to their more skilful power of climbing, must also be considered, and, to judge from Professor Dubois' remarkable discovery in Java of Pithecanthropus, which half the authorities have regarded as a small man, and half as a large gibbon, it is rather down to Hylobates than either the chimpanzee or the gorilla that we shall have to trace the point where the line of our far-away ancestors will meet that of any existing genus of monkeys.

Huxley emphasized the fact that monkeys differ from one another in bodily structure as much or more than they do from man.

We have Haeckel's authority for the statement that "after Darwin had, in 1859, reconstructed this most important biological theory, and by his epoch-making theory of natural selection placed it on an entirely new foundation, Huxley was the first who extended it to man; and, in 1863, in his celebrated three lectures on 'Man's Place in Nature,' admirably worked out its most important developments."

The work was so well and carefully done that it stood the test of time, and, writing many years afterwards, Huxley was able to say, and to say truly, that:

"I was looking through 'Man's Place in Nature' the other day; I do not think there is a word I need delete, nor anything I need add except in confirmation and extension of the doctrine there laid down. That is great good fortune for a book thirty years old, and one that a very shrewd friend of mine implored me not to publish, as it would certainly ruin all my prospects" ('Life of Professor Huxley,' p. 344).

He has told us elsewhere ('Collected Essays,' vii., p. 11) that "it has achieved the fate which is the Euthanasia of a scientific work, of being inclosed among the rubble of the foundations of knowledge and forgotten." He has, however, himself saved it from the tomb, and built it into the walls of the temple of science, and it will still well repay the attention of the student.

For a poor man—I mean poor in money, as Huxley was all his life—

to publish such a book at that time was a bold step. But the prophecy with which he concluded the work is coming true.

"After passion and prejudice have died away," he said, "the same result will attend the teachings of the naturalist respecting that great Alps and Andes of the living world—Man. Our reverence for the nobility of manhood will not be lessened by the knowledge that man is, in substance and in structure, one with the brutes; for he alone possesses the marvelous endowments of intelligible and rational speech, whereby, in the secular period of his existence, he has slowly accumulated and organized the experience which is almost wholly lost with the cessation of every individual life in other animals; so that now he stands raised upon it as on a mountain top—far above the level of his humble fellows, and transfigured from his grosser nature by reflecting here and there a ray from the infinite source of truth" ('Collected Essays,' vii., p. 155).

Another important research connected with the work of our Society was his investigation of the structure of the vertebrate skull. Owen had propounded a theory and worked it out most ingeniously that the skull was a complicated elaboration of the anterior part of the back-bone; that it was gradually developed from a preconceived idea or archetype; that it was possible to make out a certain number of vertebræ, and even the separate parts of which they were composed.

Huxley maintained that the archetypal theory was erroneous; and that, instead of being a modification of the anterior part of the primitive representative of the back-bone, the skull is rather an independent growth around and in front of it. Subsequent investigations have strenghtened this view, which is now generally accepted. This lecture marked an epoch in vertebrate morphology, and the views he enunciated still hold the field.

One of the most interesting parts of Huxley's work, and one specially connected with our Society, was his study of the ethnology of the British Isles. It has also an important practical and political application, because the absurd idea that ethnologically the inhabitants of our islands form three nations—the English, Scotch and Irish—has exercised a malignant effect on some of our statesmen, and is still not without influence on our politics. One of the strongest arguments put forward in favor of Home Rule used to be that the Irish were a 'nation.' In 1887 I attacked this view in some letters to the 'Times,' subsequently published by Quaritch. Nothing is more certain than that there was not a Scot in Scotland till the seventh century; that the east of our island from John o' Groat's House to Kent is Teutonic; that the most important ethnological line, so far as there is one at all, is not the boundary between England and Scotland, but the north and south watershed which separates the east and west. In Ireland, again, the population is far from homogeneous. Huxley strongly supported the position I had taken up. "We have," he said, "as good evidence as can possibly be obtained on such subjects that the same elements have entered into the composition of the population in England, Scotland and Ireland; and that the ethnic differences between the three lie simply in the general and local proportions of these elements in each region. . . . The population of Cornwall and Devon has as much claim to the title of Celtic as that of Tipperary. . . . Undoubtedly there are four geographical regions, England, Scotland, Wales and Ireland, and the people who live in them call themselves and are called by others the English, Scotch, Welsh and Irish nations. It is also true that the inhabitants of the Isle of Man call themselves Manxmen, and are just as proud of their nationality as any other 'nationalities.'

. . . .

"But if we mean no more than this by 'nationality,' the term has no practical significance" ('The Races of the British Isles,' pp. 44, 45).

Surely it would be very desirable, especially when political arguments are based on the term, that we should come to some understanding as to what is meant by the word 'nation.' The English, Scotch and Irish live under one Flag, one Queen and one Parliament. If they are not one nation, what are they? What term are we to use, and some term is obviously required, to express and combine all three. For my part I submit that the correct terminology is to speak of Celtic race or Teutonic race, of the Irish people or the Scotch people; but that the people of England, Scotland and Ireland, aye, and of the Colonies also, constitute one great nation.

As regards the races which have combined to form the nation, Huxley's view was that in Roman times the population of Britain comprised people of two types, the one fair, the other dark. The dark people resembled the Aquitani and the Iberians; the fair people were like the Belgic Gauls ('Essays,' V., vii., p. 254). And he adds that "the only constituent stocks of that population, now, or at any other period about which we have evidence, are the dark whites, whom I have proposed to call 'Melanochroi,' and the fair whites or 'Xanthochroi.' "

He concludes (1) "That the Melanochroi and the Xanthochroi are two separate races in the biological sense of the word race; (2) that they have had the same general distribution as at present from the earliest times of which any record exists on the continent of Europe; (3) that the population of the British Islands is derived from them, and from them only."

It will, however, be observed that we have (1) a dark race and a fair race; (2) a large race and a small race; and (3) a round-headed race and a long-headed race. But some of the fair race were large, some small; some have round heads, some long heads; some of the dark race again had long heads, some round ones. In fact, the question seems to me more complicated than Huxley supposed. The Mongoloid races extend now from China to Lapland; but in Huxley's opinion they never penetrated much further west, and never reached our islands. "I am unable," he says, "to discover any ground for believing that a Lapp element has ever entered into the population of these islands." It is true that we have not, so far as I know, anything which amounts to proof. We know, however, that all the other animals which are associated with the Lapps once inhabited Great Britain. Was man the only exception? I think not, more especially when we find, not only the animals of Lapland, but tools and weapons identical with those of the Lapps. I must not enlarge on this, and perhaps I may have an opportunity of laying my views on the subject more fully before the Society; but I may be allowed to indicate my own conclusion, namely, that the races to which Huxley refers are amongst the latest arrivals in our islands; that England was peopled long before its separation from the mainland, and that after the English Channel was formed, successive hordes of invaders made their way across the sea, but as they brought no women, or but few, with them, they exterminated the men, or reduced them to slavery, and married the women. Thus through their mothers our countrymen retain the strain of previous races, and hence, perhaps, we differ so much from the populations across the silver streak.

Summing up this side of Huxley's work, Sir M. Foster has truly said that "whatever bit of life he touched in his search, protozoan, polyp, mollusc, crustacean, fish, reptile, beast and man—and there were few living things he did not touch—he shed light on it, and left his mark. There is not one, or hardly one, of the many things which he has written which may not be read again to-day with pleasure and with profit, and, not once or twice only in such a reading, it will be felt that the progress of science has given to words written long ago a strength and meaning even greater than that which they seemed to have when first they were read."

In 1870 Huxley became a member of the first London School Board, and though his health compelled him to resign early in 1872, it would be difficult to exaggerate the value of the service he rendered to London and, indeed, to the country generally.

The education and discipline which he recommended were:

(1) Physical training and drill.

(2) Household work or domestic economy, especially for girls.

(3) The elementary laws of conduct.

(4) Intellectual training, reading, writing and arithmetic, elementary science, music and drawing.

He maintained that 'no boy or girl should leave school without possessing a grasp of the general character of science, and without having been disciplined more or less in the methods of all sciences.'

As regards the higher education, he was a strong advocate for science and modern languages, though without wishing to drop the classics.

Some years ago, for an article on higher education, I consulted a good many of the highest authorities on the number of hours per week which, in their judgment, should be given to the principal subjects. Huxley, amongst others, kindly gave me his views. He suggested ten hours for ancient languages and literature, ten for modern languages and literature, eight for arithmetic and mathematics, eight for science, two for geography and two for religious instruction.

For my own part I am firmly convinced that the amount of time devoted to classics has entirely failed in its object. The mind is like the body—it requires change. Mutton is excellent food; but mutton for breakfast, mutton for lunch, and mutton for dinner would soon make any one hate the sight of mutton, and so, Latin grammar before breakfast, Latin grammar before lunch, and Latin grammar before dinner is enough to make almost any one hate the sight of a classical author. Moreover, the classics, though an important part, are not the whole of education, and a classical scholar, however profound, if he knows no science, is but a half-educated man after all.

In fact, Huxley was no opponent of a classical education in the proper sense of the term, but he did protest against it in the sense in which it is usually employed, namely, as an education from which science is excluded, or represented only by a few random lectures.

He considered that specialization should not begin till sixteen or seventeen. At present we begin in our Public School system to specialize at the very beginning, and to devote an overwhelming time to Latin and Greek, which, after all, the boys are not taught to speak. Huxley advocated the system adopted by the founders of the University of London, and maintained to the present day that no one should be given a degree who did not show some acquaintance with science and with at least one modern language.

"As for the so-called 'conflict of studies,'" he exclaims, "one might as well inquire which of the terms of a Rule of Three sum one ought to know in order to get a trustworthy result. Practical life is such a sum, in which your duty multiplied into your capacity, and divided by your circumstances, gives you the fourth term in the proportion, which is your deserts, with great accuracy" ('Life of Professor Huxley,' p. 406).

"That man," he said, "I think, has had a liberal education, who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of nature and the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of nature or of art, to hate all vileness and to respect others as himself."

He was also strongly of opinion that colleges should be places of research as well as of teaching.

"The modern university looks forward, and is a factory of new knowledge; its professors have to be at the top of the wave of progress. Research and criticism must be the breath of their nostrils; laboratory work the main business of the scientific student; books his main helpers."

Education has been advocated for many good reasons: by statesmen because all have votes, by Chambers of Commerce because ignorance makes bad workmen, by the clergy because it makes bad men, and all these are excellent reasons; but they may all be summed up in Huxley's words that "the masses should be educated because they are men and women with unlimited capacities of being, doing and suffering, and that it is as true now as ever it was that the people perish for lack of knowledge."

Huxley once complained to Tyndall, in joke, that the clergy seemed to let him say anything he liked, 'while they attack me for a word or a phrase.' But it was not always so.

Tyndall and I went, in the spring of 1874, to Naples to see an eruption of Vesuvius. At one side the edge of the crater shelved very gradually to the abyss, and, being anxious to obtain the best possible view, I went a little over the ridge. In the autumn Tyndall delivered his celebrated address to the British Association at Belfast. This was much admired, much read, but also much criticised, and one of the papers had an article on Huxley and Tyndall, praising Huxley very much at Tyndall's expense, and ending with this delightful little bit of bathos: "In conclusion, we do not know that we can better illustrate Professor Tyndall's foolish recklessness, and the wise, practical character of Professor Huxley, than by mentioning the simple fact that last spring, at the very moment when Professor Tyndall foolishly entered the crater of Vesuvius during an eruption, Professor Huxley, on the contrary, took a seat on the London School Board."

Tyndall, however, returned from Naples with fresh life and health, while the strain of the School Board told considerably on Huxley's health.

Huxley's attitude on the School Board with reference to Bible teaching came as a surprise to those who did not know him well. He supported Mr. W. H. Smith's motion in its favor, which, indeed, was voted for by all the members except six, three of whom were the Roman Catholics, who did not vote either way.

"I have been," he said, "seriously perplexed to know by what practical measures the religious feeling, which is the essential basis of conduct, was to be kept up, in the present utterly chaotic state of opinion on these matters, without the use of the Bible. Take the Bible as a whole; make the severest deductions which fair criticism can dictate for short-comings and positive errors; eliminate, as a sensible lay-teacher would do if left to himself, all that it is not desirable for children to occupy themselves with; and there still remains in this old literature a vast residuum of moral beauty and grandeur. And then consider the great historical fact that for three centuries this book has been woven into the life of all that is best and noblest in English history; that it has become the national epic of Britain, and is as familiar to noble and simple, from John o' Groat's House to Land's End, as Dante and Tasso were once to Italians; that it is written in the noblest and purest English, and abounds in exquisite beauties of mere literary form; and, finally, that it forbids the veriest hind who never left his village to be ignorant of the existence of other countries and other civilizations, and of a great past, stretching back to the furthest limits of the oldest nations in the world. By the study of what other book could children be so much humanized and made to feel that each figure in that vast historical procession fills, like themselves, but a momentary space in the interval between two eternities, and earns the blessings or the curses of all time, according to its effort to do good and hate evil, even as they also are earning their payment for their work?"

Another remarkable side of Huxley's mind was his interest in and study of metaphysics. When the Metaphysical Society was started in 1869, there was some doubt among the promoters whether Huxley and Tyndall should be invited to join or not. Mr. Knowles was commissioned to come and consult me. I said at once that to draw the line at the opinions which they were known to hold would, as it seemed to me, limit the field of discussion, and there would always be doubts as to when the forbidden region began; that I had understood there was to be perfect freedom, and that though Huxley's and Tyndall's views might be objectionable to others of our members, I would answer for it that there could be nothing in the form of expression of which any just complaint could be made.

The society consisted of about forty members, and when we consider that they included Thompson, Archbishop of York, Ellicott, Bishop of Gloucester and Bristol, Dean Stanley and Dean Alford as representatives of the Church of England; Cardinal Manning, Father Dalgairns and W. G. Ward as Roman Catholics; among statesmen, Gladstone, the late Duke of Argyll, Lord Sherbrooke, Sir M. Grant Duff, John Morley, as well as Martineau, Tennyson, Browning, R. H. Hutton, W. Bagehot, Frederic Harrison, Leslie Stephen, Sir J. Stephen, Dr. Carpenter, Sir W. Gull, W. R. Greg, James Hinton, Shadworth Hodgson, Lord Arthur Russell, Sir Andrew Clark, Sir Alexander Grant, Mark Patteson and W. K. Clifford, it will not be wondered that I looked forward to the meetings with the greatest interest. I experienced also one of the greatest surprises of my life. We all, I suppose, wondered who would be the first President. No doubt what happened was that Roman Catholics objected to Anglicans, Anglicans to Roman Catholics, both to Nonconformists; and the different schools of metaphysics also presented difficulties, so that finally, to my amazement, I found myself the first President! The discussions were perfectly free, but perfectly friendly; and I quite agree with Mr. H. Sidgwick, that Huxley was one of the foremost, keenest and most interesting debaters, which, in such a company, is indeed no slight praise.

We dined together, then a paper was read, which had generally been circulated beforehand, and then it was freely discussed, the author responding at the close. Huxley contributed several papers, but his main contribution to the interest of the Society was his extraordinary ability and clearness in debate.

His metaphysical studies led to his work on Hume and his memoirs on the writings of Descartes.

One of his most interesting treatises is a criticism of Descartes' theory of animal automatism. Descartes was not only a great philosopher, but also a great naturalist, and we owe to him the definite allocation of all the phenomena of consciousness to the brain. This was a great step in science, but, just because Descartes' views have been so completely incorporated with everyday thought, few of us realize how recently it was supposed that the passions were seated in the apparatuses of organic life. Even now we speak of the heart rather than the brain in describing character.

Descartes, as is known, was much puzzled as to the function of one part of the brain—a small, pear-shaped body about the size of a nut, and deeply seated. Known as the pineal gland, he suggested that it was the seat of the soul; but it is now regarded, and apparently on solid grounds, as the remains of the optic lobe of a central eye once possessed by our far-away ancestors, and still found in some animals, as, for instance, in certain lizards. Descartes was much impressed by the movements which are independent of consciousness or volition, and known as reflex actions—such, for instance, as the winking of the eye or the movement of the leg if the sole of the foot is touched. This takes place equally if, by any injury to the spinal marrow, the sensation in the legs has been destroyed.

Such movements appear to be more frequent among lower animals, and Descartes supposed that all their movements might be thus accounted for—that they were, like the movements of sensitive plants, absolutely detached from consciousness or sensation, and that, in fact, animals were mere machines or automata, devoid not only of reason, but of any kind of consciousness.

It must be admitted that Descartes' arguments are not easy to disprove, and no doubt certain cases of disease or injury—as, for instance, that of the soldier described by Dr. Mesnet, who, as a result of a wound in the head, fell from time to time into a condition of unconsciousness, during which, however, he ate, drank, smoked, dressed and undressed, and even wrote—have supplied additional evidence in support of his views. Huxley, while fully admitting this, came, and I think rightly, to the conclusion that the consciousness of which we feel certain in ourselves must have been evolved very gradually, and must therefore exist, though probably in a less degree, in other animals.

No one, indeed, I think, who has kept and studied pets, even if they be only ants and bees, can bring himself to regard them as mere machines.

The foundation of the Metaphysical Society led to the invention of the term 'Agnostic.'

"When I reached intellectual maturity," Huxley tells us, "and began to ask myself whether I was an atheist, a theist or a pantheist, a materialist or an idealist, a Christian or a freethinker, I found that the more I learned and reflected, the less ready was the answer; until, at last, I came to the conclusion that I had neither art nor part with any of these denominations except the last. The one thing in which most of these good people were agreed was the one thing in which I differed from them. They were quite sure they had attained a certain 'gnosis'—had, more or less successfully, solved the problem of existence; while I was quite sure I had not, and had a pretty strong conviction that the problem was insoluble. . . ."

These considerations pressed forcibly on him when he joined the Metaphysical Society.

"Every variety," he says, "of philosophical and theological opinion was represented there, and expressed itself with entire openness; most of my colleagues were 'ists' of one sort or another; and, however kind and friendly they might be, I, the man without a rag of a habit to cover himself with, could not fail to have some of the uneasy feelings which must have beset the historical fox when, after leaving the trap, in which his tail remained, he presented himself to his normally elongated companions. So I took thought, and invented what I conceived to be the appropriate title of agnostic. It came into my head as suggestively antithetic to the gnostic of Church history, who professed to know so much about the very things of which I was ignorant; and I took the earliest opportunity of parading it at our Society, to show that I, too, had a tail like the other foxes."

Huxley denied that he was disposed to rank himself either as a fatalist, a materialist or an atheist. "Not among fatalists, for I take the conception of necessity to have a logical, and not a physical, foundation; not among materialists, for I am utterly incapable of conceiving the existence of matter if there is no mind in which to picture that existence; not among atheists, for the problem of the ultimate cause of existence is one which seems to me to be hopelessly out of reach of my poor powers."

The late Duke of Argyll, in his interesting work on 'The Philosophy of Belief,' makes a very curious attack on Huxley's consistency. He observes that scientific writers use "forms of expression as well as individual words, all of which are literally charged with teleological meaning. Men even who would rather avoid such language if they could, but who are intent on giving the most complete and expressive description they can of the natural facts before them, find it wholly impossible to discharge this duty by any other means. Let us take as an example the work of describing organic structures in the science of biology. The standard treatise of Huxley on the 'Elements of Comparative Anatomy,' affords a remarkable example of this necessity, and of its results. . . .

"How unreasonable it is to set aside, or to explain away, the full meaning of such words as 'apparatuses' and 'plans,' comes out strongly when we analyze the preconceived assumptions which are supposed to be incompatible with the admission of it. . . .

"To continue the use of words because we are conscious that we cannot do without them, and then to regret or neglect any of their implications, is the highest crime we can commit against the only faculties which enable us to grasp the realities of the world." Is not this, however, to fall into the error of some Greek philosophers, and to regard language, not only as a means of communication, but as an instrument of research. We all speak of sunrise and sunset, but it is no proof that the sun goes round the earth. The Duke himself says elsewhere:

"We speak of time as if it were an active agent in doing this, that and the other. Yet we are quite conscious, when we choose to think of it, that when we speak of time in this sense, we are really thinking and speaking, not of time itself, but of the various physical forces which operate slowly and continuously in, or during, time. Apart from these forces, time does nothing."

This is, it seems to me, a complete reply to his own attack on Huxley's supposed inconsistency.

Theologians often seem to speak as if it were possible to believe something which one cannot understand, as if the belief were a matter of will, that there was some merit in believing what you cannot prove, and that if a statement of fact is put before you, you must either believe it or disbelieve it. Huxley, on the other hand, like most men of science, demanded clear proof, or what seemed to him clear proof, before he accepted any conclusion; he would, I believe, have admitted that you might accept a statement which you could not explain, but would have maintained that it was impossible to believe what you did not understand; that in such a case the word 'belief' was an unfortunate misnomer; that it was wrong, and not right, to profess to believe anything for which you knew that there was no sufficient evidence, and that if it is proved you cannot help believing it; that as regards many matters the true position was not one either of belief or of disbelief, but of suspense.

In science we know that though the edifice of fact is enormous, the fundamental problems are still beyond our grasp, and we must be content to suspend our judgment, to adopt, in fact, the Scotch verdict of 'not proven,' so unfortunately ignored in our law as in our theology.

Faith is a matter more of deeds, not of words, as St. Paul shows in the Epistle to the Hebrews. If you do not act on what you profess to believe, you do not really and in truth believe it. May I give an instance? The Fijians really believed in a future life; according to their creed, you rose in the next world exactly as you died here—young if you were young, old if you were old, strong if you were strong, deaf if you were deaf, and so on. Consequently it was important to die in the full possession of one's faculties; before the muscles had begun to lose their strength, the eye to grow dim, or the ear to wax hard of hearing. On this they acted. Every one had himself killed in the prime of life; and Captain Wilkes mentions that in one large town there was not a single person over forty years of age.

That I call faith. That is a real belief in a future life.

Huxley's views are indicated in the three touching lines by Mrs. Huxley, which are inscribed on his tombstone:

> Be not afraid, ye wailing hearts that weep,
> For still He giveth His beloved sleep,
> And if an endless sleep He wills—so best.

That may be called unbelief, or a suspension of judgment. Huxley doubted.

But disbelief is that of those who, no matter what they say, act as if there was no future life, as if this world was everything, and in the words of Baxter in 'The Saints' Everlasting Rest,' profess to believe in Heaven, and yet act as if it was to be 'tolerated indeed rather than the flames of Hell, but not to be desired before the felicity of Earth.'

Huxley was, indeed, by no means without definite beliefs. "I am," he said, "no optimist, but I have the firmest belief that the Divine Government (if we may use such a phrase to express the sum of the 'customs of matter') is wholly just. The more I know intimately of the lives of other men (to say nothing of my own), the more obvious it is to me that the wicked does not flourish nor is the righteous punished."

One of the great problems of the future is to clear away the cobwebs which the early and mediæval ecclesiastics, unavoidably ignorant of science, and with ideas of the world now known to be fundamentally erroneous, have spun round the teachings of Christ; and in this Huxley rendered good service. For instance, all over the world in early days lunatics were supposed to be possessed by evil spirits. That was the universal belief of the Jews, as of other nations, 2,000 years ago, and one of Huxley's most remarkable controversies was with Mr. Gladstone and Dr. Wace with reference to the 'man possessed with devils,' which, we are told, were cast out and permitted to enter into a herd of swine. Some people thought that these three distinguished men might have occupied their time better than, as was said at the time, 'in fighting over the Gaderene swine.' But as Huxley observed:

"The real issue is whether the men of the nineteenth century are to adopt the demonology of the men of the first century as divinely revealed truth, or to reject it as degrading falsity."

And as the first duty of religion is to form the highest conception possible to the human mind of the Divine Nature, Huxley naturally considered that when a Prime Minister and Doctor of Divinity propound views showing so much ignorance of medical science, and so low a view of the Deity, it was time that a protest was made in the name, not only of science, but of religion.

Theologians themselves, indeed, admit the mystery of existence. "The wonderful world," says Canon Liddon, "in which we now pass this stage of our existence, whether the higher world of faith be open to our gaze or not, is a very temple of many and august mysteries. . . . Everywhere around you are evidences of the existence and movement of a mysterious power which you can neither see, nor touch, nor define, nor measure, nor understand."

One of Huxley's difficulties he has stated in the following words: "Infinite benevolence need not have invented pain and sorrow at all—infinite malevolence would very easily have deprived us of the large measure of content and happiness that falls to our lot."

This does not, I confess, strike one as conclusive. It seems an answer —if not perhaps quite complete, that if we are to have any freedom and responsibility, the possibility of evil follows necessarily. If two courses are open to us, there are two alternatives; either the results are the same in either case, and then it does not matter what we do; or the one course must be wise and the other unwise. Huxley, indeed, said in another place: "I protest that if some great power could agree to make me always think what is true, and do what is right, on condition of being turned into a sort of a clock and wound up every morning before I got out of bed, I should instantly close with the offer. The only freedom I care about is the freedom to do right; the freedom to do wrong I am ready to part with on the cheapest terms to any one who will take it of me. But when the Materialists stray beyond the borders of their path, and talk about there being nothing else in the world but Matter and Forces and necessary laws, ... I decline to follow them."

Huxley was no enemy to the existence of an Established Church.

"I could conceive," he said, "the existence of an Established Church which should be a blessing to the community. A church in which, week by week, services should be devoted, not to the iteration of abstract propositions in theology, but to the setting before men's minds of an ideal of true, just and pure living; a place in which those who are weary of the burden of daily cares should find a moment's rest in the contemplation of the higher life which is possible for all, though attained by so few; a place in which the man of strife and of business should have time to think how small, after all, are the rewards he covets compared with peace and charity. Depend upon it, if such a Church existed, no one would seek to disestablish it."

It seems to me that he has here very nearly described the Church of Stanley, of Jowett, and of Kingsley.

Sir W. Flower justly observed that "if the term 'religious' be limited to acceptance of the formularies of one of the current creeds of the world, it cannot be applied to Huxley; but no one could be intimate with him without feeling that he possessed a deep reverence for 'whatsoever things are true, whatsoever things are honest, whatsoever things are just, whatsoever things are pure, whatsoever things are lovely, whatsoever things are of good report,' and an abhorrence of all that is the reverse of these; and that, although he found difficulty in expressing it in definite words, he had a pervading sense of adoration of the infinite, very much akin to the highest religion."

Lord Shaftesbury records that "Professor Huxley has this definition of morality and religion: 'Teach a child what is wise, that is morality. Teach him what is wise and beautiful, that is religion!' Let no one henceforth despair of making things clear and of giving explanations!" ('Life and Works,' iii., 282).

I doubt, indeed, whether the debt which Religion owes to Science has yet been adequately acknowledged.

The real conflct—for conflict there has been and is—is not between Science and Religion, but between Science and Superstition. A disbelief in the goodness of God led to all the horrors of the Inquisition. Throughout the Middle Ages and down almost to our own times, as Lecky has so powerfully shown, the dread of witchcraft hung like a black pall over Christianity. Even so great and good a man as Wesley believed in it. It is Science which has cleared away these dark clouds, and we can hardly fail to see that it is just in those countries where Science is most backward that Religion is less well understood, and in those where Science is most advanced that Religion is purest. The services which Science has rendered to Religion have not as yet, I think, received the recognition they deserve.

Many of us may think that Huxley carried his scepticism too far, that some conclusions which he doubted, if not indeed proved, yet stand on a securer basis than he supposed.

He approached the consideration of these awful problems, however, in no scoffing spirit, but with an earnest desire to arrive at the truth, and I am glad to acknowledge that this has been generously recognized by his opponents.

From his own point of view, Huxley was no opponent of Religion, however fundamentally he might differ from the majority of clergymen. In Science we differ, but we are all seeking for truth, and we do not dream that any one is an enemy to 'science.'

In Theology, however, unfortunately as we think, a different standard has been adopted. Theologians often, though no doubt there are many exceptions, regard a difference from themselves as an attack on religion, a suspension of judgment as an adverse verdict, and doubt as infidelity.

It is, therefore, only just to them to say that their obituary notices of Huxley were fair and even generous. When they treated him as a foe they did so, as a rule, in a spirit as honorable to them as it was to him.

The 'Christian World,' in a very interesting obituary notice, truly observed that "if in Huxley's earlier years the average opinion of the churches had been as ready as it is now to accept the evolution of the Bible, it would not have been so startled by Darwin's theory of the evolution of man; and Darwin's greatest disciple would have enjoyed thirty years ago the respect and confidence and affection with which we came to regard him before we lost him."

"Surely it is a striking and suggestive fact that both the retiring and the incoming President of the Royal Society, by way of climax to their eulogies, dwelt on the religious side of Huxley's character. "If religion means strenuousness in doing right, and trying to do right, who," asked Lord Kelvin, "has earned the title of a religious man better than Huxley?" And similarly Sir J. Lister, in emphasizing Huxley's intellectual honesty, "his perfect truthfulness, his whole-hearted benevolence," felt impelled to adopt Lord Kelvin's word and celebrate "the religion that consists in the strenuous endeavor to be and do what is right."

Huxley was not only a great man, but a good and a brave one. It required much courage to profess his opinions, and if he had consulted only his own interests he would not have done so, but we owe much to him for the inestimable freedom which we now enjoy.

When he was moved to wrath it was when he thought wrong was being done, the people were being misled, or truth was being unfairly attacked, as, for instance, in the celebrated discussion at Oxford. The statue in the Natural History Museum is very powerful and a very exact likeness, but it is like him when he was moved to righteous indignation. It is not Huxley as he was generally, as he was when he was teaching, or when in the company of friends. He was one of the most warm-hearted and genial of men. Mr. Hutton, who sat with him on the Vivisection Commission, has recorded that "considering he represented the physiologists on this Commission, I was much struck with his evident horror of anything like torture even for scientific ends." I do not, however, see why this should have surprised him, because the position of physiologists is that it is the anti-vivisectionists who would enormously increase the suffering in the world. To speak of inflicting pain 'for scientific ends' is misleading. It is not for the mere acquisition of useless knowledge, but for the diminution of suffering and because one experiment may prevent thousands of mistakes and save hundreds of lives. The medical profession may be mistaken in this, but it is obvious that their conviction, whether it be right or whether it be wrong, is not only compatible with, but is inspired by, a horror of unnecessary suffering.

The great object of his labors was, in his own words, "to promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life." His family life was thoroughly happy. He was devoted to his children, and they to him. "The love our children show us," he said in one of his letters, "warms our old age better than the sun."

Nor can I conclude without saying a word about Mrs. Huxley, of whom her son justly says that she was "his help and stay for forty years, in his struggles ready to counsel, in adversity to comfort; the critic whose judgment he valued above almost any, and whose praise he cared most to win; his first care and latest thought, the other self, whose union with him was a supreme example of mutual sincerity and devotion."

At a time of deep depression and when his prospects looked most gloomy he mentions a letter from Miss Heathorn as having given him "more comfort than anything for a long while. I wish to Heaven," he says, "it had reached me six months ago. It would have saved me a world of pain and error."

Huxley had two great objects in life as he has himself told us. "There are," he said, "two things I really care about—one is the progress of scientific thought, and the other is the bettering of the condition of the masses of the people by bettering them in the way of lifting themselves out of the misery which has hitherto been the lot of the majority of them. Posthumous fame is not particularly attractive to me, but, if I am to be remembered at all, I would rather it should be as 'a man who did his best to help the people' than by any other title."

It is not only because we, many of us, loved him as a friend, not only because we all of us recognize him as a great naturalist, but also because he was a great example to us all, a man who did his best to benefit the people, that we are here to do honor to his memory to-day.

MALARIA.*

By GEO. M. STERNBERG, M.D., LL.D.,
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IN my address as president of the Biological Society, in 1896, the subject chosen was 'The Malarial Parasite and other Pathogenic Protozoa.' This address was published in March, 1897, in the POPULAR SCIENCE MONTLHY, and I must refer you to this illustrated paper for a detailed account of the morphological characters of the malarial parasite. It is my intention at the present time to speak of 'Malaria' in a more general way and of the recent experimental evidence in support of Manson's suggestion, first made in 1894, that the mosquito serves as an intermediate host for the parasite. The discovery of this parasite may justly be considered one of the greatest achievements of scientific research during the nineteenth century. Twenty-five years ago the best-informed physicians entertained erroneous ideas with reference to the nature of malaria and the etiology of the malarial fevers. Observation had taught them that there was something in the air in the vicinity of marshes in tropical regions, and during the summer and autumn in semi-tropical and temperate regions, which gave rise to periodic fevers in those exposed in such localities, and the usual inference was that this something was of gaseous form—that it was a special kind of bad air generated in swampy localities under favorable meteorological conditions. It was recognized at the same time that there are other kinds of bad air, such as the offensive emanations from sewers and the products of respiration of man and animals, but the term malaria was reserved especially for the kind of bad air which was supposed to give rise to the so-called malarial fevers. In the light of our present knowledge it is evident that this term is a misnomer. There is no good reason for believing that the air of swamps is any more deleterious to those who breathe it than the air of the sea coast or that in the vicinity of inland lakes and ponds. Moreover, the stagnant pools, which are covered with a 'green scum' and from which bubbles of gas are given off, have lost all terrors for the well-informed man, except in so far as they serve as breeding places for mosquitoes of the genus *Anopheles*. The green scum is made up of harmless algæ such as Spirogyra, Zygnema Protococcus, Euglena, etc.; and the gas which is given off from the mud at the bottom of such stagnant pools is for the most part a well-known and comparatively harmless compound

* Annual address of the president of the Philosophical Society of Washington. Delivered under the auspices of the Washington Academy of Sciences, on December 8, 1900.

of hydrogen and carbon—methane or 'marsh-gas.' In short, we now know that the air in the vicinity of marshes is not deleterious because of any special kind of bad air present in such localities, but because it contains mosquitoes infected with a parasite known to be the specific cause of the so-called malarial fevers. This parasite was discovered in the blood of patients suffering from intermittent fevers by Laveran, a surgeon in the French army, whose investigations were conducted in Algiers. This famous discovery was made toward the end of the year 1880, but it was several years later before the profession generally began to attach much importance to the alleged discovery. It was first confirmed by Richard in 1882; then by the Italian investigators, Marchiafava, Celli, Golgi and Bignami; by Councilman, Osler and Thayer in this country, and by many other competent observers in various parts of the world. The Italian investigators named not only confirmed the presence of the parasite discovered by Laveran in the blood of those suffering from malarial fevers, but they demonstrated its etiological rôle by inoculation experiments and added greatly to our knowledge of its life history (1883-1898). The fact that the life history of the parasite includes a period of existence in the body of the mosquito, as an intermediate host, has recently been demonstrated by the English army surgeons Manson and Ross, and confirmed by numerous observers, including the famous German bacteriologist, Koch.

The discoveries referred to, as is usual, have had to withstand the criticism of conservative physicians, who, having adopted the prevailing theories with reference to the etiology of periodic fevers, were naturally skeptical as to the reliability of the observations made by Laveran and those who claimed to have confirmed his discovery. The first contention was that the bodies described as present in the blood were not parasites, but deformed blood corpuscles. This objection was soon set at rest by the demonstration, repeatedly made, that the intra-corpuscular forms underwent distinct amœboid movements. No one witnessing these movements could doubt that he was observing a living microorganism. The same was true of the extra-corpuscular flagellate bodies, which may be seen to undergo very active movements, as a result of which the red blood corpuscles are violently displaced and the flagellate body itself dashes about in the field of view.

The first confirmation in this country of Laveran's discovery of amœboid parasites in the blood of malarial-fever patients was made by myself in the pathological laboratory of the Johns Hopkins University in March, 1886. In May, 1885, I had visited Rome as a delegate to the International Sanitary Conference, convened in that city under the auspices of the Italian Government, and while there I visited the Santo Spirito Hospital for the purpose of witnessing a demonstration, by Drs. Marchiafava and Celli, of that city, of the presence of the *plasmodium* *malariæ* in the blood of persons suffering from intermittent fever. Blood was drawn from the finger during the febrile attack and from individuals to whom quinine had not been administered. The demonstration was entirely satisfactory, and no doubt was left in my mind that I saw living parasitic micro-organisms in the interior of red blood corpuscles obtained from the circulation of malarial-fever patients. The motions were quite slow and were manifested by a gradual change of outline rather than by visible movement. After a period of amœboid activity of greater or less duration, the body again assumed an oval or spherical form and remained quiescent for a time. While in this form it was easily recognized, as the spherical shape caused the light passing through it to be refracted and gave the impression of a body having a dark contour and a central vacuole; but when it was flattened out and undergoing amœboid changes in form, it was necessary to focus very carefully and to have a good illumination in order to see it. The objective used was a Zeiss's one-twelfth inch homogeneous oil immersion.

But, very properly, skepticism with reference to the causal relation of these bodies to the disease with which they are associated was not removed by the demonstration that they are in fact blood-parasites, that they are present in considerable numbers during the febrile paroxysms and that they disappear during the interval between these paroxysms. These facts, however, give strong support to the inference that they are indeed the cause of the disease. This inference is further supported by the evident destruction of red blood corpuscles by the parasite, as shown by the presence of grains of black pigment in the amœba-like micro-organisms observed in these corpuscles and the accumulation of this insoluble blood pigment in the liver and spleen of those who have suffered repeated attacks of intermittent fever. The enormous loss of red blood corpuscles as a result of such attacks is shown by the anæmic condition of the patient and also by actual enumeration. According to Kelsch, a patient of vigorous constitution in the first four days of a quotidian intermittent fever, or a remittent of first invasion, may suffer a loss of 2,000,000 of red blood corpuscles per cubic millimeter of blood, and in certain cases a loss of 1,000,000 has been verified at the end of twenty-four hours. In cases of intermittent fever having a duration of twenty to thirty days the number of red blood cells may be reduced from the normal, which is about 5,000,000 per cubic millimeter to 1,000,000 or even less. In view of this destruction of the red blood cells and the demonstrated fact that a certain number, at least, are destroyed during the febrile paroxysms by a blood parasite, which invades the cells and grows at the expense of the continued hæmoglobin, it may be thought that the etiological rôle of the parasite should be conceded. But scientific conservatism demands more than this, and the final proof has been afforded by the experiments of Gerhardt and of Marchiafava and Celli—

since confirmed by many others. This proof consists in the experimental inoculation of healthy individuals with blood containing the parasite and the development of a typical attack of periodic fever as a result of such inoculation. Marchiafava and Bignami, in their elaborate article upon 'Malaria,' published in the 'Twentieth Century Practice of Medicine,' say:

"The transmission of the disease occurs equally whether the blood is taken during the apyretic period or during a febrile paroxysm, whether it contains young parasites or those in process of development, or whether it contains sporulation forms. Only the crescent forms, when injected alone, do not transmit the infection, as has been demonstrated by Bastianelli, Bignami and Thayer, and as can be readily understood when we remember the biological significance of these forms.

"In order that the disease be reproduced in the inoculated subject it is not necessary to inject the malarial blood into a vein of the recipient, as has been done in most of the experiments; a subcutaneous injection is all-sufficient. Nor is it necessary to inject several cubic centimeters, as was done especially in the earlier experiments; a fraction of a cubic centimeter will suffice and even less than one drop, as Bignami has shown."

After the inoculation of a healthy individual with blood containing the parasite a period varying from four to twenty-one days elapses before the occurrence of a febrile paroxysm. This is the so-called period of incubation, during which, no doubt, the parasite is undergoing multiplication in the blood of the inoculated individual. The duration of this period depends to some extent upon the quantity of blood used for the inoculation and its richness in parasites. It also depends upon the particular variety of the parasite present, for it has been ascertained that there are at least three distinct varieties of the malarial parasite—one which produces the quartan type of fever, in which there is a paroxysm every third day and in which, in experimental inoculations made, the period of incubation has varied from eleven to eighteen days; in the tertian type, or second day fever, the period of incubation noted has been from nine to twelve days; and in the æstivo-autumnal type the duration has usually not exceeded five days. The parasite associated with each of these types of fever may be recognized by an expert, and there is no longer any doubt that the difference in type is due to the fact that different varieties or 'species' of the malarial parasite exist, each having a different period of development. Blood drawn during a febrile paroxysm shows the parasite in its different stages of intra-corpuscular development. The final result of this development is a segmenting body, having pigment granules at its center, which occupies the greater part of the interior of the red corpuscle. The number of segments into which this body divides differs in the different types of fever, and there are other points of difference by which the several varieties may be distinguished one from the other, but which it is not necessary to mention at the present time. The important point is that the result of the segmentation of the adult parasites contained in the red corpuscles is the formation of a large number of spore-like bodies, which are set free by the disintegration of the remains of the blood corpuscles and which constitute a new brood of reproductive elements, which in their turn invade healthy blood corpuscles and effect their destruction. This cycle of development, without doubt, accounts for the periodicity of the characteristic febrile paroxysms; and, as stated, the different varieties complete their cycle of development in different periods of time, thus accounting for the recurrence of the paroxysms at intervals of forty-eight hours, in one type of fever and of three days in another type. When a daily paroxysm occurs, this is believed to be due to the alternate development of two groups of parasites of the tertian variety, as it has not been possible to distinguish the parasite found in the blood of persons suffering from a quotidian form of intermittent fever from that of the tertian form. Very often, also, the daily paroxysm occurs on succeeding days at a different hour, while the paroxysm every alternate day is at the same hour, a fact which sustains the view that we have to deal, in such cases, with two broods of the tertian parasite which mature on alternate days. In other cases there may be two distinct paroxysms on the same day, and none on the following day, indicating the presence of two broods of tertian parasites maturing at different hours every second day.

Manson, in his work on tropical diseases, recently published, accounts for the febrile paroxysm as follows:

"In all malarial attacks this periodicity tends to become, and in most attacks actually is, quotidian, tertian, or quartan in type. If we study the parasites associated with these various types we find that they, too, as has been fully described already, have a corresponding periodicity. We have also seen that the commencement of the fever in each case corresponds with the breaking up of the sporulating form of the parasite concerned. This last is an important point; for, doubtless, when this breaking up takes place, besides the pigment set free, other residual matters—not so striking optically, it is true, as the pigment, but none the less real—probably are liberated; a hæmoglobin solvent, for example, as I have suggested. Whether it be this hæmoglobin solvent, or whether it be some other substance, which is the pyrogenetic agent, I believe that some toxin, hitherto enclosed in the body of the parasite, or in the infected corpuscle, escapes into the blood at the moment of sporulation.

"The periodicity of the clinical phenomena is accounted for by the periodicity of the parasite. How are we to account for the periodicity of the parasite? It is true that it has a life of twenty-four hours, or of a multiple of twenty-four hours; but why should the individual parasites of the countless swarm all conspire to mature at or about the same time? That they do so—not perhaps exactly at the same moment, but within a very short time of each other—is a fact, and it is one which can be easily demonstrated. If we wish to see the sporulating forms of the plasmodium in a pure intermittent, it is practically useless to look for them in the blood during the latter stages of fever, or during the interval, or during any time but just before, during, or soon after rigor. If we wish to see the early and unpigmented forms, we must look for them during the later stage of rigor or the earlier part of the stage of pyrexia. And so with the other stages of the parasite; each has its appropriate relationship to the fever cycle."

There are numerous cases of malarial fever in which there is no distinct intermission and in which the course of the fever is either continued or remittent in character. Fevers of this type usually occur in the late summer or in the autumn (æstivo-autumnal) and are believed to be due to infection by two distinct varieties of the parasite; one, the tertian æstivo-autumnal, causes a fever characterized by a marked rise in the temperature every second day; the other, a fever in which there is a daily elevation of temperature. There are certain peculiarities relating to the intra-corpuscular development of these parasites which enable us to differentiate them from the tertian and quartan parasites of intermittent fever, but a more striking difference to be observed in their life cycle of development in the blood of man is the presence of peculiar crescentic-shaped bodies, which play an important part in their further development in the body of an intermediate host—the mosquito. Associated with these 'crescents' fusiform and ovoid bodies are often seen which are no doubt similar in their origin and function. The crescents are a little longer than the diameter of a red blood corpuscle and are about three times as long as broad. They contain in the central portion grains of pigment (melanin) derived from the hæmoglobin of the infected corpuscle which has been changed into a crescentic body as a result of the development of the malarial parasite in its interior. When a fresh preparation of malarial blood containing these crescents is observed under the microscope, while a majority of them retain the crescentic form, others may be seen, after an interval of ten minutes or more, to change in form, first becoming oval and then round; then, in the interior of these round bodies an active movement of the pigment granules occurs; this is followed by the thrusting forth from the periphery of several filaments—usually four, which have flagella-like movements. These, as a rule, become detached and continue to move rapidly among the blood corpuscles. With reference to the function of these motile filaments, Marchiafava says:

"In these later days there is increasing belief in the theory, which we uphold, that the crescents and the flagellata are sexual forms of the malarial parasite, and that a reproductive act (in which the flagellum represents the male element and an adult crescent the female cell) gives rise to the new being which begins its existence in the tissues of the mosquito."

These crescentic bodies may be found in the blood of man long after all febrile symptoms have disappeared, and it is generally recognized that they are not directly concerned in the production of the phenomena which constitute a malarial attack and that the administration of quinine has no influence in causing them to disappear from the blood. On the other hand, the febrile phenomena are directly associated with the appearance of the amœboid form of the parasite in the interior of the red blood corpuscles and the administration of suitable doses of quinine has a marked effect in causing these amœba-like micro-organisms to disappear from the blood.

These crescentic bodies are not found in the benign tertian and quartan intermittent fevers, but are characteristic of the malignant forms of malarial infection, including the so-called æstivo-autumnal fever. In these forms of fever they are not seen at the outset of the attack, and they have no direct influence upon the course of the fever. A week usually elapses between the first appearance of the amœboid form of the parasite and that of these crescentic bodies. They are often found in the blood some time after all symptoms of fever have disappeared, and are associated with the malarial cachexia which follows an attack of æstivo-autumnal fever. When blood containing these crescents is ingested by a mosquito of the genus *Anopheles* the following very remarkable transformations occur: Some of the crescents are transformed into hyaline flagellate bodies having active movements; others are changed into granular spheres. The flagella break away from the hyaline bodies and, approaching the granular spheres, appear to seek energetically to enter these bodies. A minute papilla is given off from the surface of the sphere, seeming to be projected to meet the attacking flagellum. At this point, one of the flagella succeeds in entering the sphere, causing an active movement of its contents for a brief time, after which the flagella disappear from view, and the contents become quiescent. This is no doubt an act of impregnation. After a time the impregnated granular sphere alters its shape, becoming oval, and later vermicular in form. The pigment granules are now seen at the posterior part of this body, which, after the changes mentioned, exhibits active movements. It is believed that this motile vermicular body penetrates the wall of the mosquito's stomach. Here it grows rapidly and, after a few days, may be seen projecting from the surface as a spherical mass. In the meantime the contents are transformed into spindle-shaped bodies (sporozoites) which are subsequently set free by the rupture of the capsule of the mother cell. According to Manson, these spindle-shaped bodies pass from the body cavity of the mosquito, probably by way of the blood, to the three-lobed veneno-salivary glands, lying on each side of the fore part of the thorax of the insect. "These glands communicate with the base of the mosquito's proboscis by means of a long duct along the radicles of which the clear, plump cells of the gland are arranged. The sporozoites can be readily recognized in many, though not in all, of the cells, especially in those of the middle lobe, and also free in the ducts. So numerous are they in some of the cells that the appearance they present is suggestive of a bacillus-laden lepra-cell."

The hypothesis that malarial infection results from the bites of mosquitoes was advanced and ably supported by Dr. A. F. A. King, of Washington, D. C., in a paper read before the Philosophical Society on February 10, 1883, and published in the Popular Science Monthly in September of the same year. In 1894, Manson supported the same hypothesis in a paper published in the 'British Medical Journal' (December 8), and the following year (1895) Ross made the important discovery that when blood containing the crescentic bodies was ingested by the mosquito, these crescents rapidly underwent changes similar to those heretofore described, resulting in the formation of motile filaments, which become detached from the parent body and continue to exhibit active movements. In 1897, Ross ascertained, further, that when blood containing crescents was fed to a particular species of mosquito, living pigmented parasites could be found in the stomach walls of the insect. Continuing his researches with a parasite of the same class which is found in birds, and in which the mosquito also serves as an intermediate host, Ross found that this parasite enters the stomach wall of the insect, and, as a result of its development in that locality, forms reproductive bodies (sporozoites), which subsequently find their way to the veneno-salivary glands of the insect which is now capable of infecting other birds of the same species as that from which the blood was obtained in the first instance. Ross further showed that the mosquito which served as an intermediate host for this parasite could not transmit the malarial parasite of man or another similar parasite of birds (halteridium). These discoveries of Ross have been confirmed by Grassi, Koch and others, and it has been shown that the mosquitoes which serve as intermediate host for the malarial parasites of man belong to the genus *Anopheles* and especially to the species known as *Anopheles claviger*.

The question whether mosquitoes infected with the malarial parasite invariably become infected as a result of the ingestion of human blood containing this parasite has not been settled in a definite manner, but certain facts indicate that this is not the case. Thus there are localities noted for being extremely dangerous on account of the malarial fevers contracted by those who visit them, which on this very account are rarely visited by man. Yet there must be a great abundance of infected mosquitoes in these localities, and especially in low, swampy regions in the tropics. If man and the mosquitoes are alone concerned in the propagation of this parasite, how shall we account for the abundance of infected mosquitoes in uninhabited marshes? It appears probable that some other vertebrate animal serves in place of man to maintain the life cycle of the parasite, or that it may be propagated through successive generations of mosquitoes.

It is well known that persons engaged in digging canals, railroad cuts, etc., in malarious regions are especially liable to be attacked with one or the other of the forms of malarial fever. This may be due to the fact that the digging operations result in the formation of little pools suitable for the development of the eggs of *Anopheles*, but another explanation has been offered. Ross and others have found in infected mosquitoes certain bodies, described by Ross as 'black spores,' which resist decomposition and which may be resting spores capable of retaining their vitality for a long time. The suggestion is that these 'black spores' or other encysted reproductive bodies may have been deposited in the soil by mosquitoes long since defunct 'and that in moving the soil these dormant parasites are set at liberty and so in air, in water or otherwise, gain access to the workmen engaged' (Manson). This hypothesis is not supported by recent observations, which indicate that infection in man occurs only as a result of inoculation through the bite of an infected mosquito. The question is whether malarial fevers can be contracted in marshy localities independently of the mosquito, which has been demonstrated to be an intermediate host of the malarial parasite? Is this parasite present in the air or water in such localities as well as in the bodies of infected mosquitoes? Its presence has never been demonstrated by the microscope; but this fact has little value in view of the great variety of micro-organisms present in marsh water or suspended in the air everywhere near the surface of the ground, and the difficulty of recognizing the elementary reproductive bodies by which the various species are maintained through successive generations. It would appear that a crucial experiment for the determination of this question would be to expose healthy individuals in a malarious region and to exclude the mosquito by some appropriate means. This experiment has been made during the past summer and the result, up to the present time, has been reported by Manson in the London 'Lancet' of September 29. Five healthy individuals have lived in a hut on the Roman Campagna since early in the month of July. They have been protected against mosquito bites by mosquito-netting screens in the doors and windows and by mosquito bars over the beds. They go about freely during the daytime, but remain in their protected hut from sunset to sunrise. At the time Manson made his report all these individuals remained in perfect health. It has long been known that laborers could come from the villages in the mountainous regions near the Roman Campagna and work during the day, returning to their homes at night, without great danger of contracting the fever, while those who remained on the Campagna at night ran great risk of falling sick with fever, as a result of 'exposure to the night air.' What has already been said makes it appear extremely probable that the 'night air,' *per se*, is no more dangerous than the day air, but that the real danger consists in the presence of infected mosquitoes of a species which seeks its food at night. As pointed out by King, in his paper already referred to, it has repeatedly been claimed by travelers in malarious regions that sleeping under a mosquito bar is an effectual method of prophylaxis against intermittent fevers.

That malarial fevers may be transmitted by mosquitoes of the genus *Anopheles* was first demonstrated by the Italian physician Bignami, whose experiments were made in the Santo Spirito Hospital in Rome. The subjects of the experiment, with their full consent, were placed in a suitable room and exposed to the bites of mosquitoes brought from Maccarese, 'a marshy place with an evil but deserved reputation for the intensity of its fevers.' It has been objected to these experiments that they were made in Rome, at a season of the year when malarial fevers prevail to a greater or less extent in that city, but Marchiafava and Bignami say:

"It is well known to all physicians here that, although there are some centers of malaria in certain portions of the suburbs, the city proper is entirely free from malaria, as long experience has demonstrated, and at no season of the year does one acquire the disease in Rome."

In view of the objection made, a crucial experiment has recently been made in the city of London. The result is reported by Manson, as follows:

"Mosquitoes infected with the parasite of benign tertian malarial fever were sent from Rome to England, and were allowed to feed upon the blood of a perfectly healthy individual (Dr. Manson's son, who had never had malarial disease). Forty mosquitoes, in all, were allowed to bite him between August 29 and September 12. On September 14 he had a rise of temperature, with headache and slight chilliness, but no organisms were found in his blood. A febrile paroxysm occurred daily thereafter, but the parasites did not appear in the blood until September 17, when large numbers of typical tertian parasites were found. They soon disappeared under the influence of quinine."*

We have still to consider the question of the transmission of malarial fevers by the ingestion of water from malarious localities. Numerous medical authors have recorded facts which they deemed convincing as showing that malarial fevers may be contracted in this way. I have long been of the opinion that while the observed facts may, for the most part, be authentic, the inference is based upon a mistake in diagnosis. That, in truth, the fevers which can justly be ascribed to the ingestion of a contaminated water supply are not true malarial fevers—*i. e.*, they are not due to the presence of the malarial parasite in the blood. This view was sustained by me in my work on 'Malaria and Malarial Diseases,'

* Quoted from an editorial in the 'New York Medical Journal' of October 20, 1900.

published in 1883. The fevers supposed to have been contracted in this way are, as a rule, continued or remittent in character and they are known under a variety of names. Thus we have 'Roman fever,' 'Naples fever,' 'Remittent fever,' 'Mountain fever,' 'Typho-malarial fever,' etc. The leading physicians and pathologists, in regions where these fevers prevail, are now convinced that they are not malarial fevers, but are simply more or less typical varieties of typhoid fever—a disease due to a specific bacillus and which is commonly contracted as a result of the ingestion of contaminated water or food. The error in diagnosis, upon which the inference has been based that malarial fevers may be contracted through drinking water, has been widespread, in this country, in Europe and in the British possessions in India. It vitiated our medical statistics of the Civil War and of the recent war with Spain. In my work already referred to, I say:

"Probably one of the most common mistakes in diagnosis, made in all parts of the world where malarial and enteric fevers are endemic, is that of calling an attack of fever, belonging to the last mentioned category, malarial remittent. This arises from the difficulties attending a differential diagnosis at the outset, and from the fact that having once made a diagnosis of malarial fever, the physician, even if convinced later that a mistake has been made, does not always feel willing to confess it. The case, therefore, appears in the mortality returns, if it prove fatal, or in the statistical reports of disease, if made by an army or navy surgeon, as at first diagnosed."

I have already mentioned the fact that Marchiafava denies that malarial fevers prevail in the city of Rome, yet every one knows how frequently travelers contract the so-called 'Roman fever' as a result of a temporary residence in that city. In our own cities numerous cases of so-called 'remittent' or 'typho-malarial' fevers are reported in localities where typical malarial fevers (intermittents) are unknown, and at seasons of the year when these fevers do not prevail even in the marshy regions where they are of annual occurrence—during the mosquito season. Malarial fevers may, of course, occur in cities as a result of exposure elsewhere to the bites of infected mosquitoes of the genus *Anopheles*, either as primary attacks or as a relapse, or in urban localities in the vicinity of marshy places or pools of water suitable as breeding places for *Anopheles*. But when a previously healthy individual, living in a well-paved city, in a locality remote from all swampy places is taken sick with a 'remittent fever,' and especially when the attack occurs during the winter months, it is pretty safe to say that he is not suffering from malarial infection, and the chances are greatly in favor of the view that he has typhoid fever. It must be remembered that a remittent or intermittent course is not peculiar to malarial fevers. Typhoid commonly presents a more or less remittent character, especially at the outset of an attack; the hectic fever of tuberculosis is intermittent in character.

The formation of an abscess, an attack of tonsilitis, etc., are usually attended by chills and fever, which may recur at more or less regular intervals. Indeed, in certain cases of pyæmia the febrile phenomena are so similar to those of a malarial attack that a mistake in diagnosis is no unusual occurrence. Finally, I may say that it is the fashion with many persons and with some physicians to ascribe a variety of symptoms, due to various causes, to 'malaria' and to prescribe quinine as a general panacea. Thus a gentleman who has been at the club until one or two o'clock at night and has smoked half a dozen cigars—not to mention beer and cheese sandwiches as possible factors—reports to his doctor the next morning with a dull headache, a furred tongue and a loss of appetite which he is unable to account for except upon the supposition that he has 'malaria.' Again the symptoms arising from indigestion, from crowd-poisoning, from sewer-gas-poisoning, from ptomaine-poisoning (auto-infection), etc., are often ascribed to 'malaria' and quinine is prescribed, frequently with more or less benefit, for the usefulness of this drug is not limited to its specific action in the destruction of the malarial parasite.

As stated at the outset, it is evident, in the present state of our knowledge, that the term 'malaria' is a misnomer, either as applied to the cause of the periodic fevers or as used to designate this class of fevers. It would be more logical to use the name plasmodium fever and to speak of a plasmodium intermittent or remittent, rather than of a malarial intermittent. But it will, no doubt, be difficult to displace a term which has been so long in use, which up to the present time has had the sanction of the medical profession, and which expresses the popular idea as to the origin of that class of fevers which we now know to be due to a blood-parasite, introduced through the agency of mosquitoes of the genus *Anopheles*.

A STUDY OF BRITISH GENIUS.

By HAVELOCK ELLIS.

1. INTRODUCTORY.

UNTIL now it has not been possible to obtain any comprehensive view of the men and women who have chiefly built up English civilization. It has not, therefore, been possible to study their personal characteristics as a group. The sixty-three volumes of the 'Dictionary of National Biography,' of which the last has been lately issued, have for the first time enabled us to construct an authoritative and well-balanced scheme of the persons of illustrious genius, in every department, who have appeared in the British Isles from the beginning of history down to the end of the nineteenth century; and, with a certain amount of labor, it enables us to sum up their main traits. It has seemed to me worth while—both for the sake of ascertaining the composition of those elements of intellectual ability which Great Britain has contributed to the world, and also as a study of the nature of genius generally—to utilize the 'Dictionary' to work out these results. I propose to present here some of the main conclusions which emerge from such a study.

The 'Dictionary' contains some record—from a few lines to several dozen pages—of some thirty thousand persons. Now, this is an impracticable and undesirable number to deal with—impracticable because, regarding a large proportion of these persons, very little is here recorded or is even known; undesirable because it must be admitted that the majority, though persons of a certain note in their own day or their own circle, cannot be said to have made any remarkable contribution to civilization or to have displayed any very transcendent degree of native ability. My first task, therefore, was to ascertain a principle of selection in accordance with which the persons of relatively less distinguished ability and achievement might be eliminated. At the outset one class of individuals, it was fairly obvious, should be omitted altogether in the construction of any group in which the qualities of native intellectual ability are essential—I mean royalty, and members of the royal family, as well as the hereditary nobility. Those eminent persons, the sons of commoners, who have founded noble families, are, of course, not excluded by this rule, according to which any eminent person whose father, at the time of his birth, had attained the rank of baronet or any higher rank, is necessarily excluded from my list. Certainly the son of a king or a peer may possess a high degree of native ability, but it is practically impossible to estimate how far that ability would have carried him had he been the son of an ordinary citizen; it might be maintained that a successful merchant, ship-owner, schoolmaster or tradesman requires as much sagacity and mental alertness as even the most successful sovereign; by eliminating those individuals in whom the accident of birth counts for so much, we put this insoluble question out of court. I am surprised to find how few persons of obviously preeminent ability are excluded by this rule, and how many whom, at first, one would imagine it excludes, it really allows to pass, especially in the case of sons born before the father was created a peer. In order to avoid any scandalous omissions, I have thought it well to rule in all those sons of peers whose ability has clearly been of a kind which could not be aided by position and influence; thus I have included the third Earl of Shaftesbury, for it cannot be held that the possession of an earldom tends to aid a man in becoming a philosopher. It has, however, very rarely indeed been necessary to accord this privilege; I have always refrained from according it in the case of soldiers and statesmen.

Having eliminated those whose position in the world has clearly been influenced by the accident of birth, it remained to eliminate those whose place in the world, as well as in the 'Dictionary,' was comparatively small. After some consideration I decided that, generally speaking, those persons to whom less than three pages were allotted were evidently not regarded by the editors, and could scarcely be generally regarded, as of the first rank of eminence. Accordingly, I excluded all those individuals to whom less than that amount of space was devoted. When this was done, however, I found it necessary to go through the 'Dictionary' again, treating this rule in a somewhat more liberal manner. I had so far obtained some 700 names, but I had excluded many persons of undoubtedly very eminent ability and achievement; Hutton, the geologist, and Jane Austen, the novelist, for instance, could scarcely be omitted from a study of British genius. It was evident that persons with eventful lives had a better chance of occupying much space than other persons of equal ability with uneventful lives. Moreover, I found that a somewhat rigid adherence to the rule I had laid down had sometimes resulted in groups that were too small and too ill-balanced to be useful for study. In the case of musical composers, for instance, while those of recent times, of whom much is known, were dealt with at length, the earlier musicians, of whom little is known, though their eminence is much greater, were excluded from my list. On the other hand, a certain number of persons had been included because, though of quite ordinary ability (like Bradshaw, the regicide), they happened by accident to have played a considerable part in history. In going through the

'Dictionary' a second time, therefore, I modified my list in accordance with a new rule, to the effect that biographies occupying less than three pages might be included if the writers seemed to consider that their subjects had shown intellectual ability of a high order, and that those occupying more space might be excluded if the writers considered that their subjects displayed no high intellectual ability. At the same time, I eliminated those persons who rank chiefly as villains (like Titus Oates), and have little claim to the possession of any eminent degree of intellectual ability. I have also felt compelled to exclude women (like Lady Hamilton) whose fame is not due to intellectual ability, but to beauty and to connection with eminent persons.

So far as possible, it will be seen, I have sought to subordinate my own private judgment in making the selection. It has been my object to place the list, so far as possible, on an objective basis. At the same time, it is evident that, while I only reserved to myself a casting vote on doubtful points, there is necessarily a certain proportion of cases where this personal vote had to be given. A purely mechanical method of making selections would necessarily lead to various absurdities, and all that I can claim is that the principles of selection I have adopted have involved a minimum of interference on my part. It is certainly true that, even after much consideration and repeated revision, I remain myself still in doubt regarding a certain proportion of people included in my list and a certain proportion omitted. However often I went through the 'Dictionary,' I know that I should each time make a few trifling readjustments, and any one else who took the trouble to go over the ground I have traversed would likewise wish to make readjustments. But I am convinced that if my principles of selection are accepted, the margin for such readjustment is narrow.

I must here remark that a slightly lower standard of ability has been demanded from the women selected than from the men. It was not my desire that this should be so, and in the first list the same standard was demanded from women as from men. But it soon became clear that this was not practicable. On account of the greater rarity of intellectual ability in women, they have often played a large part in the world on the strength of achievements which would not have allowed a man to play a similarly large part. It seemed, again, impossible to exclude various women of powerful and influential personality, though their achievements were not always considerable; I allude to such persons as Hannah More and Mrs. Montague. Even Mrs. Somerville, the only feminine representative of science in my list, could scarcely be included were she not a woman, for she was little more than the accomplished popularizer of scientific results. In one department, and one only, the women seem to be little, if at all, inferior to the men in ability; that is in acting.

Putting aside the women for the moment, we find that Great Britain has produced no fewer than 859 men of a high degree of intellectual eminence. These I classify, according to the direction of their activities, as follows: Actors, 23; Artists (painters, sculptors, architects), 69; Business Men, 3; Divines, 128; Doctors, 7; Lawyers, 35; Men of Letters, 150; Men of Science (and inventors), 94; Musical Composers, 14; Philanthropists, 4; Philosophers, 27; Poets, 98; Politicians (statesmen, agitators, administrators, etc.), 113; Sailors, 29; Scholars, 40; Schoolmasters, 4; Soldiers, 46; Travelers and Explorers, 9.

It is necessary to make certain remarks concerning this classification. In the first place, there is some amount of duplication, owing to one man having sometimes distinguished himself in more than one field. This I have sought to minimize by placing a man only in those departments in which he really reached a high degree of eminence; thus many individuals belonging to the church or the law appear in my lists only as Politicians, Philosophers or Men of Letters, and not as Divines or Lawyers. It must be admitted, however, that, in a large proportion of cases, the question of classification and of duplication remains difficult and doubtful. The longest and most miscellaneous group is that of Men of Letters. It would have been possible to include the Poets also in this group, and in some cases (especially in regard to some of the Elizabethan dramatists) it has been difficult to decide into which group a writer should fall; but, on the whole, the Poets were too large, important and homogeneous a group to be merged into the miscellaneous body of Men of Letters. The smallness of the group of Business Men will probably attract attention. It would, indeed, be possible to enlarge the group somewhat, especially by including various prosperous publishers and newspaper proprietors; but it scarcely appeared that the biographers of these worthies regarded them as persons of extraordinary intellectual ability, and it was also notable that in many cases they owed much to birth and circumstances; in any case, the group would still remain small. It may seem strange that 'a nation of shopkeepers' should have produced so few merchant princes entitled to figure brilliantly in this 'Dictionary.' The real reason seems to be that a man of marked ability is not content to achieve success in business only; he uses his business capacity merely as an instrument for attaining further ends, to become free to devote himself to literary or scientific aims, and especially to obtain an entry into politics; business success is thus subordinated to success in other fields. It must be added that, while many inventors have used their scientific activity to build up large businesses, their claim to recognition in the 'Dictionary' remains that of men of science. Another unexpectedly small group is that of Doctors. Here, again, it would have been possible to enlarge the group somewhat by including a certain number of medical men, who are not, however, considered by their biographers to have really attained a durable reputation. Just as a really able business man is not satisfied with business success, so a really able doctor is not satisfied with professional success, but seeks a higher success, especially in science. A number of eminent men in science, letters and philosophy have been doctors, but it has not been in medical practice that their reputations have been made. I have no comments to make on the other groups, which, in all cases, I believe, fairly correspond to the real distribution of high ability. The group of Divines may seem large, but it certainly appears that religion has offered, in the past, if not in the present, a peculiarly favorable field for the development of mental ability.

There are 43 eminent women, the proportion to eminent men being only about 1 to 20, although, as I have already pointed out, a somewhat lower standard of intellectual ability seems here to be demanded in order to attain eminence. The eminent women fall into the following groups: Actresses, 13; Women of Letters, 23; Women of Science, 1; Philanthropists, 1; Poets, 5. It will be noticed that women have only attained eminence in five out of the eighteen departments, although, even allowing for legal and other disabilities, they have been free to attain eminence in at least twelve departments.

Having now explained how these lists have been obtained, it may be well at this stage to enumerate the individuals who thus appear entitled to rank as the preeminent men and women of genius produced by the British Isles. Names appearing in more than one group are marked by an asterisk. It has not been thought necessary to distinguish the very numerous cases in which individuals of the same name appear in different groups, since no confusion should thus be caused.

Actors.—Betterton, Booth, Burbage, Cibber, Cooke, Elliston, Foote, Garrick, Kean, Kemble, King, Lewis, Liston, Macklin, Macready, C. Mathews, C. J. Mathews, Palmer, Phelps, Quin, Webster, Wilks, Woodward.

Artists.—Adam, Banks, C. Barry, J. Barry, Bewick, Blake,* Bonington, Browne, Cattermole, Chantrey, Cockerell, Constable, Cooper, Copley, Cotman, Cox, Cozens, Crome, Cruikshank, Danby, Dawson, Dobson, Doyle, Dyce, Eastlake, Etty, Flaxman, Gainsborough, Gibson, Girtin, Gillray, Haydon, Hogarth, Holl, Inigo Jones, Keene, Landseer, Lawrence, Lewis, Linnell, Leech, Maclise, Morland, Mulready, Northcote, Opie, Phillip, Pugin, Raeburn, Reynolds, Romney, Rossetti,* Rowlandson, Sandby, D. Scott, G. Scott, Stevens, Stothard, Street, Stubbs, Turner, Vanbrugh,* Varley, Walker, Wilkie, Wilson, Woolner, Wren, Wright.

Business Men.—Gresham, Paterson, Whittington.

Divines.—Abbot, Adrian IV., Ainsworth, Alesius, Allen, Andrewes,* Atterbury, Bancroft, Barclay, Barrow,* Baxter, Bedell, St. Boniface, Bonner, Bradshaw, Browne, Burges, Burnet,* Butler,* Campion, Candlish, St. Thomas de Cantelupe, Cartwright, Challoner, Chalmers, Chichele, Chillingworth, Clarke, Colenso, St. Columba, St. Columban, Cooke, Cosin, Coverdale, Cranmer, Cudworth, St. Cuthbert, Dolben, Doddridge, Donne,* Duff, St. Dunstan, St. Edmund, Emlyn, Erskine, Faber, Ferrar, Fox, Foxe,* Fuller, Garnett, Henderson,* Heylin, Hoadley, Hook, Hooker, Irving, Jewel, Keble, Ken, King, Knox,* Langton,* Lardner, Latimer, Laud, Law, Leighton, Leslie, Liddon, Lightfoot, Lloyd, Loftus, Manning, Marsh, Marshall, Maurice, Melville, Middleton, Milner, Moffat, Montague, Naylor, Newman, Nowell, Owen, Paley,* Parker, Parsons, St. Patrick, Payne, Pearson,* Pecock, Peirce, Penry, Perkins, Peters, Powell, Preston, Pusey, Ridley, Sancroft, Sharp, Sheldon, Stanley,* Tait, Taylor, Tillotson, Tyndale,* Walsh, Warham, C. Wesley, J. Wesley, Blanco White, Whitefield, Whitehead, Whitgift, Wilberforce, St. Wilfrid, Willett, D. Williams, R. Williams, Wilson, Wiseman, Wishart, Wordsworth, St. Wulfstan, Wycliffe.*

Doctors.—Caius,* Linacre,* Mead, Pott, Sydenham, Cheselden, Cullen.

Lawyers.—Abinger, Ashburton, Austin, Blackstone, Cairns, Camden, Campbell, Clare, Cockburn, Coke, Curran, Denman, Eldon, Ellenborough, Fortescue, Haddington, Hale, Hardwicke, Kenyon, Littleton, Lyndhurst, Macclesfield, Maine, More,* Noye, St. John, Selbourne, Selden, Somers, Stair, Stephen, Stowell, Thurlow, Westbury, Williams.

Men of Letters.—Addison, Alcuin, Ascham, Bagehot, Banim, Barclay, Beckford, Bede, Borrow, Boswell, Browne, Buchanan,* Buckle, Bunyan, Burton, Calamy, Camden, Carleton, Carlile, Carlyle, Cibber,* Cobbett, Collier, Colman, Congreve, Cotton, Cowley,* Croker, D'Avenant, Day, Defoe, Dekker, Dempster, De Quincey, D'Ewes, Dickens, Digby, Dugdale, Elyot, Etheridge, Fanshawe, Farquhar, Fielding, Foxe, Francis, Galt, Geoffrey of Monmouth, Gibbon, Gifford, Giraldus, Goldsmith, Green, Grote, Hall, Hallam, Halliwell-Phillips, Hamilton, Harrington, Hazlitt, Herbert, Holcroft, Hood, Hook, Howell, Hume,* Hunt, Jeffrey, Jerrold, Johnson, Jonson, Kemble, Kennett, Killigrew, Kingsley, Knowles, Lamb, Landor, Lee, Leland, L'Estrange, Lever, Lewes, Lillo, Lingard, Lockhart, Lodge, Lover, Lyly, Lytton, Macaulay, Mackenzie, Maginn, Malone, Marryatt, Map, Milman, More,* Nash, Oliphant, Oldys, Paine, Paris, Perry, Pater, Pepys, Prynne, Raleigh,* Reade, Richardson, Ritson, Robertson, Roscoe, Scott, Seeley, Sheil, Sheridan,* Smollett, Southey, Sprat, Sidney Smith, Stanley,* Steele, Sterne, Steevens, Stevenson, Stow, Swift, Symonds, H. Taylor, W. Taylor, Temple,* Thackeray, Thirlwall, Trelawney, Trollope, Tyndale,* Udall, Urquhart, Vanbrugh,* Wakley,* Walton, Warburton, Warton, Whately, William of Malmesbury, William of Newburgh, Williams, Wilson, Wolcot, Wright, Wycherley.

Men of Science.—Arkwright, Babbage, R. Bacon,* Baily, Balfour, Banks, Barrow,* Baskerville, Bell, Bentham, Black, Boyle, Bradley, Brewster, Carpenter, Carrington, Cavendish, Caxton, Clifford, Colby, Cotes, Dalton, C. Darwin, E. Darwin, Davy, Dee, De Morgan, Drummond, Falconer, Faraday, Ferguson, Flamsteed, Flinders,* E. Forbes, J. D. Forbes, Gilbert, Glisson, Grew, Hales, Halley, Hamilton, Harvey, Herschel, Hooker, Horrocks, Hunter, Hutton, Jenner, Jevons, Joule, Knight, Lefroy, Lister, Lyell, Maclaurin, Malthus, Maxwell, Milner, Morland, Murchison, Murdoch, Napier, Newton, Oughtred, Owen, Parkes, Petty, Priestley, Ray, Sabine,* Sadler, Sedgwick, Sinclair, A. Smith, H. J. Smith, R. A. Smith, W. Smith, Stephenson, Sturgeon, Telford, Trevitheck, Tyndall, Wallis, Ward, Watson, Wedgwood, Whewell, White, Whitworth, Wilkins, Williamson, Wollaston, A. Young, T. Young,

Musical Composers.—Arne, Balfe, Bennett, Blow, Boyce, Byrd, Dowland, Gauntlett, Gibbons, Lawes, Macfarren, Purcell, Tallis, Tye.

Philanthropists.—Howard, Oglethorpe, Owen, Wakley.*

Philosophers.—Bacon, Roger Bacon,* Bentham, Berkeley, Bradwardine, Butler,* Duns, Erigena, Godwin, Hamilton, Hartley, Hinton, Hobbes, Hume,* Locke, Mackintosh, J. Mill, J. S. Mill, Ockham, Paley, Price, Reid, Shaftesbury, Stewart, Toland, Ward, Wycliffe.*

Poets.—Barbour, Barclay, Barham, Barnfield, Beaumont, Beddoes, Blake,* Breton, Browne, Bruce, Burns, Butler, Byron, Caedmon, Campbell, Campion, Chapman, Chatterton, Chaucer, Churchill, Clare, Clough, S. T. Coleridge, H. Coleridge, Collins, Cotton, Cowper, Crabbe, Crashaw, Daniel, Davies, Denham, Dibdin, Dobell, Donne,* Douglas, Drayton, Drummond, Dryden, Dunbar, D'Urfey, Fletcher, Ford, Fergusson, Fitzgerald, Gascoigne, Gay, Gower, Gray, Greene, Herbert, Herrick, J. Heywood, T. Heywood, Hogg, Hood, Keats, Keble, Langland, Lindsay, Lovelace, Lydgate, Marlowe, Marvell, Massinger, Middleton, Milton, Moore, Munday, Norton, Otway, Peele, Pope, Prior, Quarles, Rogers, Rossetti,* Rowe, Savage, Shakespeare, Shelley, Shirley, Sidney,* Skelton, Smart, Southwell, Spenser, Suckling, Tennyson, Thomson, Vaughan, Waller, Watson, Wither, Wordsworth, Wotton, Wyatt, Young.

Politicians.—Arthur, A. Bacon, N. Bacon, Bateman, Bradford, Brooke, Brougham, Burke, Burghley, Burnet,* Cade, Canning, Earl Canning, Carstares, Chatham, Chichester, Clarendon, Clive, Cobbett,* Cobden, Cork, Coutances, O. Cromwell, T. Cromwell, Eliot, Ellenborough, Fawcett, Fletcher, Forster, Fox, Foxe,* Frere, Gardener, Grattan, G. Grenville, W. Grenville, Hampden, Harrington, Hastings, Henderson,* Horner, Hubert Walter, Huskisson, Ireton, Kemp, Kirkcaldy, Knox,* S. Langton, W. Langton, Law, Lawrence, Leslie, Lewis, Lilburne, Lucas, Ludlow, Lytton, Macdonald, Macnaghten, Malcolm, Marten, Melville, Northumberland, O'Connell, Oldcastle, O'Leary, O'Neill, Paget, Parkes, Parnell, Peel, Penn, Pitt, Pownall, Pulteney, Pym, Raffles, Reid,* Roe, Rose, Sacheverell, St. Leger, Shaftesbury, Sherbrooke, Sheil,* Sheridan,* T. Smith,* Stratford de Redcliffe, Stirling, Temple,* Thurloe, Tone, Tooke, Tunstall, Vane, Wallace,* Walpole, Walsingham, Warriston, Waynflete, Wentworth, Whitbread, Whitelocke, Wilberforce, Wilkes, Williamson, Windham, Winthrop, Winwood, Wolsey, Wotton, Wykeham, Wyse.

Sailors.—Anson, Blake, Brooke, Byng, Cavendish, Cook, Dampier, Deane, Drake, Duncan, Exmouth, Flinders,* Franklin, Frobisher, Gilbert, Hawke, Hawkins, Hood, Leake, Nelson, Penn, Popham, Raleigh,* Rodney, Smith, St. Vincent, Trollope, Vernon, Willoughby.

Scholars.—Andrewes,* Adamson, Barrow,* Bentley, Bingham, Boece, Buchanan,* Caius,* Cheke, Colebrooke, Colet, Conington, Crichton, Dodwell, Grocyn, Grosseteste, Hales, Hickes, John of Salisbury, Jones, Lane, Lightfoot, Linacre,* Lowth, Montague, Morton, Palmer, Pattison, Pearson,* Pocock, Porson, Salesbury, Savile, T. Smith, W. R. Smith, Spelman, Thomas, Ussher, Whiston, Wordsworth.

Schoolmasters.—Arnold, Bell, Lancaster, Parr.

Soldiers.—Abercrombie, Cadogan, Campbell, Dundee, Edwardes, Gordon, Hardinge, Havelock, Hawkwood, Jones, Knollys, Lake, Lambert, H. Lawrence, S. Lawrence, Leven, Mackay, Marlborough, Moore, Morgan, Munro, Napier, Neill, Nicholson, Nott, Ochterlony, Oglethorpe,* Outram, Picton, Pollock, Raleigh,* Reid, H. D. Ross, R. Ross, Sabine,* Sale, Sidney,* Smith, Tarleton, F. Vere, H. Vere, Wallace,* Waller, Williams, Wilson, Wolfe.

Travelers.—Barrow, Bowring, Bruce, Chesney, Clapperton, Lander, Livingstone, Park, Speke.

The women fall into the following groups:

Actresses.—Abington, Anne Barry, Elizabeth Barry, Bracegirdle, Cibber, Clive, Jordan, Kelley, Oldfield, O'Neil, Siddons, Woffington, Yates.

Philanthropist.—Fry.

Poets.—Baillie, Browning, Hemans, Landon, Rossetti.

Women of Letters.—Austen, Barbauld Behn, Burney, C. Brontë, E. Brontë, Centlivre, Cowley, Edgeworth, Eliot, Ferrier, Gaskell, Godwin, Inchbald, Jameson, Martineau, Mitford, Montague, More, Morgan, Newcastle, Opie, Radcliffe.

Women of Science.—Somerville.

It may be asked how these 902 persons of preeminent intellectual ability have been distributed through the course of English history. I find that from the fourth to the eleventh centuries, inclusive, there are only 14 men of sufficient distinction to appear in my lists. From that date onwards (reckoning by the date of birth) we find that the twelfth century yields 10, the thirteenth 9, the fourteenth 16, the fifteenth 31, the sixteenth 156, the seventeenth 182, the eighteenth 352, the nineteenth 132. It is probable that the estimate most nearly corresponds to the actual facts as regards the seventeenth and eighteenth centuries. Before that time our information is usually too scanty, so that many men of notable ability have passed away without record. In the nineteenth century, on the other hand, the material has been too copious, and the national biographers have probably tended to become unduly appreciative of every faint manifestation of intellectual ability. The extraordinary productiveness of the eighteenth century is very remarkable. In order to realize the significance of the facts, however, a century is too long a period. Distributing our persons of genius into half-century periods, I find that the following groups are formed:

1101–1150 4	1151–1200 6	1201–1250 2	1251–1300 7	1301–1350 6	1351–1400 10
1401–1450 6	1451–1500 25	1501–1550 49	1551–1600 107	1601–1650 107	1651–1700 75
		1701–1750 129	1751–1800 223	1801–1850 131	

Only one individual belongs to the second half of the nineteenth century. It is scarcely necessary to remark that the record for the first half of the nineteenth century is still incomplete. Taking the experience of the previous century as a basis, it may be estimated that some 40 per cent. at least of the eminent persons belonging to the first half of the nineteenth century are still alive. This would raise that half-century to the first place, but it may be pointed out that the increase on the previous half-century would be small, and also that the result must be discounted by the inevitable tendency to overestimate the men of our own time. When we bear in mind that the activities of the individuals in each of these groups really fall, on the whole, into the succeeding group, certain interesting points are suggested. We note how the waves of Humanism and Reformation, when striking the shores of Britain, have stirred intellectual activity, and have been prolonged and intensified in the delayed English Renaissance. We see how this fermentation has been continued in the political movements of the middle of the seventeenth century, and we note the influence of the European upheaval at the end of the eighteenth century. The extraordinary outburst of intellect in the second half of that century is accentuated by the fact that, taking into account all entries in the 'Biographical Dictionary,' the gross number of eminent men of the low standard required for inclusion shows little increase in the eighteenth century (5,789, as against 5,674 in the preceding century, is the editor's estimate); the increase of ability is thus in quality rather than in quantity. It is curious to note that, throughout these eight centuries, a marked rise in the level of intellectual ability has very frequently, though not invariably, been preceded by a marked fall. It is also noteworthy that in nearly every century the majority of its great men have been born in the latter half; that is to say, that the beginning of a century tends to be marked by an outburst of genius, which declines through the century. This outburst is very distinct at the beginning of the nineteenth century, and, as we have seen reason to believe, it was probably succeeded by an arrest, if not a decline, in the production of genius. If that is so, we may probably expect a fresh outburst of intellectual ability at the beginning of the twentieth century. It would seem that we are here in the presence of two factors: a spontaneous rhythmical rise and fall in the production of genius, so that a period of what is improperly called 'decadence' is followed by one of expansive activity; and also, at the same time, the stimulating influence of great historical events, calling out latent intellectual energy. These considerations, however, are merely speculative, and it is sufficient to accord them this brief passing notice.

Having thus explained the nature of the data with which we have to deal, and the methods by which it has been obtained, we may now proceed, without further explanations, to investigate it. We have to study the chief characteristics—anthropological and psychological—of the most eminent British men and women of genius (using that word merely to signify high intellectual ability), in so far as these characteristics are revealed by the 'Dictionary of National Biography.'*

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*In a certain number of cases I have supplemented or corrected the information derived from the 'Dictionary' by reference to other reliable sources, in many cases of more recent date.

THE WEATHER VS. THE NEWSPAPERS.

By HARVEY MAITLAND WATTS.
THE PHILADELPHIA 'PRESS.'

"APRIL 4, 1668. I did attend the Duke of York and he did carry us to the King's lodgings; but he was asleep in his closet; so we stayed in the green-room; where the Duke of York did tell us what rule he had of knowing the weather; and did now tell us we should have rain before to-morrow (it having been a dry season for some time) and so it did rain all night almost; and pretty rules he hath, and told Brouncker and me some of them, which were such as no reason can readily be given for them."—*Pepys' Diary.*

In 1668 the inquisitive Pepys had warrant for his exclusion of weather lore from the domain of reason, but with three centuries gone all things have changed, save the ready disposition of men of a certain literary bent to cry 'mystery' where there is none, and of all the popular phrases in use to-day, when the weather is up for discussion in the newspapers, none is so abused in the over-using as that which points out that science has 'no reasonable explanation' to offer, and this of phenomena explained in school books!

Indeed, though the secular newspaper is not otherwise given to an observance of Biblical philosophy, no saying is more devoutly believed, no maxim more rigidly accepted as the guiding principle of journalism in its treatment of the weather, than that of the famous text: 'The wind bloweth where it listeth and thou hearest the sound thereof, but canst not tell whence it cometh or whither it goeth.'

The indifference to weather facts is all the more extraordinary, since the weather is not a casual matter, but one of necessitated daily interest to the public, and, consequently, to the newspaper. That the newspaper recognizes this interest, that it caters to it, that it makes a special effort to meet a taste which it, in fact, partly creates, is shown by the extreme industry evinced in the collection, classification and presentation of storm news; in the constant appearance of the 'weather' assignment on the city editor's list, and in a zeal for a weather 'spread,' with a pomp of type and details; unfortunately, however, not according to knowledge, and, so far as the public is concerned, too often making 'confusion worse confounded.'

In view, therefore, of popular interest in the weather, and in view of the great change that has come over the science of the weather in the past twenty-five years, it is as amazing as it is deplorable that such an indictment of the newspaper treatment of the weather can be made, since; although in this matter the newspaper reflects public ignorance and adds to it, in other lines of endeavor the average newspaper is quick to reflect knowledge and expertness. But with the weather it is otherwise. Instead of informing, most newspapers merely confirm popular error. Although for a generation the main facts of weather drift have been settled beyond dispute, they know nothing of it; they are still in the swaddling clothes of belief, and still accept the concepts of their grandfathers, who swore by the 'Shepherd of Banbury's Rules,' and knew a wet moon when they saw it. As under normal circumstances this profound ignorance would give way slowly to the new science, it is regrettable that on the part of journalism there should be so gross a dereliction, and that at this late day, instead of being the harbinger of the new fact, it should still be the handmaiden of the old obscurantism. If, believing the problem of meteorology to be too difficult to understand, the newspaper would let the weather alone, things might improve. But, unfortunately, the weather will not let the newspaper alone, and so, through government forecast and actual incident and accident, the newspaper must keep pegging away at it, editorially and 'reportorially,' until the present anomalous state of things is developed, for which there is no excuse in the nature of science or in the intelligence of those who 'get out' the modern newspaper. A daily journal is not a technical publication. One does not expect to see worked out in it problems in the differential calculus. One might forgive a casual error in the statement of the formulæ for hydrocarbon compounds, since organic chemistry is not served up as a daily dish, but the persistent indifference to meteorological explanations, within the capacity of a boy of fifteen, is inexcusable, and, unfortunately, as the comments on the Galveston horror show, there is no sign of a change for the better. A few, a very few, newspapers—exceptions but prove the rule—reflect expertness and evince common-sense accuracy, still at the same time losing nothing in the way of presenting the subject in an interesting and attractive manner; but, for the most part, the average newspaper fails in its duty to the public, so far as the weather is concerned, in the four following particulars:

1. By reason of a misapprehension and misrepresentation of the simplest fundamental facts of atmospheric circulation and weather movement, effects being treated as causes, etc.

2. By reason of a constant confusion of terminology and a generally slipshod use of weather terms and facts.

3. By reason of a persistent refusal to recognize much, if any, difference between the scientist and the charlatan, between the expert and the quack; and, in fact, by a disposition—marked in some quarters—to give undue prominence to bogus weather prophets and wonder-

mongers, at the expense of the equipped and reputable students of the subject.

4. By reason of a hypercritical but uninformed attitude toward the daily forecasts of the United States Weather Bureau, by which the work of the Bureau is hampered and its value to the public materially reduced.

Such is the situation. If the apprehension of the simple fundamental facts of the weather—taking the first count in the indictment into consideration—were difficult, if the problems were beyond the ability of the man in the street, one would excuse the newspaper and quash the indictment, but the practical questions at issue are as clear as crystal and as simple as A, B, C. There is no dispute among observers as to the fundamental facts, and the surface phenomena themselves are as regular as the progress of the sun from tropic to tropic. The abstract and controversial discussion as to final causes which occupies certain meteorologists is not germane, so far as the treatment of the daily weather goes, and it is the newspaper, not the weather men, who cannot tell a meteorological 'hawk from a hand-saw.'

Because a Dolbear, a Trowbridge and a Lodge may not agree on the ultimate expression for electric energy does not prevent a citizen from distinguishing between arc and incandescent lights, or between a trolley car and a call bell. And so it is with the simple weather facts. The synthesis of American weather, which can be given in two sentences, is within the understanding of any one, for American weather is the resultant of a west to east drift in the general circumpolar circulation of the north temperate zone, which drift is broken up into two great eddies, and only two, the cyclonic and the anti-cyclonic; the former, the cyclonic, the center of general storm phenomena, and the condition and cause of local storm disturbances (tornadoes, squalls, thunderstorms, etc., as local conditions and the seasons determine); the latter, the anti-cyclonic, the center of clear weather phenomena. Into this circumpolar system intrude the tropical anti-cyclone and the tropical cyclone, and play their part in the proper season and region. That is all.

The great circumpolar drift moves in ceaseless round from the Pacific to the Mississippi Valley, from the Mississippi Valley to the Atlantic, from the Atlantic to Europe, to Asia, to the Pacific, and back again. In it appear the two great atmospheric eddies, oftentimes over a thousand miles in diameter, and covering 1,000,000 square miles of the earth's surface. These two type eddies, the cyclonic and the anti-cyclonic, are the real distributers of the weather, as we know it. They can be seen to shift as a whole from west to east, not necessarily along a straight line, however, for they have a way of bellying down, or sidling from the northwest to the southeast, and from the southwest to the northeast, or from all points in the west between north and south to all points in the east between north and south, making all sorts of combinations, accelerating in speed, slowing up, sometimes standing still seemingly, but yet progressing surely, certainly, inevitably to the east.

The anti-cyclone, judging it wholly from its invariable surface effects, which can be seen day after day on the United States Weather Bureau's daily maps, is essentially a down-draught eddy or center of dispersion for the winds; an area where the barometric pressure is above the normal (Chart No. 1). The cyclone, also invariably, so far as the surface levels of the atmosphere go, is an up-draught eddy, a center of wind concentration; an area where the barometric pressure is below the normal (Chart No. 2). When it is remembered that the winds circulate outward from the high pressure center of an anti-cyclone spirally, from left to right, clockwise, while the winds move into the low pressure of a cyclone spirally, from right to left, counter clockwise, some idea of the simplicity of weather causation is gained. Remembering also that, by reason of the descent of relatively cool, dry air and its dispersion, the polar anti-cyclone is the cause of clear and cool weather phenomena, while by reason of the rushing in of warm, moist air on one side, its expansion and cooling as it rises, and cool, dry air on the other, the cyclone is the seat of storm phenomena, the first primary lesson in American weather is over.

Through a failure to grasp the greater synthesis of the weather, terminology and local storm differentiation have naturally become hopelessly muddled in the newspapers, though here the difficulty of grasping the facts is even less than in the first issue. The cyclone is the center of rhetorical disturbance, and inky clouds of misuse and abuse gather about it, since, as a parent of storms and as a weather-breeder of no mean type, the cyclone plays the dramatic leading rôle in American meteorology. It is not only itself capable of great development of storm energies in the winter, early spring and late autumn, but in its milder summer moments is particularly likely to be the parent of specific local disturbances. With one of these, the tornado, it is identified popularly by the newspapers, which, in spite of all explanation on the part of the Weather Bureau, have not yet seen the absurdity of applying to a secondary phenomenon, insignificant in size compared with the primary eddy, the name of the general disturbance. The cyclone, sweeping along with warm, moist weather in front, clear and cool weather in its rear, attended by a general rain, and in its sphere of influence covering a dozen States or more, surely may be separated from the local tornadoes, which, though destructive and terrifying, are but mere local incidents in the parent circulation. This is so markedly shown in the weather map of March 27, 1890, that, once seen, it is incomprehensible how error can so hold its own (Chart No. 3).

The simplest study of the invariable facts shows that the tornado is a small eddy, superinduced under favorable meteorological and topographical conditions in the outer circulation (southwest to southeast quadrant) of a general low area disturbance (cyclone). It is of extreme intensity, the rotary motion of its winds around the central core (vortex) being inconceivably swift (100 to 500 and perhaps 1,000 miles an hour), but is limited as to duration—it lasts, at the longest, but a few hours; limited as to the width of path, this may vary from fifty to five hundred yards, one of a mile in width being exceptional, and limited as to the length of track, which if it exceeds 100 miles is unusual. Now, a cyclone is continental in magnitude, and may travel for weeks, going two-thirds of the way around the globe. Just as the cyclone's path is determined by interaction of barometric stresses in the general drift of the whole atmosphere, so the path of tornadoes is determined by the interaction of currents in the cyclonic drift. Individual tornadoes do not cross the country intact, as so many weather quacks prophesy, but the parent cyclone that conditions a number of them in the Western States one day, having traveled further east the next day, if local conditions allow, may superinduce similar local outbursts in the Middle States.

Thunder-storms, as a rule, are familiar enough and definite enough to escape the general muddlement, but even they have not escaped the tendency to 'cyclonize' every weather phenomenon. Hence the old-fashioned thunder-gust, the familiar straight outrush of the thunder squall, sometimes destructive, figures nowadays as a 'cyclone,' a 'tornado,' or mayhap a 'hurricane.' Not only this, but the thunder-storms that occur along the line of change from the warm front of a cyclone to the cooler rear—a cool anti-cyclone following—are accused of causing the anti-cyclone when they are an effect of the advancing anti-cyclone and not its cause, any more than the cow-catcher is the cause of the approach of a train.

Above all, the most extraordinary pother and confusion prevail over another storm type, the hurricane or tropical cyclone. Here the newspapers are seconded in their obscurantism by writers of books on the West Indies or the Philippines, all of whom should know better, or could know better if they only so elected. The hurricane—the typhoon is its Asian congener—though the smallest of cyclones, since its diameter usually ranges from 100 to 500 miles, is easily differentiated from the biggest tornado, since the latter's diameter at the greatest barely reaches one mile. As the tornado in its narrow swath kills tens and hundreds, so the hurricane, with vast areas of sea and land swept by the besom of its great winds and washed by its tremendous storm wave, runs the death total up to the hundreds and thousands. The hurricane does not originate in the circumpolar drift, but is a cyclonic whirl developed on the periphery of the great North Atlantic anti-cyclone. It is a tropical intruder, the only general storm disturbance the tropical circulation gives us. It is no new type, but simply one of the two great eddies known to the general atmospheric circulation the world over. As it is a concentrated cyclone, the winds blow in and about its central vortex with a velocity that may easily reach 100 miles an hour, while velocities of sixty and seventy miles an hour are not uncommon at great distances—500 miles or so—from the center. It is the most violent tempest the newspapers are called upon to chronicle, but its characteristics are so invariable, its paths so well known—determined largely by the position of the North Atlantic anti-cyclone in relation to the continental anti-cyclones—that it is surprising to witness the confusion that marks news and editorial comment when one is at hand. Though every boy has seen a spinning top meandering over the pavement, most newspapers find it difficult to understand the slow forward progressive motion of the whole rotating cyclonic mass on its track. And yet Franklin, over 100 years ago, fathomed the secret of the apparent paradox that the storms that condition our northeast gales actually have their center to the southwest; and Redfield, in 1830-50, taught the American public all about these revolving storms of the Atlantic Ocean, while Piddington, a Briton, in 1848, in his 'Sailor's Horn Book,' made the broad facts plain to the simple-minded, unlearned, every-day navigator, and himself invented* the technical term 'cyclone' specifically to describe the rotary storms, then believed to be peculiar to the tropical oceans. (Chart No. 4).

Hand in hand with misunderstanding and misapprehension of weather phenomena has gone the booming of the weather quack. In some ways this is the most discreditable feature of the newspaper treatment of the weather, since ignorance plus the quack represents a recrudescence of medievalism which would seem incredible, were it not a persistent factor in the 'popular' weather article that is given prominence by leading newspapers, while the waste of telegraphic tolls in sending broadcast the views of some pseudo-scientific zany, whose star for the moment is in the ascendant, is an extravagance which, if spent in the right direction, might save the news-gathering organization money and give it reputation. It is about time the newspapers learned that there are only two classes of weather quacks and wonder-mongers—those who are greater knaves than fools; those who are greater fools than knaves.. The whole business belongs to the slimy byways of astrology, or represents the fecklessness of those who peddle a quack nostrum composed of one per cent. bogus science to ninety-

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* 'The Sailor's Horn Book for the Law of Storms,' by Henry Piddington, London, 1848, page 8.

nine per cent. of piety. And yet these creatures are quoted and exploited, their forecasts are printed in a conspicuous manner and they are encouraged to fleece the ignorant by the authority and circulation given them even by metropolitan journalism.

The spectacle is stultifying, and yet, in the face of this, in the face of the fact that Weather Bureau stations in the great centers of population have been compelled to phrase their forecasts in primer English, because 'cyclone' and 'anti-cyclone' puzzled the newspapers and frightened the people, whose idea had been formed on newspaper interpretation of the forecasts; because 'highs' and 'lows' were deemed too mysterious for comprehension; in face of all this humiliating confusion, the forecasts, if they err, are criticized in a way that not only brings out all the old, but a new ignorance that is as invincible as it is hypercritical, and raises a popular prejudice against the Weather Bureau wholly unwarranted by the facts. Making no quack claims, the Bureau officials are discredited as to short-range or long-range forecasts, while the Wigginses and Devoes take the tripod and scatter storms, floods and dooms, as the irresponsible bad boy splashes water, and are acclaimed therefor. The essential fundamental difficulty of the question of forecasts is—aside from the blank misunderstanding of forecasts that are verified by results—that those who criticize forecasting not only exaggerate the percentage of error, but are wholly oblivious to the fact that forecasting is an art rather than a *science*. The art is based on science, and as the science improves so will the art; but being an art, the personal equation—knowledge of facts being equal—plays a very important part in results. If criticism were directed to any real shortcomings in the Bureau's organization, the Bureau's interests would be promoted; but here, as in other features of weather discussion, the real issues not being apprehended, the discussion is usually pointless and without result. Equipped as the average first-class American newspaper is in plant and staff, alert, keenly anxious to be up to date, impatient of humbug, a unique opportunity is given it by the first year of the new century—always a season of repentance—for that about-face in its treatment of the weather that its past lapses in this respect and the pressing importance of the subject demand.

CHART No. 1.—In this chart, and in all the succeeding ones, the heavy continuous lines are isobars, the lines connecting points that have the same barometric pressures. They thus map out the area in which the barometer may be above or below the normal. The dotted lines are isotherms connecting points that have the same temperatures. On the morning of September 18, 1900, the weather over the central and Atlantic Coast States was dominated by a typical anti-cyclonic eddy, central over Wisconsin. This anti-cyclone moved into the United States over Montana on the fifteenth, and its drift, being a little south of east, its center passed out to sea off Cape Cod on the twentieth. It was accompanied for the most part by clear, cool, crisp autumn weather and was the first real break in the reign of warm weather since the cool wave (anti-cyclone) of the last three days of July. As can be seen on the chart, the winds disperse from the center, where the barometer is the highest, and the character of the winds and the local weather it distributes to any one place vary as the center of the anti-cyclone passes north or south of the locality. Since anti-cyclones are the seat and area of high atmospheric pressures, the barometric normal being thirty inches, in the scientific slang of the Weather Bureau they are denominated 'high areas,' or 'highs,' for short. In summer, when coming from the north, the 'highs' are the cause of the cool, and, in the winter, of cold waves, lower or low temperatures invariably accompanying the polar anti-cyclonic eddies. It must be remembered that many anti-cyclones are not so regular in character as the one charted. They are often vague in form and extent—this is also true of cyclonic eddies—

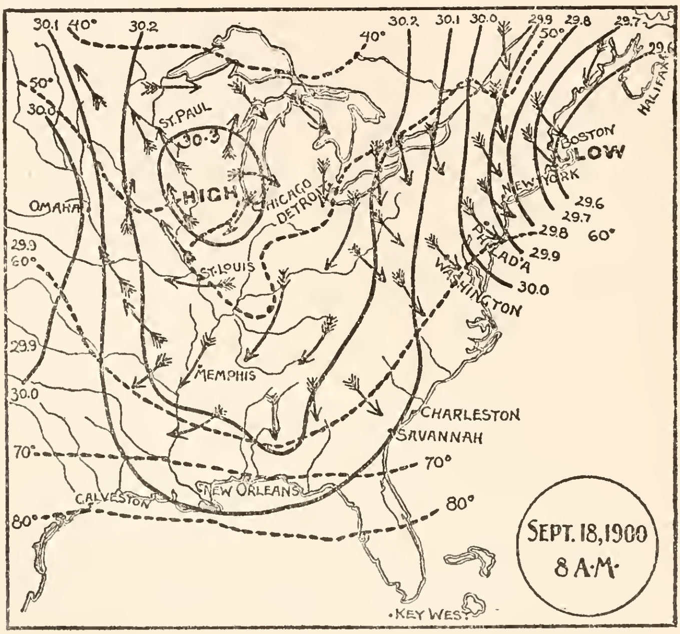

FIG. 1.

and the center may be trough-shaped instead of circular, as was the case with this one by the time it had reached the Atlantic Coast. Certain anti-cyclones that move along the southern circuit or that intrude from the tropical 'high,' as they tend to set up a vigorous circulation from the south to the north, are the predisposing cause of hot waves in summer, and warm waves in winter. The anti-cyclone is the most important eddy in the general circulation, but it was neither discovered nor named till long after the cyclonic circulation had been the subject of an abundant literature.

CHART No. 2.—The cyclonic eddy is the most interesting weather phenomenon the United States knows. Its sphere of influence is marked by extraordinary contrasts, particularly in between seasons. This typical cyclone, of November 24, 1898, shows how the warm southerly winds, blowing in toward the cyclone in front, push the isotherms to the north and create a warm wave (relatively) known as the 'sirocco front' (shaded on the chart), while at the same time the cold northerly and westerly winds, blowing south in the rear, carry down the isotherms and mark the extent of the cold wave that follows. Hence around and about an intense early winter cyclone we may have warm, moist rains on the southeast, cool rains, turning to snow, on the east and northeast, with blizzard conditions on the northwestern flank and clear, cold weather on the extreme southwestern, as was the case in this instance. In consequence of this, the possible contrasts through the center of the average early winter cyclone are such as to jump any locality over which it passes from summer (60° to 70°) temperatures to winter (40° to 20°) in a few hours, and it is the passage of a typical cyclone over any given locality that gives the violent changes peculiar to American weather. Wholly independent of its own circulation of winds about its

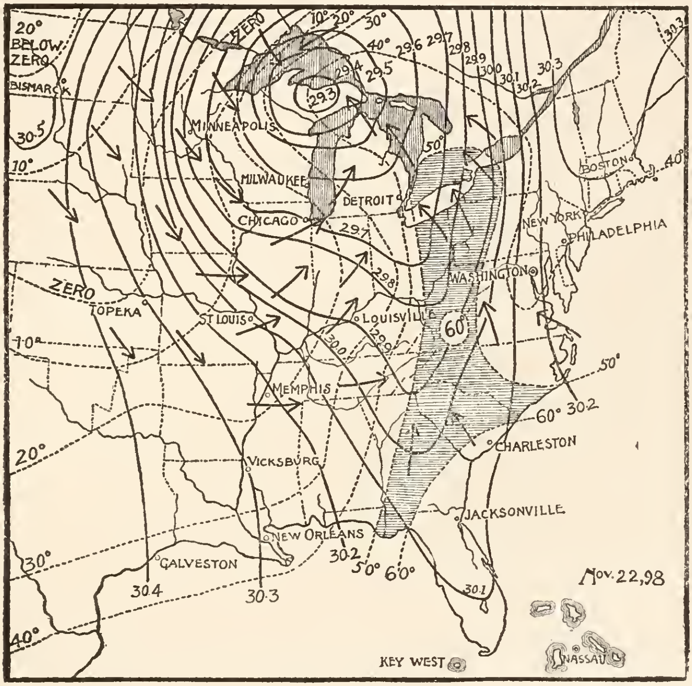

FIG. 2.

center, the cyclone moves forward in the circumpolar drift at the rate of from fifteen to thirty-five miles and more an hour. If it passes north of a place, the locality is affected by its southeasterly, southerly and southwesterly to westerly winds and the weather that belongs to these quadrants. If it moves along a line south of any given place, the locality is affected by its easterly and northeasterly to northerly and northwesterly winds, which make up the coldest and stormiest side of the cyclone. As the barometer at its center is always low, the cyclone is called a 'low area,' or 'low,' for short, and as such appears in Weather Bureau reports. Storm intensity in a cyclone is in due relation to the minima of its own barometric pressures and to the maxima of the anti-cyclone nearest it. All forecasting is based on an effort to balance the probable paths that the cyclones and anti-cyclones will take with respect to the regions east of their point of origin.

Chart No. 3.—The line of tornado frequency naturally moves north with the sun, the tornadoes of winter and spring occurring in the south or border States, while the maximum of tornado frequency for the northern States is in June. Tornadoes are superinduced by unstable conditions of the atmosphere, which are particularly likely to prevail to the southeast and south of a cyclonic center, and the relation of these violent local storms to the great central disturbances is strikingly shown on the United States weather map of March 27, 1890, the day of the Louisville tornado. The parent cyclone was of enormous, though not abnormal, area. It had caused, and was causing, snow and rains from the Rocky Mountain slope to the Hudson Valley, from Arkansas to Minnesota. Its vortex, with a barometric pressure of 29.10 inches—as low as in some of our most destructive tropical cyclones or hurricanes—covering a large part of Illinois,

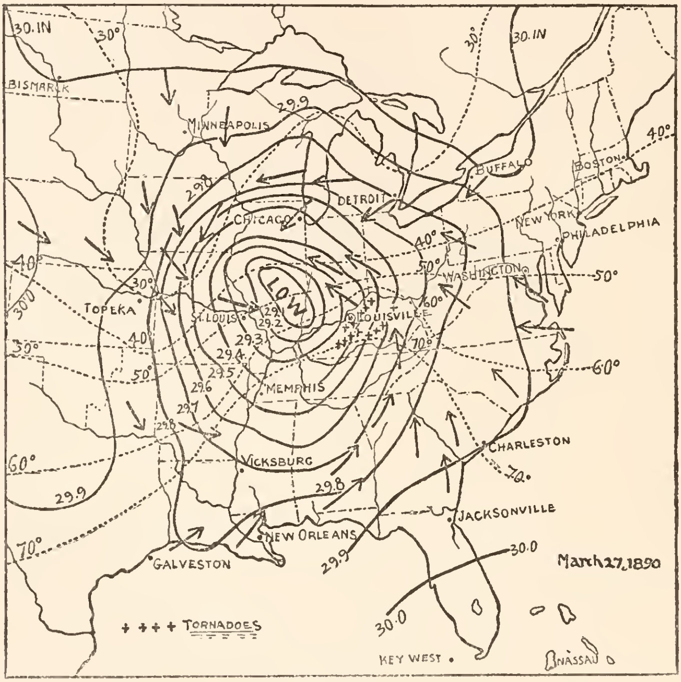

Fig. 3.

was drawing to it winds from all over the United States, from the Rocky Mountains to the Atlantic, from the Gulf of Mexico to the Canadian border. In front of the cyclone, pushed up by the warm southerly winds, the temperatures were all above freezing and, in its southeastern quadrant, reached summer temperatures of 70°. Several hundred miles through its center, in the rear, the temperatures were below freezing in its northwestern quadrant and 30° cooler in its southwestern quadrant than in its southeastern quadrant. Compared with this tremendous storm disturbance, the tornadic outbursts it caused in Kentucky were insignificant local eddies which, on this map, can only be indicated by crosses, though their violence caused a loss of 113 lives and property losses of over $3,000,000, 76 being killed, 200 injured, and property damaged to the extent of $2,500,000 in Louisville alone.

The only difference between the conditions that caused the Louisville and near-by tornadoes and those that superinduced the St. Louis tornado and near-by outbreaks, on May 27, 1896, was in degree, not in kind. The March cyclone of 1890 was extensive in area and of great intensity; the parent cyclone of May 27, 1896, was a vague low area of the mild summer type, with a pressure at the center of only 29.70 inches, covering several States, St. Louis being in its southeast quadrant in the afternoon. The tornadoes this vague, weak cyclone set up in numerous localities were very destructive, the losses of life in and about St. Louis reaching to over 300 killed, with property losses of $12,000,000. The parent cyclone moved northeast and was central over the Lakes between Lake Huron and Lake Ontario on the afternoon of the 28th, with an increase in intensity, its center having a pressure of 29.40 inches, and, as local conditions allowed, it

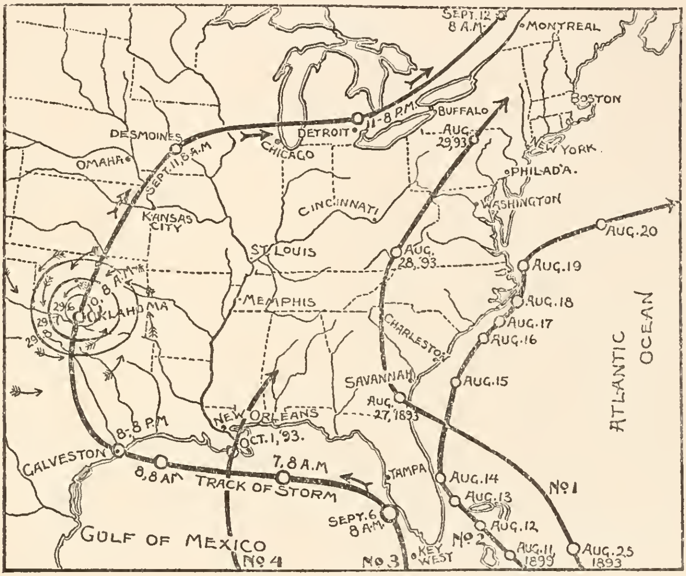

Fig. 4.

caused a handful of small tornadoes in Maryland, Pennsylvania and New Jersey, as well as a large number of thunderstorms.

Chart No. 4.—This chart gives the track of four destructive tropical cyclones, known colloquially as 'hurricanes.' The hurricane differs from the continental cyclones of the North Temperate Zone in its surface effects in nothing but its intensity. The wind circulation is true to the cyclonic type (the term 'cyclone' was invented to describe the movement of the winds in the tropical tempest), but reaches great velocities, and, whereas the barometer in an intense continental cyclone may only fall to 29 inches in the tropical cyclone, its vortex may record 28 inches, and, in certain cases, the barometer has fallen to 27. In consequence of this, the vortical velocity of the wind is very great, reaching in gusts a rate of 80, 90, 100 and 125 miles an hour. As one of these tropical eddies advances from the West Indies and moves up the Atlantic Coast, it gives all localities north of its center, successively, gales from the northeast. These August-September, northeast gales, erroneously called 'equinoctials,' are but a part of the hurricane's whirl, but with the heavy rain and high tides are its most familiar attribute to the Gulf Coast and Atlantic Seaboard peoples.

The violence of these northeast gales and of all the hurricane winds that blow about the vortex has nothing to do with the storm's progressive motion, which is often less than 10 miles an hour, since this is controlled by the general circulation; the westward drift of the tropics, until it gets north of the parallel of 30°, and later by the eastward-moving currents of the North Temperate Zone. When the tropical cyclone gets into this more northerly system it behaves exactly as a regular continental cyclone, and has to take its chances in the action and interaction of the polar cyclones and anti-cyclones that cover the continent. Hence the variations in its path, a few of which are given here.

Track No. 1 is that of the cyclone that caused the disaster on the Sea Islands near Savannah and Charleston, in September, 1893, causing a loss of over 400 lives (some claim 1,000 in all), leaving 30,000 homeless and destitute. It also proved destructive as far north as Long Island. Track No. 2 is that of the Porto Rican cyclone of August 8, 1899, that caused a loss of 2,900 lives with 500,000 people more or less affected by its devastating effects. Track No. 4 is that of the storm that caused a loss of nearly 2,000 lives along the coast and in the bayou district of Louisiana, in October, 1893.

In the case of the great Galveston cyclone (track No. 3), an anti-cyclone lying over the Middle States held it up as it was moving in toward Florida, and its path was deflected westward. It moved about 10 miles an hour along its track from September 6 to September 9, while the vortical winds were blowing toward and about the center at a rate of from 50 to 100 miles an hour, as Galveston learned on the 8th, the severest blow coming from the southeast after the center had passed Galveston. From the 9th to the 11th it decreased in intensity, and, when central over Oklahoma, on the 10th, had all the appearance of an ordinary rainy 'low area.' In jumping from Des Moines on the 11th to near Montreal on the 12th, it increased in energy; the rate of progression was about 50 miles an hour, at the same time its vortical winds over the Lakes reached a velocity of 72 miles. On the 13th it was over Newfoundland, and caused great damage to shipping on the 'Banks,' and reached Iceland on the 20th, traveling from September 1, when it originated south of Porto Rico, to September 20, over 7,000 miles, and at times covering, in diameter, regions 1,000 miles across.

THE PHILIPPINES TWO HUNDRED YEARS AGO.

BY PROFESSOR E. E. SLOSSON,
UNIVERSITY OF WYOMING.

"I NOW and then, as occasion offers, undertake to plead the cause of the *Indians* in the *Philippine* Islands, as many more have for those of *America:* This is tolerable because grounded on compassion, mercy and the inclination of our kings and their supreme council of the *Indies,* who love them as their children, and give repeated orders every day for their good, advantage, quiet, satisfaction and ease. There is no other fault to be found with those poor creatures but that which *S. Peter Chrisologus* found in the holy innocents, *whose only crime was that they were born.* There is no reason for all their sufferings but their being in the world; and it is worth observing that tho' so many pious, gracious, and merciful orders have passed in favor of them, yet they have taken so little effect. . . . So that these Wretches have been several times redeemed, yet they remain in perpetual servitude. *Salvianus, lib. 6, de Provid.* says thus, *All captives when once redeemed enjoy their liberty, we are always redeemed and never free.* This sutes well with what we speak of. To which we may add that of *St. Paul, 2 Cor. 8. 13.* It is a subject deserves to be considered, and much authority and a high hand must make the remedy work a due effect."

These words, written by R. F. F. Dominick Fernandez Navarette, Divinity Professor in the College and University of St. Thomas, at Manila, are as applicable to-day as in 1656. The natives have been delivered several times since then, but are still in bondage, and much authority and a high hand are still needed to carry into effect the good intentions of their distant rulers. The good father does not let his piety blind him to the sins of his own brethren, but declares plainly that the 'Christians of *Manila* are worse than the infidels of *Japan.*' On the other hand, he never omits an opportunity to praise the docility and innocence of the Filipinos. "All those *Indians* are like our plain countrymen, sincere and void of malice. They come to church very devoutly; not a word was spoke to them but produced fruit; would to GOD the seed were sown among them every day; but they have mass there but once in two or three years. When they die, there's an end of them; but great care is taken to make them pay their taxes, and the curate's dues." "It were endless to descend to particulars. I know that in my time a governor of *Ilocos* in two years made fourteen thousand pieces of eight of his government; what a condition did he leave the *Indians* and their country in? It were well that those who write from thence would speak plain, and point at persons and things, and not do in general terms, leaving room to blame those that are innocent, and clear the guilty. This must be either a design or malice." Our newspaper correspondents at the present time would do well to follow this advice.

The Filipinos at that time were not only oppressed by taxation and corvées, but they were transported as slaves in such numbers as to threaten to depopulate the islands. "There is not a ship sails from Manila, whether it belong to *Siam*, *Camboxa*, or the *Portugueses*, &c., but carries away *Indians* out of the islands."

A missionary who was in earnest had no easy time of it in those days in the Philippines. Perils from wild beasts, earthquakes, storms, disease and shipwrecks were frequent enough to abash the stoutest heart, and, according to Navarette's naive account, it appears that his fortitude was due more to the presence of courage than to the absence of fear. He was badly frightened by thunder and the upsetting of his canoe, but he managed to absolve his companions who were floating in the water, although he was in great distress that there was no one to absolve himself. Although all his personal possessions were lost in this accident, he rejoices that the bottle of mass wine, being nearly empty, floated and was washed ashore. His first experience with an important earthquake is quaintly told. "Upon St. *Philip* and *Jacob's* day I was in great trouble; I was hearing confessions in the chapel, and observed that the cane chair on which I sat moved. I imagined a dog got under it, and bid the *Indian* to turn him out. He answered, Father, it is no dog, but an earthquake. It increased to such a degree, that leaving the penitent, I kneeled down, to beg mercy of God. I thought that the end of the world had been at hand."

One of his fellow priests was devoured by an alligator, a fate that distressed Father Navarette exceedingly, since such a burial-place could hardly be consecrated, but he consoled himself with the saying of St. Augustine that "a good death is that which follows a good life, be it of what sort it will. . . . The good *F. Lewis Gutierrez* having lived so virtuously, said two masses that day, and being about to say the third, who is there that can doubt of his good disposition?"

As if the natural dangers of the Philippines were not enough, he was molested by enemies from the lower world. At Batam (Batan?) he was much disturbed by witches or fairies, who made a great noise, threw stones and hurled about chairs in a terrible manner. Evidently the predilection of spirits for furniture moving is not purely American, as has been supposed.

The reception given by the people of Manila to the Japanese Christians, who were driven out of their native land by the great 'cross-trampling' persecutions, elicits the highest praise from one author; "Many were sick and with the leprosy, yet charity was such, that they carried them home to their houses to be cured; and they that had one of them fall to his share, thought themselves happy, they looked upon them as saints, and valued them as relics of inestimable value. The governor, counsellors, townsmen, religious persons and soldiers, went, as it were to snatch a *Japanese*, either sound or sick. I don't question but it much edified the *Chinese* infidels that looked on; for tho' they observe and take notice of our faults, yet at that time they were sensible of the wonderful efficacy of our holy law. The presence of so many witnesses, and such as they are, ought to make our carriage and deportment such, as may make them by it know and glorify our God; a point *S. Thomas* proposes and treats of in his *opusc.* to the churches of *Brabant*. I heard afterwards some *Europeans* behaved themselves not so well towards the banished people of *Ireland*."

The date line gave trouble in those days, as it has since. On reaching the Portuguese possessions in Macasar, he found that his Thursday was their Friday, a circumstance that caused some affliction to his conscience, for he had eaten flesh that day for dinner. With true professional ingenuity he overcame the difficulty by eating fish for supper and 'as to the divine office, tho' I was not obliged to all that of Friday, yet having time to spare, perform'd for both days.'

Volume IV. of this same collection of 'Voyages and Travels', which generally goes by the name of its publisher, Churchill, contains the 'Voyage Around the World' by Dr. John Francis Gemilli Careri. This author gives a longer and more detailed account of the Philippine Islands, and it is especially valuable for its description of all the various islands, their natural resources and the customs of the natives. He mentions seven localities where gold is found, and states on the authority of the governor of Manila that the annual production of gold gathered without the help of fire or quicksilver amounted to 200,000 pieces of eight. "As for Manila, the author of nature placed it so equally between the wealthy kingdoms of the east and west, that it may be accounted one of the greatest places of trade in the world. I am of the opinion that there are no such plentiful islands in the world." The author fully justifies his opinion by the statistics he gives of the cotton, tobacco, hemp, amber, civet, wax, pearls, quicksilver, sulphur and rare woods and medicinal herbs too numerous to mention here. The whole book is worth publishing, as there are nearly one hundred pages of the productions, history, geography, ethnology and natural history of our new possessions as they were in 1697. Most of it appears reliable, for Gemilli is careful to distinguish what he sees from what he hears, and, although he includes many incredible stories, it is not uncritically. For example, he has an account of a leaf which when it ripens becomes an insect and flies off. A diagram is given of this, showing how the stem becomes the head, the mid-vein the body and the side fibers the legs of the insect, and the statement is sworn to by the provincial of St. Gregory's, an eye-witness of the metamorphosis, and attested by a bishop. Still the author ventures a rationalistic interpretation, that the leaf conceals a worm which hatches into a butterfly. A more probable explanation, judging from the cut, is that it is a case of leaf mimicry by a moth.

On the Island of Panay, the Spaniards told him that when it thunders there fall crosses of a greenish-black stone which have great virtue. Here, too, the author is skeptical and suggests that 'it is possible they might make 'em of the stones that fell.' It is, however, not uncommon for fulgurites, formed by the fusion of the sand by lightning, to have a branching form like a rude cross.

It appears that a great many of those curious creatures of the class described by Herodotus, Ptolemy, Pliny and Mandeville have taken refuge from advancing civilization in the Philippines. Here were to be found mermaids, not only of the common species, but its converse form. Besides were-wolves, there were even 'were-crocodiles,' if such a word can be used. The missing link was also a native of the Island of Mindoro, with tails half a span long. The account of the same tribe of Negrillos, four pages beyond, seems to have been written later, for the tails had grown. "Some fathers of the society of great credit told me, that these *Mangihani* have a tail a span long. In other respects they are brave, and pay tribute, but have not as yet embraced the Christian faith." The clause connecting the two sentences is more logical than it sounds. Mention should also be made of the Amazons which inhabited islands near the coast of Palapa; of the serpents which magnetized their victims, and of the monkeys which caught oysters weighing several pounds by fishing with their tails.

From a political point of view, it is important to note that not a tenth of the inhabitants of the Philippines owned allegiance to the King of Spain, and also that the Moluccas were formerly included as a part of the Philippines.

From Manila Dr. Gemilli set sail for California, which he gives evidence to prove *was* not an island, as had been commonly supposed, but *was* a part of New Spain. The paragraph in which he gives his opinion of the ocean, misnamed Pacific, is as stately and antiquated in its architecture as a seventeenth century galleon and forms a suitable close to these extracts from the ancient history we have annexed:

"The voyage from the *Philippine* islands to *America* may be call'd the longest, and most dreadful of any in the world; as well because of the vast ocean to be cross'd, being almost the one-half of the terraquous globe, with the wind always a-head; as for the terrible tempests that happen there, one upon the back of the other, and for the desperate diseases that seize people, in seven or eight months living at sea, sometimes near the line, sometimes cold, sometimes temperate, sometimes hot, which is enough to destroy a man of steel, much more flesh and blood, which at sea had but indifferent food."

PREHISTORIC TOMBS OF EASTERN ALGERIA.

BY PROFESSOR ALPHEUS S. PACKARD,
BROWN UNIVERSITY.

FROM the wonderful hot baths at Hamman-Meskoutine, which are situated near the Tunisian border of Algeria, on the railroad leading from Constantine to Tunis, one can visit the little-known necropolis of Roknia.

On a delightful morning near the last of January, with a Moorish guide, we set out for this locality. We had arrived at the baths only the evening previous, having left Constantine a couple of days before. In passing along the 'Tell,' or Algerian highland, the nights had been cool and we saw the hoar frost along the railroad at Setif; the pools of standing water were frozen over and the distant low mountains were capped with snow. But at this early hour flocks of thick-wooled sheep, and long-haired goats and herds of undersized whitish-gray cattle, with long, downy, thick hair, such as one sees on the highlands and elevated plains of Asia Minor, were grazing in the fields, while among them were scattered a few camels bending their tortuous necks over the herbage. Although in some winters an inch of snow may fall in the streets of Constantine, yet the winter climate of Algeria is most delightful. On sunny days the morning soon grows warmer, and by noon the heat is almost summer-like.

We had not heard of Roknia and its dolmens until the evening we arrived at Hamman-Meskoutine, when we at once made arrangements for a horse and guide to the tombs, and for an early start the next morning.

Meanwhile, we found the springs wonderfully interesting. They lie about half a mile from the railroad station, on the edge of a plateau. The water carries lime in solution, is of a temperature of about 220° Fahr., and has deposited on the hillside an elevated platform of calcareous sinter and travertine, with several imposing crater or tower-like cones, six and ten feet high, from which formerly poured streams of hot water and steam. The water of the stream overflows the tanks and natural basins, and passes in cataracts down the declivity to enter the little river, the Oued Chedakra, draining the valley, while clouds of steam hover over the scene. These baths were used by the Romans, and the grounds of the hotel are adorned with the remains of bathtubs, statues and broken columns of marble.

Our way to Roknia lay for six miles through a hilly country, with

Kabyle farms and houses near the point of departure; but beyond it stretched along narrow paths, winding around the brow of hills, up towards the mountains, which form an extended amphitheater. The horse furnished me by the proprietor of the hotel was a phenomenally wretched steed, by no means boasting of Arab blood.

After a couple of hours' march, we passed a 'douar' or Berber village on our left, a little off the path, partially hidden among the scrubby mastic trees. The little houses were built of stone and mud, with thatched roofs. Three villagers came out to meet us, one of them armed with a gun, and the question arose in my mind whether these good people were honest or had no reputation to lose; but soon the gunner left us, perhaps on the quest for partridges, while our beturbaned Moors in their ragged burnooses spent the rest of the day with us and seemed mild and inoffensive, receiving our parting salutations and backsheesh with kindly glances.

In another half-hour we reached the site of the necropolis. The vast cemetery is finely situated on the brow of a hill, or range of hills, facing west and overlooking the village of Roknia at its foot. This hillside or plateau itself is a spur of the Diebel-Debar range, somewhat elevated, being about 2,000 feet above the Mediterranean, and surrounded to the west, northwest and north by an amphitheater of distant mountains. The tombs themselves mostly occur in openings among the low trees or shrubs, which are scattered over the plains, or form dense thickets concealing the ruins of the dolmens. Scattered about the vicinity of this once sacred ground are the farms of the little hill villages, or 'douars' of the natives.

The material for the rock structures crops out here and there, the soil being thin—a pale gray, moderately hard limestone of cretaceous age, not containing any fossils and evidently weathering somewhat rapidly, as it is naturally somewhat porous and cavernous. The rock was not jointed, and evidently was not easily quarried; hence the blocks are very irregular and were never hammered.

The guide led us to the best preserved and most typical dolmen, which was smaller than we expected, being much less than half as large as those we had some years previously visited in Brittany. It is built of three rude slabs of limestone, one on each side, and a shorter stone at the end, the opposite end of the enclosure being open and facing the east. The enclosure thus walled in was covered by a single large slab, about six feet long, irregularly triangular in shape, the ends of which projected beyond the enclosure. Another less perfect tomb was built of two side-stones and an oblong slab on top, about five feet long and two feet wide. The space thus enclosed averaged about four by two feet. A still larger dolmen consisted of two side-slabs and one at the end, covered by an irregular slab, about six feet long and four feet wide. The largest dolmen observed was covered by a quite regularly oblong slab about nine and a half feet long and four or five feet wide. There were but two side stones, but several at the end. It was only about a foot above the level of the ground, and the interior was about four feet deep and three and a half feet wide. In another the lateral stones were nine feet long and over five feet high, with eight or nine stones at each end. Others had a slab at each end. These may have been modified at a later period, for the Romans had occupied this valley, this region being a portion of the Numidia of Latin authors.

The average measurements of the dolmens given by Bourguignat are from one meter to 1.25 in length, 0.50 to 0.75 in breadth, and 0.60 to 0.80 meter in height.

The dolmen-field, so far as time allowed us to observe it, was from about eight hundred to a thousand yards long, and in width about five hundred feet. The dolmens themselves were arranged irregularly in lines about fifty feet apart, and the lines extended in an easterly and westerly direction. Bourguignat states that the general orientation is southwest and northwest, the four angles of the dolmens corresponding to the four cardinal points.

The rows of dolmens extend down to near the bottom of the valley, to a point near the little hamlet of Roknia, which is built of stones, with the pitched roofs thatched, and the rough walls not whitewashed, though they often are in the well-to-do 'douars.'

The interior or floor of the dolmen consisted of a soft black loam, and I set one of the Moors, whom we will call Mahmoud, digging up the soil with his stick. He soon unearthed a human radius, some vertebræ and a portion of a human skull, besides several specimens of the common European snail (*Helix aspersa*), of which more anon.

It will be readily seen that the bodies of the dead in dolmens of the dimensions of those of Algeria must have been bent or doubled up in order to be buried. The dolmens of the land of Moab, east of the Dead Sea, are also said to be small. On the other hand, those of France and Holland are often twelve feet in length and in some of them a person could stand upright.

There were no traces of tunnels (*allées couvertes*) to be seen by us, nor any indications that earth had been heaped over the dolmens, as is frequently the case in Brittany. Bourguignat, however, states that the dolmenic chamber was covered with a tumulus. On the other hand, no tumuli are known to exist in Tunisia.

In the time at our command it was not possible to examine the whole cemetery, as the greater part of it was in ruins or overgrown with the mastic or lentisk shrubs (*Pistacia lentiscus*) which yield the gum-mastic.

Moreover, many of the dolmens had evidently been destroyed, as we found but few perfect ones, and it is stated that some French officers had wantonly destroyed them.

In 1867 Dr. Bourguignat, the well-known conchologist and archeologist of Paris, visited this necropolis, camped on it, and his account is the only complete one. He put the number of dolmens remaining in his time at fifteen hundred, and estimated the total number formerly existing at several thousand. He regarded this vast assemblage of megalithic sepulchers as a colossal cemetery.

In the following year General Faidherbe, in a paper published in the 'Annales de l'Académie de Bone,' attributed these sepulchers to the troglodyte Libyans, whose actual descendants were, he states, the Kabyles and Berbers.

The people living in this vicinity, and, presumably, the builders of these sepulchers, were of a later date than the neolithic or later stone epoch, for the art-objects excavated by Bourguignat from the interior were bronze rings or bracelets, amulets and rings of silver gilded with gold; and earthern vases. According to the well-known anthropologist, Pruner-Bey, the human skeletons contained in the tombs were those of Aryans, of negroes, Egyptians and Kabyles, with hybrids between the negro and Kabyle women. The Aryans occupied the large sepulchers; their cranial type resembled that of ancient Italy.

The dominant race, according to French statements, had imposed on the other peoples its mode of burial and its religious beliefs, since the eastward orientation of the sepulchers of Roknia is identical with the traditional position made sacred by Aryan customs.

The remains of the men were distinguished by an earthen vase placed near the head, but the women were not considered worthy of the honor of a funeral vase.

The question arises as to the exact age of these dolmens and their builders. Were they contemporaneous with the early Egyptians, and was the bronze age of northern Africa of the same or of an earlier date than the bronze epoch in Egypt?

Dr. Collignon has, more recently, thrown much light on the affinities of the builders of these dolmens, who, he suggests, were Berbers, and perhaps of the same race as the dolmen-builders of France and the Cromagnon family whose remains were found at Les Eyzies, in Dordogne, France. Of the races of the sedentary population now living in Tunisia, where also occur numerous dolmens, especially at Ellez (which is situated about 100 miles east of Roknia), there are five types of Berbers. "One of these types reaches its greatest purity in the neighborhood of Ellez and its area of distribution almost exactly covers the area of distribution of dolmens. Moreover, this race presents plainly the special anatomical characters of the bones found in the dolmens of France, notably at Sordes and at Homme-Mort, *i. e.*, a feeble

FIG. 1. THE DOLMENS AT ROCKNIA, ALGERIA.

size (1^m, 63), dolichocephaly of 74 and especially a short face, broad and disharmonic, of a character absolutely analogous to the conformation of the crania of Cromagnon. They are not blonds.

"Another race of large size (1^m, 69, about), very dolichocephalic, mesorhine to 75, etc., were probably the descendants of the men who worked the silver in this region, and they represent the most ancient ethnic layer existing in the country." He adds that in Tunisia, as in Europe, there was a gradual transition from the Chelléan to the Mousterian epoch, and also down through the Magdalenian epoch to the Neolithic. Flint implements were still used during the Roman occupation, though the nomadic Getulæ or Numidians used metal purchased of the Phœnicians and Romans.

It is now tolerably well settled that at the time of the paleolithic or old stone epoch in Egypt and Nubia, the Nile was much larger and wider than now, as the paleolithic axes and scrapers, precisely like those of France, have been found on the river gravels out on the desert as high as 400 feet above the present level of the Nile. On the other hand, the polished axes or celts, the arrow-heads and flint knives and scrapers of the neolithic epoch found under the temples and in the sand about the towns built within historic times, though extending back 2,500 to 4,000 years, preceded the bronze period, which may have begun about 1.500 years B. C. Since the opening of the neolithic epoch in Egypt, the Nile has assumed its present size, the country having become dry and rainless. There are everywhere, as we ascend the Nile to the first cataract, evident traces in the eroded hills on either bank of the Nile of a rainy and cooler climate during paleolithic times.

And everywhere in Morocco, Algeria and Tunis, and on the edge of the Sahara Desert, we saw evidences of an originally moist, rainy, cooler climate. Old lake-bottoms, on the Tell, where the rivers, now dry, had widened into lakes; conical hills, outstanding pinnacles and ancient water-worn courses extending down the sides of the now dry and barren cliffs or slopes, told the story of a climate more favorable than now for the sustenance of a comparatively large population; one fond of uplands, forest clad, cool and shady in the summer, and whose farms suffered less from the parching heats of summer. During the tertiary period, at least until the pliocene, the Sahara was a Mediterranean sea; northern Africa belonged then more to Europe than to central and southern Africa.

Rabourdin asserts that the desert of the central Sahara was formerly a fertile and inhabited country, and afforded pasturage for cattle. Herodotus states that the cattle had larger and thicker hides. There are rock pictures representing cattle with large horns.

Weisgerber states that according to local traditions the Sahara was formerly not a desert; that there were springs, streams and a luxuriant vegetation, and that it supported a race, not numerous, however, which cultivated the soil. (Monuments archéologiques du Sahara, 1881, Bull. Soc. d'Anthropologie, Paris.)

Strong confirmation of the view that decided climatic changes have taken place in eastern Algeria since the time when the Roknia necropolis was built, is afforded by the excavations of Dr. Borguignat in these dolmens. He found in the dolmens numerous shells of *Helix aspersa*, a large snail common in the gardens and fields of Europe. These shells were similar to those living in the damp and cool climate of Europe, while those actually living at Roknia offer features produced by the dry and hot climate of the present day. This sufficiently indicates a decided change of climate, which must have occurred certainly more than a thousand years before the time of Homer, or of the founding of Rome. We dug up some of these semi-fossil shells, and also found plenty of the recent ones on top of the soil within the dolmens.

Many authors attribute the dryness and sterile nature of the eastern lands to the removal of forests by man within historic periods, but this is a decided mistake. There has been a slow secular process of elevation, desiccation and consequent deforestation of the regions around the Mediterranean, which began to take place thousands of years before the founding of the ancient civilization of Egypt, Babylon and Assyria, at, if not before a time when neolithic culture gradually supplanted that of the race which used only rough, unpolished, unmounted flint implements, scrapers and spear-heads. But for several thousand years, at least from 5,000 to 10,000 years B. C., if not throughout the neolithic epoch, the scenic features and climate of Egypt, Libya and Algeria have remained unchanged.

Bourguignat claims that the climate indicated by the snails of the Roknia dolmens nearly corresponds to that of Paris, whose mean temperature at our time is 10°.1 C. (about 52° F.), while that of Roknia is 17°.5, being a difference of 7°.4.

Reasoning from these data and certain astronomical calculations, this author decides that the mean annual temperature of Roknia, at a period 2,200 years B. C., was 10°C. Moreover, as the snail shells showing the influence of this cool, rainy climate were found in the lower beds of the sepulchral chambers, in the strata in contact with the human bones, he concludes that the megalithic monuments of Roknia extend back to that date. They are thus not less than about 4,000 years old, and thus it would appear that the bronze age of ancient Libya goes back that length of time.

This once decided, Dr. Bourguignat explained the presence of ornaments of bronze and gilded silver, which he supposed the inhabitants were unable to make themselves, to commercial exchange with the Egyptians and what he calls the people of Nigritia. The Kabyle industry, he thought, was confined to the manufacture of large coarse pottery, evincing an incipient stage in the ceramic art, and indicating a pastoral people, with abundant flocks and herds, the hillsides and plains there being covered with magnificent forests and affording abundant pasturage, there being perhaps 150 rainy days instead of 50 in the year, as at present.

But the noonday hour had passed, and we ate our frugal lunch, provided by the landlady at the hotel, with a bottle of native Algerian wine. We were forced to eat it alone, for in vain did we press on our guide and the two Moors a bit of bread and butter and a drink of the mild beverage. They steadfastly refused, for it was the month of the Ramadan. They were strict, consistent Mohammedans, and could not be tempted.

On our return, not far from the necropolis we passed by Moorish farmers stirring the light soil with their primitive wooden ploughs, shares and all, the yoke being bound around the neck of a cow or steer by cords behind the horns. The cattle were all gray and dirty white, no red or parti-colored ones being observed. Half way back we paused to examine the Roman ruins, portions of basement stones strewn about the ground. The warmth of the afternoon sun was like that of a June day. We left the native 'douars' behind, and after two or three hours' descent from the hills behind us, forded the little river and entered the village of Hamman-Meskoutine.

THE NEW YORK AQUARIUM.

BY PROFESSOR CHARLES L. BRISTOL,
NEW YORK UNIVERSITY.

WHEN the municipality of New York transformed Castle Garden from an immigrant station to a public Aquarium, its location alone solved two problems incident to the usefulness and maintenance of such an institution. Its position, at the end of the Island of Manhattan, at the confluence of two great rivers and the harbor, in close proximity to all the lines of communication with all the boroughs, makes it equally accessible to all portions of the population, and provides for an abundant supply of salt water.

The Aquarium has well repaid the labors of those who conceived and wrought out the idea, and has justified the care and personal interest bestowed upon it by President George C. Clausen, of the Park Commission, if one may judge by the delight expressed by the great number of people, young and old, rich and poor alike, who daily enjoy the marvelous exhibition of fishes and other aquatic animals there set before them. Col. James E. Jones—the director—takes great pride, and justly, too, in the unbroken record of an 'open house,' and the general well-being and contentment of his finny charges.

The doors of the Aquarium are open free to all comers every day between the hours of nine and four, and, at this writing, the average daily attendance is more than fifty-one hundred people, while on Sunday this number rises to eleven thousand.

A word about the building before we enter it. It was built just before the war of 1812, and named Castle Clinton. It was then two hundred feet away from the shore, and was connected with it by a bridge; later the shore line was extended to its present location so as to include the building within it. Never very useful, the Federal Government gave it to the city in 1822. As a public hall the city welcomed in it many prominent persons, among whom were La Fayette, whose landing was commemorated in the blue and white pottery of those days; Kossuth, the Hungarian patriot, and the present Prince of Wales. Jenny Lind made her début there under the management of Phineas T. Barnum, at that time a youth unknown to fame. Then its halcyon days passed, and it became the reception hall for the vast numbers of immigrants who yearly passed through it into the life of the republic. In 1896, it was restored to the people as a place of amusement, and entered upon its second and, let us hope, its permanent career as an

Aquarium. As we approach, before passing into the dim light of the Aquarium, it is well to linger for a moment in the park, and gaze upon the wonderful scene spread out before our eyes—the commodious harbor, alive with the craft of all nations, the hills of Staten Island and the Narrows beyond.

Its circular fort form is admirably adapted to its present use, as the plans and illustrations show, and but few changes were necessary to make it available. Upon entering, the visitor's attention is attracted to the seven great pools on the floor. A second glance reveals the wall tanks, arranged in two tiers. These have glass fronts, and, at a

Fig. 1. The New York Aquarium.

distance, look like beautiful pictures in great frames. They are lighted from behind and above, and the spaces immediately in front of the main and gallery tiers are thrown into deep shade by the gallery floor and the ceiling. The light coming through the tanks being the only source of illumination, the colors and markings of the fishes are brilliantly displayed to the spectator, who might easily imagine himself wandering in some submarine gallery.

In the great central pool there is, ordinarily, a collection of sharks and the common fishes of the coast, but when a whale or other large specimen is secured it occupies this place of honor. The three pools on the north side of the floor contain, respectively, salmon raised from the fry, harbor seals and sturgeon. The harbor seals are always surrounded by an admiring throng, who watch the graceful manœuvres of 'Nelly' and her companion, the 'Babe.' 'Nelly' has occupied her quarters since the Aquarium was opened, and is a great pet with her keepers. The pools on the south side contain striped bass, the West Indian seal and sea turtles. The specimen of the West Indian seal—*Monachus tropicalis* (Gray)—is unique among zoological collections. It was captured at the Triangles, off the coast of Yucatan, in 1897, and has thriven in captivity at the Aquarium. It has developed into a humorist, and a favorite trick is to sit upright in the pool and look innocently

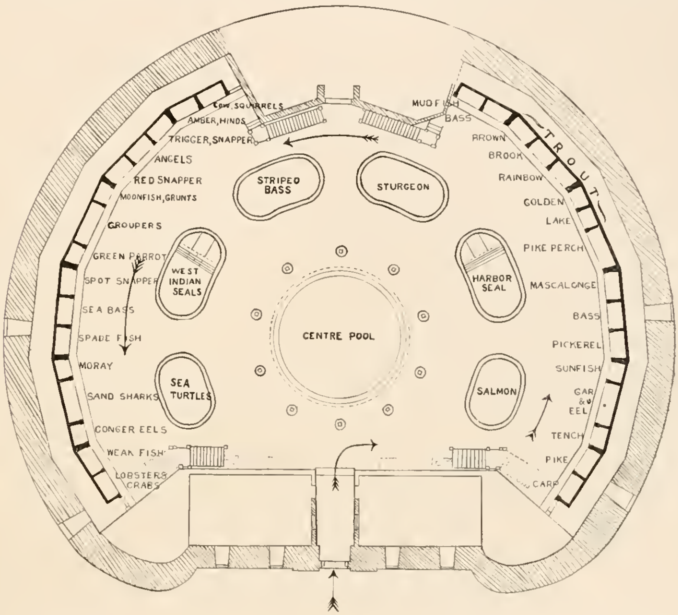

FIG. 2. PLAN OF THE MAIN FLOOR.

around until someone attracts its attention. Then, without a gesture of warning, it spurts a mouthful of water at him and dives away to swim for some time as fast as it can about the pool.

These pools, and the wall tanks to the left of the entrance, are devoted to salt-water animals, while the wall tanks on the other side are stocked with fresh water animals, as shown in the plan of the floor (Fig. 2).

In the display of fresh-water fishes, the trout family holds first place, occupying more tank room than any other family, and comprising eleven species. This is largely due to the interest taken by the fishing fraternity in this family and to the generous contributions of the Fish Commissioners of several States.

The sunfishes make a brilliant display, as do the pearl roaches caught in Harlem Mere at Central Park. For downright homeliness the great eighty-pound channel catfish from the Mississippi takes the first place. The bow fin (*Amia*) and the gar (*Lepidosteus*) always attract attention, together with the carp and the whitefish that come from the Great Lakes.

Along with the fresh-water fishes are three groups of amphibians: great bullfrogs from New York State, the mud puppy (*Necturus*) from the great lakes, and the hellbender *(Cryptobranchus)* from the Ohio River. There is always a group of visitors in front of the tanks of the two latter animals, watching the beautiful gills of the mud puppy and commenting on the loose suit of clothes worn by the hellbender.

On the salt-water side, the tropical fishes furnish by far the greatest beauty and attraction. Their gaudy colors and strange forms are in strong contrast to the somewhat monotonous hues of most of our coastwise fishes, but both are harmonious with their surroundings. In the clear, limpid waters of Bermuda and the West Indies, under a tropic sun, the 'sea gardens' flourish, and great purple sea-fans, bright saffron sea-rods, large clumps of bright red and vivid green sea-weeds make a brilliant setting for the higher forms of life.

The world below the brine.
Forests at the bottom of the sea—the branches and leaves,
Sea-lettuce, vast lichens, strange flowers and seeds—the thick tangle, the openings and the pink turf,
Different colors, pale gray and green, purple, white and gold—the play of light through the water,
Dumb swimmers there among the rocks—coral, gluten, grass, rushes—and the aliment of the swimmers,
Sluggish existence grazing there, suspended, or slowly crawling close to the bottom.

In such environment the beautiful Angel-fish, with its long, streaming, yellow fins and sky-blue body, is no longer conspicuous as in the tanks. The ruddy Hind conceals itself easily at the bottom, while the little Four-eyed-fish (so called), brilliant in golden livery with jet-black markings, vanishes from sight by merely shifting its position. On the other hand, the Parrot fishes—which range in color from bright grass green through blues and browns—are boldly conspicuous in their warning colors, for their flesh is poisonous to other animals, including man. The Squirrel-fish, in his brilliant scarlet coat, is equally conspicuous; for woe to the unwary captor that attempts to swallow him! His strong, sharp spine and rough scales would lacerate the maw of the hardiest carnivore, and he swims about among them free from any fear.

These tropical fishes exhibit the function of changing their color in a high degree. The great Groupers are worth watching as they move about in the tanks. Now they are a dirty brown, now they change to alternating blotches of black and white, and *presto*, they are pure white. The Red-snappers and Yellow-tails change in the twinkling of an eye so as to be almost unrecognizable. Nearly all these fishes may emit flashes of light apparently at will.

The Cow-fish and its relative the Trunk-fish always excite the interest of the visitors, who are amused at their triangular, box-like bodies and odd manœuvres. Equally attractive are the Morays, of which two varieties are shown; the beautiful Speckled Moray and the great Green Moray. The specimens of the latter now in the Aquarium measure, respectively, seven and one-half feet and six feet long.

The collection of coastwise fishes is excellent, and it contains many rare and little-known varieties, such as the weird Moon-fish, the Spade-fish, the Crevallé, the Orange file-fish and the Barracuda, as well as the common food fishes of the markets.

The first requisite of an Aquarium is water, and, while very small aquaria may be, and are, successfully maintained without changing the water, by the use of plants to supply oxygen, this system would not answer at all for large tanks. In England and on the Continent many of the large aquaria store great quantities of water, both fresh and salt, in dark reservoirs, and use it over and over again, filtering and aerating it each time.

In the New York Aquarium this system is not used. Fresh and salt water are supplied to the tanks but once and carried away to the sewer. The fresh water is furnished from the city water mains. The salt-water supply was originally taken direct from the harbor, but, while digging in the cellar to lay a foundation, the workmen pierced a layer of hardpan clay, and water rushed into the excavation. Pumping did not lower it, and tasting proved it to be salt. It was at once utilized as a source of supply and proves to be excellent. The layer of sand underneath the clay is an immense filter bed that removes all suspended matter and furnishes clear, limpid water in unlimited quantity.

Both kinds of water are pumped into large reservoirs and flow thence by gravity to the tanks. Some of the piping is gutta-percha, but practice has demonstrated that first-quality galvanized iron pipe is entirely satisfactory, and it is largely used. Between the reservoirs and the tanks are devices for regulating the temperature, and these are necessitated by the extreme diversity of the collection.

In the summer, the fresh water supplied to the salmon family must be kept down to 55° F., while in winter the tropical salt-water fishes demand 70° F. The former is maintained by an ordinary refrigerating machine, the latter by utilizing the waste steam from the radiators and the pumps.

The exhibition tank, like much of the plant, is the outgrowth of experience and failure. The front is made of plate glass nearly an inch thick, and this is fastened into a strong frame of iron, which, in turn, is firmly secured to the building. The joint between the glass and the iron must be water-tight, of course, but it must also be somewhat flexible, to accommodate the changes due to temperature and the bulging due to pressure. It is made by wedging the glass into a rebate with strips of dry basswood as firmly as possible; when these become water-soaked they swell, so as to make the joint perfect, and yet to allow the necessary play. To the rear side of the iron frame is bolted a wooden tank, narrower at the bottom than the top, and when this is in place it is given a coat of Portland cement for a lining. This lining gives a pleasing neutral tint for a background, is very clean, and,

Fig. 3. Pools and Wall Tanks.

should occasion demand, it may be readily replaced. The largest glass used is ninety by forty-eight inches for a single tank, but in some cases two tanks are thrown into one by cutting the partition walls, as shown in the shark tank (Fig. 3).

Between the exhibition tanks and the outer wall of the building is an annular corridor devoted to the purposes of administration, and to this the public is not admitted. Here the keepers and their helpers are occupied almost constantly in the multifarious duties that the conditions of maintenance impose; here the pumping machinery and the temperature-regulating apparatus are located, and here are the tanks that hold the reserve stock and those used for hospital purposes.

Cleanliness equal to that found on a private yacht is maintained, as a matter of course, and lies at the foundation of the uninterrupted success of the institution. Subdivision of the work makes possible a routine of duties that proceeds as regularly and orderly as on board a man-of-war, and this is necessary, for now and then the sinuous eel plays his pranks and stops some outlet, threatening the institution with flooding.

No less important is an intimate knowledge of the fishes themselves. When fishes of different kinds are put together in a tank, they often war with each other until one kind is exterminated, and sometimes fishes of the same kind will not tolerate certain individuals. In one of the gallery tanks may be seen a single angel-fish brought from Bermuda four years ago. It is of surpassing beauty, but it kills every other angel that is put in the tank with it. No matter how

Fig. 4. The Corridor Behind the Tanks.

many of the curious, triangular, hard-bodied trunk-fishes are put together, one is always made the butt of the rest, and worried by them until it dies, and then another is pestered, until but one is left. In many of the tanks where the fishes dwell in harmony together, there will be one that dominates all the others. It seems to demand a certain deportment and procedure from the others, and is always on the alert to exact compliance. The familiar story of the Mexican shepherds who know each individual in their vast flocks finds its parallel in the intimate knowledge of their charges possessed by the men who care for the tanks at the Aquarium, and this enables them to keep a delicate touch on the daily life in the tanks that contributes largely to the success recognized by the public.

For instance, a slight uneasiness in one of the fishes in a certain tank was noticed one day; it continued, and the next day the fish was removed and carefully examined. It was found to have a few parasites upon it, and these were killed. Every fish in that tank was then examined and cleaned, the tank was thoroughly cleansed, and finally the reserve tank from which it came was similarly treated, with the result that no deaths resulted from that cause.

Besides animal parasites, they are always on the lookout for fungus growths, for some of these would decimate the tanks in short order if they were not destroyed. Fortunately, most of these yield readily to the treatment of a change of water. The salt-water fish is put for a short time in brackish or fresh water, or *vice versa*, and the plant is killed before the fish is injured. Sometimes one eye or both will bulge out of its socket, giving rise to what the Aquarium people graphically call 'bung-eye.' This is regularly treated in the hospital tanks and usually with success. Wounds and abrasions, mopishness and other troubles are recognized and treated in aquatic animals quite successfully.

Fully as exacting as questions of disease are the conditions surrounding the matter of feeding. The food must be fresh, much of it needs preparation, and it must be fed at proper intervals. Some fishes require feeding every day, others take it at intervals of three or four days or a week. The small fishes take their tiny meals of chopped clam every day, the larger fishes at varying intervals.

The dietary is varied, as the following list of some of the foods will show: Quahaugs or hard clams, soft clams, live shrimps, sand fleas, killifish (salt-water minnows), minnows, earthworms, sandworms (both white and red), fresh dead fish from which the bones are removed, salted codfish and beef's liver. Some of these are staples, some are tid-bits to tempt the appetite of moping or sick fishes, and of this latter sort salted codfish is far and away the most tempting.

The death rate among the inhabitants is surprisingly low; some forms will not endure captivity for any considerable time, as might be expected, but among those kinds that will live and thrive in confinement, there are many individuals that were put into the tanks when the Aquarium was opened in 1896.

The area from which the supply for exhibition is drawn is very large, exceeding, probably, that of any other aquarium in the world, and in this respect the collection in the New York Aquarium differs widely from those of the great aquariums of Europe, which rely upon the fauna of the immediately adjacent waters. The Gulf of St. Lawrence furnishes white whale; the Gulf of Mexico the West Indian seal. The cold streams of Maine supply the salmon, while from Bermuda come the tropical fishes of the West Indies. The great lakes contribute the whitefish and others, while the Mississippi Valley sends the catfish. Besides these, the fishes of the neighboring waters are well represented.

CHAPTERS ON THE STARS.

By Professor SIMON NEWCOMB, U. S. N.

THE CLUSTERING OF THE STARS.

A STUDY of Schiaparelli's planispheres, which we gave in the last chapter, shows that some regions of the heavens are especially rich in lucid stars and others especially poor.

Neither telescope nor planisphere is necessary to show that many of those stars are collected in clusters. That the Pleiades form a group of stars by itself is clear from the consideration that six stars so bright would not fall so close together by accident. This conclusion is confirmed by their common proper motion, different from that of the stars around them. The singular collection of bright stars which form Orion, the most brilliant constellation in the heavens, and the little group called Coma Berenices—the Hair of Berenice—also suggest the problem of the possible connection of the stars which form them.

The question we now propose to consider is whether these clusters include within their limits an important number of the small stars seen in the same direction. If they and all the small stars which they contain were within their actual limits removed from the sky, would important gaps be left? The significance of this question will be readily seen. If important gaps would be left, it would follow that a large proportion of the stars which we see in the direction of the clusters really belong to the latter, and that, therefore, most of the stars would be contained within a limited region. The clusters which we shall especially study from this point of view are the Pleiades, Coma Berenices, Præsepe and Orion.

The Pleiades.—In the case of this cluster the question was investigated by Professor Bailey, by means of a Harvard photograph 2° square, having Alcyone near its center. It was divided into 144 squares, each 10′ on a side. The brighter stars of the cluster were included within 42 of these squares. The count of stars gave the results:

Within cluster: 1,012 stars, or 24 per square.
Without cluster: 2,960 stars, or 29 per square.

It, therefore, seems that the portion of the heavens covered by the cluster is actually poorer in stars than the region around it.

Two opposite conclusions might be drawn from this fact. Assuming that the difference is due to the presence of the cluster, we might suppose that the latter was formed of material that otherwise would have gone into numerous smaller stars. Accepting this view, it would follow that the material in question was a sheet so thin that the thickness of the space filled by the cluster was an appreciable fraction of that oc-

FIG. 1. PHOTOGRAPH SHOWING STRUCTURE OF THE MILKY WAY, BY BARNARD.

cupied by the stars. In other words, one-fifth of the stars of the region would be contained in a thin sheet. This result seems too improbable to be accepted.

The other and more likely conclusion is that the number of very minute stars included in the cluster is no greater than that in the surrounding regions, and that the lesser number in the region is to be regarded as accidental.

FIG. 2. RIFTS IN THE MILKY WAY, PHOTOGRAPHED BY BARNARD.

Coma Berenices.—This cluster, which may be seen east, south or west of the zenith on a spring or summer evening, contains seven stars visible to the naked eye, each of the fifth magnitude. It may be considered as comprised within the limits 12h. 13m. and 12h. 25m. of R. A., and 25° to 29° of declination, an area of 10°.5. This existence of seven lucid stars within so small an area suggests that they belong together, and may have smaller stars belonging to the group, and making the star-density of this area greater than that of the sky in general.

The question whether there is any corresponding excess of richness in the fainter stars will be decided by a count of those contained in Graham's section of the A. G. Catalogue, which extends to the ninth magnitude. With the area above defined this catalogue gives seventy-one stars. Subtracting the seven lucid stars, we have sixty-four small stars left within the area. To the same belt of declination 336 stars are listed in the twelfth hour of R. A., giving an average of sixty-seven stars to an area equal to that of the cluster. The small stars are, therefore, no thicker within the area of the cluster than around it. It may be added that the seven lucid stars do not seem to have any common proper motion, so that their proximity is probably an accident.

Præsepe.—This object, situate in the constellation Cancer, appears to the naked eye as a patch of nebulous light. It is actually a condensed group of stars, of which the brightest are of the seventh magnitude. The stars of the ninth magnitude included within the area of the group probably belong, for the most part, to it, but they are too few to serve as the base for any positive conclusion.

Orion.—I find by measurement and count that a circle 20° in diameter, comprising the brightest stars of this constellation, contains eighty stars to magnitude 6.3. Of these six are of the first or second, leaving seventy-four from the third to the sixth. The resulting richness is 24 to 100 square degrees, about the average richness along the borders of the galaxy. It follows that this remarkable collection of bright stars has no unusual collection of faint stars associated with it.

A very natural inquiry is whether the bright stars in Orion have any common proper motion, indicating that they form a system by themselves. The answer is shown in the following statement of the proper motions in a century:

Star.	Mag.	Proper Motions. R. A.	Dec.
		″	″
Rigel	1	+ 0.1	0.0
η Orionis	3	+ 0.1	— 0.3
γ Orionis	2	— 0.6	— 1.7
δ Orionis	2	0.0	— 0.2
ε Orionis	2	0.0	+ 0.1
ζ Orionis	2	0.0	— 1.4
κ Orionis	2	+ 0.1	— 0.3
α Orionis	1	+ 3 0	+ 0.9

For the most part these motions are too small to be placed beyond doubt, even by all the observations hitherto made. In the case of

α Orionis the motion is established; in those of γ and ζ it is more or less probable, but not at all certain; in all the other cases it is too small to be measured.

This minuteness of the motion makes it probable that these stars are very distant from us, an inference which is confirmed by the smallness of their parallaxes. The careful and long-continued measures of Gill show no parallax to Rigel, while Elkin finds one of only 0″.02 to α Orionis.

The general conclusion from our examination is this: *The agglomeration of the lucid stars into clusters does not, in the cases where it is noticeable to the eye, extend to the fainter stars.*

Let us now study the question on the opposite side. The planispheres show regions of great paucity in lucid stars; is there here any paucity of telescopic stars?

The two regions of greatest paucity are near the equator; one extends through the hour of 0 of R. A.; the other from 12h. 20m. to 12h. 40m. The richness of these and of the adjoining regions may be inferred from Boss's zone of the A. G. Catalogue, including a belt from 1° to 5° of declination. The number of stars in each hour from 23h. to 3h. is as follows:

In 23h.:	271 stars.
In 0h.:	293 stars.
In 1h.:	299 stars.
In 2h.:	295 stars.

These numbers show no paucity in the hour 0, and no excess in the hour 2, which is much richer in lucid stars than the hour 0.

In the strip from 12h. 20m. to 12h. 40m. the catalogue contains seventy-eight stars, a richness of 234 to the hour. In the hour preceding there are 211 stars; in that following, 225. There is, therefore, no paucity in the strip in question.

THE STRUCTURE OF THE MILKY WAY.

The most salient problems suggested by the appearance of the Milky Way are to be approached on lines quite similar to those followed in the last chapter. We begin with a description of this wonderful object as it appears to the observer. We recall that it can be seen through some part of its course on any clear night of the year, and in the evening of any season except that of early summer. We begin with the portion which will be visible in the late summer or early autumn. We can then trace its course southward from Cassiopeia in the northwest. It passes a little east of the zenith down to Sagittarius, near the south horizon. This portion of the belt is remarkable for its diversity of structure and the intensity of the brighter regions.

In Cassiopeia it shows nothing remarkable, but above this constellation, in Cephcus, we notice in the midst of the brighter region a nearly circular patch several degrees in diameter, in which little light is seen. A little farther along we notice a similar elongated patch in Cygnus lying across the course of the belt. In this region the brighter portions are of great breadth, more than 20°.

In Cygnus begins the most remarkable feature of the Milky Way, the great bifurcation. Faintly visible near the zenith, as we trace it towards the south, we see it grow more and more distinct, until we reach the constellation Aquila, near the equator. Between Cygnus and Aquila the western branch seems to be the brighter and better marked of the two, and might, therefore, be taken for the main branch. About Aquila the two appear equal, but south of this constellation we see the western branch diverge yet farther toward the west, leaving the gap between it and the eastern yet broader and more distinct than before. This branch finally terminates in the constellation Ophiuchus, while the eastern branch, growing narrower, can still be followed toward the south.

Between the equator and the southern horizon we have the brightest and most irregular regions of all. Several round, bright patches of greater or less intensity are projected on a background sometimes moderately bright and sometimes quite dark. If the night is quite clear and moonless we shall see that, after a vacant stretch, the western branch seems to recommence just about the constellation Scorpius. In this constellation we have again a bifurcation, a dark region between two bright ones.

This is about as far as the object can be well traced in our middle latitudes. From a point of view nearer to the equator it can be traced through its whole extent. South of Scorpius and Sagittarius it becomes broad, faint and diffused through the constellations of Norma and Circinus. It reaches its farthest southern limit in the Southern Cross, where it becomes narrower and better defined. The most remarkable feature here is the 'coal sack,' a dark opening of elliptical shape in the central line of the stream. West and north of this, in the constellation Argo, is the broadest and most diffused part of the whole stream, the breadth reaching fully 30°. Here we again reach the portion which rises above our horizon.

Returning now to our starting point, we shall notice that, as we make our observations later and later in the autumn, the southern part, which we have been mostly studying, is seen night by night lower down in the west, while new regions are coming into view in the northeast and east. These regions rise earlier every evening, and, if we continue our observations to a later hour, we shall see more and more of them above the eastern or southeastern horizon. By midwinter Cassiopeia will be seen in the northwest, and we can readily trace the course of the galaxy from that constellation in the opposite direction from that which we have been following. South of Cassiopeia we see, near the central line, the well-known cluster forming the sword-handle of Perseus. Farther south the belt grows narrower and fainter; although the irregularities of structure continue, they are far less striking than on the other side. On a moonlight evening it will scarcely be visible at all. If the moon is absent and the air clear we shall see that it grows slightly brighter toward the southern horizon, near which will be the narrowest part of its entire course. Below is the broad and diffused region in Argo.

One conclusion from the inequalities of structure which we have described will be quite obvious. The Milky Way is something more than the result of the general tendency of the stars to increase in number as we approach its central line. There must be large local aggregations of stars, because, as we have already pointed out, there cannot be such diversity of structure shown in a view of a very widely stretched stratum of stars. When, instead of a naked eye view of the belt, we study the photographs of the Milky Way, we find this evidence of clustering to grow still stronger. It is shown very strikingly in the photograph by Barnard, showing the singular rifts in the Milky Way in the constellation Ophiuchus. Yet more singular are three-minute openings in the constellation Aquila, the positions of which are:

(1). R. A.	= 19h. 35.0m.;	Dec. = + 10° 17′
"	= 19h. 36.5m.;	" = + 10° 37′
"	= 19h. 37.2m.;	" = + 11° 2′

The fundamental question which we meet in our farther study of this subject is: At what magnitude do these agglomerations of stars begin? Admitting, as we must, that they are local, are they composed altogether of stars so distant as to be faint, or do they include stars of considerable brightness? We consider this question in a way quite similar to that in which we discussed the clustering of the stars in the last chapter. We mark out on a map of the Milky Way the brightest regions—that is, those which include the densest agglomeration of very faint stars. We also mark out the darkest regions, including the coal sack. For this purpose I have taken the maps found in Heis's *Atlas Cœlestis* for the northern portion of the Milky Way and the Atlas of Gould's *Uranometria Argentina* for the southern portion. In order to enable any one to repeat and verify the work I give the position of the central part of each patch or region studied. This serves simply for the purpose of identification. The outlines can be drawn by any one when the patch is identified. The third column of the table is given, approximately, the number of square degrees in the patch as outlined. Then follows the number of stars as found on the map. Here are included stars somewhat fainter than those regarded as lucid.

Heis maps all stars down to about magnitude 6.2 or 6.3. Gould gives the places of all stars to the seventh magnitude.

A.—*Number of lucid stars in certain bright regions or patches of the Milky Way.*

I.—Northern portion, from Heis.

Position of patch. R. A.	Dec.	Square degrees.	Number of stars.
19h. 10m.	+35°	60	21
20h. 0m.	+37°	25	11
20h. 20m.	+47°	20	11
21h. 5m.	+45°	12	4
0h. 20m.	+60°	25	9
2h. 20m.	+55°	60	16
3h. 30m.	+36°	32	7
3h. 40m.	+44°	43	12
Sums		277	91

II.—Southern portion, from Gould:

Position.		Area.	Stars.
8h. 4m.	—47°	10	14
2h. 24m.	—44°	9	7
10h. 35m.	—58°	12	19
11h. 40m.	—62°	10	11
16h. 10m.	—53°	7	7
18h. 0m.	—28°	25	9
18h. 10m.	—18°	8	5
18h. 42m.	— 8°	16	5
Sums		97	77

B.—*Number of lucid stars in the darker regions or patches of the Milky Way.*

I.—Northern part, from Heis.

Position. R. A.	Dec.	Area. Sq. Deg.	Stars.
21h. 0m.	+ 50	26	10
22h. 0m.	+ 67	33	7
22h. 25m.	+ 60	30	12
0h. 0m.	+ 69	56	10
4h. 0m.	+ 55	98	19
4h. 20m.	+ 35	98	13
6h. 15m.	+ 18	86	17
6h. 12m.	+ 4	48	9
Sums.		475	97

II.—Southern part, from Gould.

Position.			
7h. 22m.	— 38°	18	8
7h. 28m.	— 38°	12	5
8h. 0m.	— 22°	11	4
8h. 40m.	— 50°	30	16
9h. 0m.	— 45°	12	6
10h. 0m.	— 52°	11	5
12h. 40m.	— 63°	18	2
15h. 10m.	— 56°	31	3
17h. 30m.	— 27°	18	3
18h. 10m.	— 35°	18	7
18h. 0m. 18h. 30m.	— 22° — 8°	24	10*
18h. 50m.	— 5°	16	5
Sums.		219	74

To derive the best conclusions from these numbers we must compare them with the mean star-density for the sky in general, and for the regions near the galactic plane. Heis has 3,903 stars north of the equator; Gould, 6,755 south of it. The area of each hemisphere is 20,626 square degrees. It will be convenient to express the various star-densities in terms of 100 square degrees as the unit of area. Thus we have the following star-densities according to the two authorities:

	Heis.	Gould.
Star-density of the entire hemisphere	19.0	32.7
Star-density of the darker galactic regions	20.4	33.8
Star-density of the bright-galactic regions	32.9	79.4

The first two pairs of numbers lead to the remarkable and unexpected conclusion that the darker regions of the Milky Way are but slightly richer in lucid stars than the average of the whole sky; certainly no richer than is due to the general tendency of all the stars to crowd toward the galactic plane. On the other hand, the bright areas are 60 per cent. richer according to Heis, and more than 100 per cent. richer according to Gould, than the darker areas seen among and around them. The conclusion is that an important fraction of the lucid stars which we see in the same areas with the agglomerations of the Milky Way is really in those agglomerations and form part of them.

A study quite similar to this has been made by Easton for the portions of the Milky Way between Cygnus and Aquila, where the diversities of brightness are greatest. His count of the stars in the bright and dark regions differs from that made above, principally by including all the stars of the Durchmusterung, which we may suppose to extend to about the ninth magnitude.†

* A long narrow region between these limits.

† Easton's work is given in detail in the 'Astronomische Nachrichten,' Vol. 137, and the 'Astrophysical Journal,' Vol. I, No. 3.

He divides the regions studied into six degrees of brightness. For our present purpose it is only necessary to consider three regions, the brightest, the faintest and those intermediate between the two. Besides the count from the Durchmusterung he made a count of the same sort from Dr. Wolf's photographs and from Herschel's gauges of the heavens. In the following table I have reduced all his results, so as to express the number of stars in a square degree in the three separate regions. At the top of each column is given the authority, whether Argelander, Wolf or Herschel. Wolf had two sets of photographs, one supposed to include all the stars to the eleventh, the other to the twelfth magnitude. The magnitudes included are given in the second line. That Herschel's count extends to the fifteenth magnitude is by no means certain; but we can judge from the great number of his stars that it goes considerably beyond Wolf's in the faintness of the stars included. Below this we give, in the regions A, B and C, which are, respectively, those of least, of medium and of greatest brightness, the number of stars per square degree according to each of the authorities:

Authority	Arg.	Wolf (A).	Wolf (B).	Hersch.
Magnitude	1—9	1—11	1—12	1—15 (?)
Region A	23	72	224	405
Region B	33	134	764	4114
Region C	48	217	1,266	6,920
C—A	25	145	1,042	6,425
Ratio C : A	2.1	3.0	5.7	14.0

The vastly greater number of individual stars per square degree in the brighter regions is what we should expect from the studies we have made of the lucid stars. But what is of most interest in the table is the continual increase in the proportion of faint stars in the separate regions. We notice that, when we consider only the stars of the ninth magnitude, there are twice as many in the brightest as in the darkest portions. When we go to the eleventh magnitude, as shown by Wolf's photograph A, we find the number of stars in the brighter regions to be threefold. When the twelfth magnitude is included we find that there are between five and six times as many stars in the bright regions as in the dark ones. Finally, when we come to stars from Herschel's gauges there are fourteen times as many stars per square degree in the brighter regions as in the dark.

At first sight this result seems to show a great difference between the clusters of stars described in the last chapter, and the collections of the Milky Way, in that the former include few or no faint stars, while the latter include a greater and greater number as we ascend in the scale of magnitude. This difference is important as showing a vastly greater range of actual brightness among the galactic stars than among those which form the scattered clusters. Allowing for this difference, the results from the two classes of objects can be brought to converge harmoniously toward the same conclusion.

We have collected abundant evidence that, separate from the accumulations of stars in the Milky Way, perhaps extending beyond them, there is a vast collection of scattered stars, spread out in the direction of the galactic plane, as already described, which fill the celestial spaces in every direction. We have shown that when, from any one area of the sky, we abstract the stars contained in clusters, this great mass is not seriously diminished. We have also collected abundant evidence that the distances of this great mass are very unequal; in other words, there is no great accumulation, in a superficial layer, at some one distance. The question which now arises is whether the darker areas which we see in the Milky Way are vacancies in this mass. Although some of the counts seem to show that they are, yet a general comparison leads to the contrary conclusion. In the darkest areas of the Milky Way, when of great extent, the stars are as numerous as on each side of the galactic zone. Our general conclusion is this:

If we should remove from the sky all the local aggregations of stars, and also the entire collection which forms the Milky Way, we should have left a scattered collection, constantly increasing in density toward the galactic belt.

THE INCREASING NUMBER OF STARS WITH DIMINISHING BRIGHTNESS.

We mentioned in an earlier chapter that, when we compare the number of stars of each successive order of magnitude with the number of the order next lower, we find it to be, in a general way, between three and four times as great. The ratio in question is so important that a special name must be devised for it. For want of a better term, we shall call it the star ratio. It may easily be shown that there must be some limit of magnitude at which the ratio falls off. For, a remarkable conclusion from the observed ratio for the stars of the lower order of magnitude is, that the totality of light received from each successive order goes on increasing. Photometric measures show, as we have seen, that a star of magnitude m gives very nearly 2.5 times as much light as one of magnitude $m+1$. The number of stars of magnitude $m+1$ being, approximately, from 3 to 3.75 times as great as those of magnitude m, it follows that the total amount of light which they give us is some 40 or 50 per cent. greater than that received from magnitude m. Using only rough approximations, the amount of light will be about doubled by a change of two units of magnitude; thus the totality of stars of the sixth magnitude gives twice as much light as that of the fourth; that of the eighth twice as much light as that of the sixth; that of the tenth twice as much again as of the eighth, and so on as far as accurate observations and count have been made.

To give numerical precision to this result, let us take as unity the total amount of light received from the stars of the first magnitude. The sum total for this and the other magnitudes, up to the tenth, will then be:

Mag. 1	Light =	1.0
" 2	" =	1.4
" 3	" =	2.0
" 4	" =	2.8
" 5	" =	4.0
" 6	" =	5.7
" 7	" =	8.0
" 8	" =	11.3
" 9	" =	16.0
" 10	" =	22.6
Total		74 8

That is, from all the stars to the tenth magnitude combined, we have more than seventy times as much light as from those of the first magnitude.

There must, evidently, be an end to this series, for, were this not the case, the result would be that which we have shown to follow if the universe were infinite; the whole heavens would shine with a blaze of light like the sun. At what point does the rate of increase begin to fall off?

We are as yet unable to answer this question, because we have nothing like an accurate count of stars above the ninth, or at most, the tenth magnitude. All we can do is to examine the data which we have and see what evidence can be found from them of a diminution of the ratio.

It must be pointed out, at the outset, that the ratio must be greater in the galactic region than it is in other regions. This follows from the fact that the proportion of small stars increases at a more rapid rate in the galaxy than elsewhere. This is shown by the comparisons we have already made of the Herschelian gauges with the counts of the brighter stars. While the galactic region is less than twice as dense as the remaining regions for the brighter stars, it seems to be ten times as dense for the Herschelian stars. If we knew the limiting magnitude of the latter, we could at once draw some numerical conclusion. But unfortunately, this is quite unknown. All we know is that they were the smallest stars that Herschel could see with his telescope.

The ratio in various regions of the heavens has been very exhaustively investigated by Seeliger, in the work already quoted. The bases of his investigations are the counts of stars in the Durchmusterung. Instead of taking the ratio for stars differing by units of magnitude, as we have done, Seeliger divides them according to half magnitudes. The reproduction of his numbers in detail would take more space than we can here devote to the subject and would not be of special interest to our readers. I have, therefore, derived their general mean results for different parts of the sky with reference to the Milky Way and for stars of the various orders of magnitude. The following table shows the conclusions:

Zone.	Ratio of increase. D. M.	S. D.	Diff.	Concluded result.
I.	2.99	—	—	3.24
II.	3.00	3.49	0.49	3.25
III.	3.07	3.72	0.65	3.37
IV.	3.32	3.85	0.53	3.58
V.	3.55	4.15	0.60	3.85
VI.	3.28	3.68	0.40	3.48
VII.	3.23	3.55	0.32	3.37
VIII.	3.44	3.56	0.12	3.40
IX.	—	3.49	—	3.24

In the first column we have the designation of the zone or region of the sky, as already given.

In the second and third columns we have the mean ratio of increase for whole magnitudes as derived from the Durchmusterung and the southern Durchmusterung, respectively. It will be recalled that region I., around the north galactic pole, is entirely wanting in the S. D., while the adjoining regions, II. and III., are only partially found, and that, in like manner, the D. M. includes none of region IX. around the south galactic pole, and but little of the adjoining region.

It will be seen that there is a very remarkable systematic difference between the two lists, the ratio of the number of faint to that of bright stars being much greater in the S. D. This difference is shown in the fourth column. I have assumed that the two systems are equally good, and there diminished all the ratios of the S. D. by 0.25, and increased those of the D. M. by the same amount. The mean of the two corrected results was then taken, giving the principal weight to the one or the other, according to the number of stars on which they depend.

It will be seen that the increase of the ratio from either galactic pole to the Milky Way itself is as well marked as in the case of the richness of the respective regions in stars. We may condense the results in this way:

In the galactic zone,	ratio = 3.85
In zones IV. and VI.,	" = 3.53
In polar zones I., II., VIII. and IX.,	" = 3.28

It will be recalled that zone V. is a central belt 20° broad, including the Milky Way in its limits. But the latter, as seen by the eye, especially its brightest portions, does not fill this zone. These portions, as we know, comprise the irregular collection of cloud-like masses described in the last chapter. Seeliger has investigated the ratio within these masses, and compared it with the stellar density, or the number of stars per square degree. The mean results are:

In that portion of the galaxy extending from Cassiopeia to the equator near 6″ of R. A., ratio = 4.02.

In that portion from Cassiopeia in the opposite direction to near 19″ of R. A. in Aquila, ratio = 3.70.

These remarkable results are derived from the D. M., and will be yet more striking if corrected by half the difference between it and the S. D., as we have done for the sky generally. They will then be 4.27 and 3.95, respectively.

As might be expected, the regions of greater star density have generally, though not always, the higher ratio. The highest of all is in a patch south of Gemini, between 6^h and 7^h of R. A., and about 5° of declination. Here it amounts to 5.94, showing that there are eighty-six stars of magnitude 9.0 to every one of magnitude 6.5.

The D. M. does not stop at magnitude 9, as the above numbers do, but extends to 9.5, while the S. D. extends to magnitude 10. For these magnitudes Seeliger finds a yet higher ratio. This is, however, to be attributed to the personal equation of the observers, and need not be further considered.

The only available material for finding the ratio of increase above the ninth magnitude is found in the Potsdam photographs for the international chart of the heavens, which extend to magnitude 11. These are published only for a few special regions. Five of the published plates fall in regions not far from the galactic pole. I have made a count by magnitudes of the 312 stars contained in these plates. An adjustment is, however, necessary from the fact that the minuter fractions of a magnitude could not be precisely determined from the photographed images. The results are practically given to fourths of a magnitude, although expressed in tenths. But it is found that the numbers corresponding to round magnitudes and their halves are disproportionately more frequent than those corresponding to the intermediate fourths. For example, there are only nineteen stars of magnitude 10.7 and 10.8 taken together; while there are forty-nine of 10.5. Under these circumstances I have made an adjustment to half magnitudes by taking the stars of quarter magnitudes, and dividing them between half magnitudes next higher and next lower. The result is as follows:

Mag.	Stars.
6.5	2
7.0	2
7.5	4
8.0	11
8.5	15
9.0	29

Mag.	Stars.
9.5	33
10.0	39
10.5	64
11.0	115

It is difficult to derive a precise value of the star ratio from this table, owing to the small number of stars of the brighter magnitudes which are insufficient to form the first term of the ratio. Assuming, however, that the ratio is otherwise satisfactorily determined up to the ninth magnitude, we find that there is but a slight increase from the ninth up to the tenth. The number of the eleventh magnitude is, however, nearly three times that of the tenth and nearly double that of 10.5.

Another way to consider the subject is to compare the total number of stars of the fainter magnitude with the number of lucid stars corresponding, which, in the general average, will be found in the same space. We may assume that near the poles of the galaxy there is about one lucid star to every ten square degrees. The five belts included in the above statement cover about thirteen square degrees. The region is, therefore, that which would contain about one star of the sixth magnitude. An increase of this number by somewhat more than 100 times in the five steps from the sixth magnitude to the eleventh, would indicate a ratio somewhat less than 3; about 2.5. But the comparison of the photographic and visual magnitudes renders this estimate somewhat doubtful. Besides this, it is questionable whether we should not reckon among stars of the eleventh magnitude those up to 11.5, which would greatly increase the number. It is a little uncertain whether we should regard the limit of magnitude on the Potsdam plates as 11.0 or 11 plus some fraction near to one-half.

Altogether, our general conclusion must be that up to the eleventh magnitude there is no marked falling off in the ratio of increase, even near the poles of the galaxy.

I have not made a corresponding count for the galactic region, but the great number of stars given on the plate show, as we might expect, that there is no diminution in the ratio of increase.

The question where the series begins to fall away is, therefore, still an undecided one, and must remain so until a very exact count is made of the photographs taken by the international photographic chart of the heavens, or of the Harvard photographs.

There is also a possibility of applying a photometric study of the sky to the question. From what has already been shown of the total amount of light received from stars of the smaller magnitudes, it would seem certain that a considerable fraction of the apparently smooth and uniform light of the nightly sky may come from these countless telescopic stars, even perhaps from those which are not found on the most delicate photographs. It is certain that the background of the sky itself is by no means black. The only question is, whether the light from this background is mostly reflected by our atmosphere from the stars. It may seem questionable whether such is the case, because the fraction reflected in a clear atmosphere is not supposed to exceed one-tenth the total amount of light of the stars themselves. On the other hand, the seemingly blue color of the sky might seem to militate against this view, since the average color of all the stars is white rather than blue. The subject is an extremely interesting one and requires further investigation before a definitive conclusion can be reached.

A CENTURY OF THE STUDY OF METEORITES.

By Dr. OLIVER C. FARRINGTON,
CURATOR OF GEOLOGY, FIELD COLUMBIAN MUSEUM.

THE close of the nineteenth century will mark the end of the first century of the study of meteorites. Up to the beginning of this century the attitude of scientific men toward the accounts of stones reported to have fallen from the sky was in general one of scorn and incredulity. Thus an account prepared with great care by the municipality of Juillac, France, telling of a stone shower which occurred there in July, 1790, was characterized by Berthelon at the time as "a recital, evidently false, of a phenomenon physically impossible" and "calculated to excite the pity not only of physicists but of all reasonable people." Bonn, in his Lithophylacium Bonnianum, refers to the Tabor, Bohemia, meteorite which fell in 1753, as "e coelo pluvisse creduliores quidam asseverant." Chladni, writing in the early part of the century, speaks of many meteorites which were thrown away in his day because the directors of museums were ashamed to exhibit stones reported to have fallen from the sky. President Jefferson when told that Professors Silliman and Kingsley had described a shower of stones as having taken place at Weston, Conn., in 1807, said: "It is easier to believe that two Yankee professors will lie than to believe that stones will fall from heaven."

The change of opinion on the part of intelligent and especially scientific men, which took place at the beginning of this century, was due largely to the investigation by the French Academy of the shower of stones which fell at L'Aigle in 1803. This investigation established so absolutely the fact of the fall to the earth at L'Aigle of stones from outer space that scientific men were logically compelled to give credence to the reports of similar occurrences elsewhere. Further, the papers of Chladni and Howard published about the same time, strenuously urging that other masses reported to have fallen upon the earth could not, because of their structure and composition, be of terrestrial origin, had much to do with fixing the growing faith that solid cosmic matter not of terrestrial origin does at intervals come to the earth. Since this beginning the study of meteorites has been one of constantly widening interest and purport.

The essentially distinguishing features of meteorites were early made out. Howard in 1802, from a chemical investigation of various "stony and metallic substances which at different times are said to have fallen on the earth, also of various kinds of native iron," drew the conclusion that a content of nickel characterized most such bodies. He also found that the meteoric stones were made up chiefly of silica and magnesia and that the iron sulphide of meteorites was distinct from the terrestrial mineral pyrite. He further noted the chondritic structure as characteristic of many of the meteoric stones. The correctness of his observations was soon confirmed by analyses made by Fourcroy, John, Klaproth and others. In 1808 Alois von Widmanstätten, by heating a section of the Agram iron, brought out the figures which have since proved so characteristic of meteoric irons in general and which are now known by his name. Thus the data were early at hand for distinguishing meteorites from terrestrial bodies and it soon became possible to collect the 'sky stones' even when they had not been seen to fall. Systematic efforts for the collection of these bodies were not put forth, however, for many years. Up to 1835 there were only fifty-six different meteorite falls represented in the Vienna collection, and in 1856 only one hundred and thirty-six. Up to 1860 those of the British Museum collection numbered only sixty-eight and those of the Paris collection only sixty-four. The studies of these bodies during the first half of the century were made, therefore, upon a relatively limited number. The earlier investigations were chiefly chemical in character, various elements being discovered in succession. Manganese was discovered in the stone of Siena by Klaproth in 1803, chromium in the stone of Vago by Laugier in 1806, carbon in that of Alais by Thenard in 1808, chlorine in that of Stannern by Scheerer in the same year and cobalt by John in the Pallas iron in 1817. The number of elements discovered since has brought the total up to twenty-nine, none being found, however, which are not already known upon the earth. Many of the chemical compounds of meteorites were early isolated and their identity with terrestrial minerals established. Count Bournon showed in 1802 that the transparent green mineral accompanying the iron of Krasnojarsk was olivine. The same mineral was found in other meteorites by later observers, and Rose was able in 1825 to make angular measurements of the crystals which showed them to be identical with those of terrestrial olivine. Laugier separated chromite from the stones of Ensisheim and L'Aigle in 1806. Augite was recognized by Mohs in the stone of Stannern in 1824 and by Rose in that of Juvinas in 1825. Haüy recognized a feldspar which he thought to be orthoclase in the stone of Juvinas in 1822, but three years later Rose showed it to be plagioclase; and the existence of orthoclase in meteorites has yet to be proved. Continued investigations of the compounds found in meteorites up to the present time have resulted in the detection of at least twenty-one whose composition is certain, besides several of a somewhat problematic nature. Of these compounds seven have been found to differ in composition from any known terrestrial substances. The character of these indicates the complete absence of water and of oxygen in any large amount from that portion of nature's laboratory where meteorites are formed. Important investigations as to the gases occluded by meteorites were begun by Boussingault in 1861 and have been continued by Wright, Ansdell, Dewar and others. It has been proved that large quantities of hydrogen, as well as carbonic acid gas, are contained in these bodies, under pressure greater than that of the earth's atmosphere. These investigations led further to the spectroscopic study of meteorites by Vogel, Wright and Lockyer. The spectra thus obtained when compared with those exhibited by comets showed striking resemblances, which have led to a growing belief among scientific men in the identity of origin of comets and meteorites. Lockyer has indeed pushed this conclusion to the point of believing that "all self-luminous bodies in the celestial spaces are composed either of swarms of meteorites or of masses of meteoritic vapor produced by heat," and he draws from this many important deductions relating to the origin of the stars, comets and nebulæ, and the physical conditions prevailing in them. It will remain for the twentieth century to test the correctness of such conclusions, but the facts already brought out have considerably shaken the confidence hitherto placed in the nebular hypothesis. Another interesting result of the century has been the establishment of a general similarity between shooting stars and meteorites. This idea was first suggested by Chladni in 1798, but it has remained for Newton, Adams and Schiaparelli to give it shape and proof. The general verdict of science is now in accord with the belief of Newton, "that from the faintest shooting star to the largest stone meteor we pass by such small gradations that no clear dividing lines can separate them into classes." Moreover, the long-existing belief in *le vide planétaire*, space filled only with a mysterious fluid called ether, has been shown to be untenable. Careful records and estimates have shown that 20,000,000 cosmic bodies large enough to produce the phenomena of shooting stars are encountered by the earth daily. The number of these bodies existing in space must be, therefore, beyond all calculation, and their existence implies that of smaller particles in sufficient number to form a widely pervasive cosmic dust. Many remarkable meteorite falls have occurred during the century. Beginning with the stone shower of L'Aigle in 1803, when 2,000 to 3,000 stones fell, no less than eleven such showers have been recorded. In the shower of Pultusk, Poland, which occurred in 1868, 100,000 stones are estimated to have fallen, their total weight reaching over 400 pounds. In the shower at Mocs, Germany, in 1882, more than 3,000 stones fell. In our own country about 750 pounds of meteoric matter fell at Estherville, Iowa, in 1879, and several thousand stones fell over an area nine miles in length and one mile wide near Forest City, Iowa, in 1890. Many of these falls have been marked by extraordinary phenomena of light and sound, making them events never to be forgotten by those who witnessed them and worthy to be reckoned among the most remarkable natural occurrences of the century. About two hundred and eighty-five actually observed meteoric falls is the total recorded during the century. It is a remarkable fact regarding the nature of the material fallen that only five of these have been of meteoric irons. One of these irons fell at Mazapil, Mexico, during the star shower of November, 1885, at the time when the return of Biela's comet was looked for, and was thus considered an occurrence corroborative of the already suspected relationship among comets, shooting stars and meteorites.

The indifference to the collecting of meteorites which characterized the early part of the century has given place in its latter days to an extraordinary diligence in the search for these bodies. One meteorite has of late acquired a value equal to four times its weight in gold and several can be sold for two and three times their weight by the gold standard. The meteorite collection of the Natural History Museum in Vienna has for many years been the leading one. What it has cost to build it up may be known from the fact that it is considered the most valuable of any single collection in that great treasure house. Representatives of over five hundred meteoric falls are exhibited in this collection, and the meteoric matter has a total weight of seven tons. The collection of the British Museum of Natural History is nearly as large, while at Paris, Berlin, St. Petersburg and Calcutta, together with Washington, Chicago, Cambridge and New Haven, in our own country, are gathered extensive and important collections. The establishment of such large collections has for the first time put the study of meteorites on a satisfactory basis and given lively hope that important truths will be discovered by researches thus made possible. The general similarity of the stony meteorites to the basic volcanic rocks of the earth has been established, and similarity of many physical structures such as brecciation, slicken-sided surfaces and veins has been proved. The chondritic structure and the crystalline structure represented by the Widmanstätten figures are, however, so far as is yet known, peculiar to meteorites, and it will remain for the twentieth century to discover what these structures mean. Classifications of meteorites based on their mineralogical and structural characters have been established, and important differences among meteorites shown, in spite of their family resemblances. It would be idle perhaps to recount, as might be done, many theories regarding the nature and origin of meteorites which have been found untenable as a result of the century's study. The theory of the lunar origin of meteorites had at times such able supporters as Laplace and J. Lawrence Smith. Other able observers have believed meteorites to be material ejected at some past period from the earth's volcanoes; some have regarded them of solar origin and still others as fragments of a shattered planet. All of these theories may be said to have been proved fallacious. The discovery reported by Hahn in 1880 of remains of sponges, corals and plants in meteorites excited for a time eager inquiries into the possibilities of proving by the study of meteorites the existence of life outside our own globe. No satisfactory evidence of the existence of extra-terrestrial life has, however, as yet been obtained from meteorites. The most positive and enduring results of the century's study may, therefore, perhaps be summed up as the establishment of the fact of the fall of solid cosmic matter to the earth and a sufficient knowledge of its nature to distinguish it from matter of terrestrial origin. Satisfactory conclusions as to the origin of this matter and its relations to the visible bodies of the great outlying universe remain yet to be drawn.

DISCUSSION AND CORRESPONDENCE.

A DEFENSE OF CHRISTIAN SCIENCE.

To the Editor: You informed me in my recent interview with you that discussions of a religious nature did not come within the scope of the purpose of your magazine. I am convinced by your fair, frank and kindly manner that you are unaware of the injustice done a large class of thinking people and many readers of your magazine by the article in question between us written by Professor Jastrow and published in the September number of the POPULAR SCIENCE MONTHLY. Nevertheless a great injustice has been done in that you have, even inadvertently, allowed a religious movement to be attacked through the press, while the rules of your publication allow no redress. This seems neither in consonance with justice, free speech nor a free press; and now accepting the situation as no motive or act of yours, and inasmuch as you must refuse to publish an article defending Christian Science, unless the said article be written wholly from a scientific viewpoint, excluding scriptural basis and argument; and inasmuch as Christian Science is not merely a philosophy but a science, having for its principle God, for its text-book the Scriptures and for its proof the moral, spiritual and physical betterment of thousands of its adherents; and inasmuch as the philosophy, works and phenomena of Christian Science can only be discussed or understood from a Christianly scientific standpoint based on the Scriptures, and not from the standpoint of so-called material science or from any hypothesis of a universe without a creator, who is omniscience (all science), and who, therefore, governs His creation with spiritually scientific, not material, law; and inasmuch as that compilation which our race and nation call the Bible, and believe to be a revelation from God as well as ancient history; inasmuch as this book with its key alone unlocks and reveals the consistent beauty, grandeur, might and majesty of spiritual law or science which the world cannot see, does not understand, and the 'wise' call foolish and inconsistent.—Considering all these points and conceding them—because you cannot deny from an opposite premise what I find true—and now, my dear sir, I will ask you to publish this, my letter to you, and a few remarks on Professor Jastrow's article, 'The Occult.'

To begin with, let it be understood that in very fact Professor Jastrow did not attack Christian Science at all. He thought he did, and was no doubt perfectly honest in decrying a thing so occult and wrong as what he believed Christian Science to be; and were it such a thing I would join issue with our critic against it—but behold the fact: Christian Science is as far above what Professor Jastrow attacked in the 'occult' as the science of astronomy is above 'tiddledewinks.'

Professor Jastrow says: "Logic is the language of science. Christian Science and what sane men call science cannot communicate, because they do not speak the same language." Here the Professor, a material scientist, confesses profound ignorance of our spiritual premises, yet sits in judgment on mentally scientific and metaphysical statements in *Science and Health*, vilifies the science and calls its votaries insane. Such a position makes our critic's logic lame. Surely, Professor Jastrow must be cognizant of the fact that very many, as erudite as he, swell the ever-increasing ranks of scientific

Christianity; and in face of these facts his position, to say the least, seems unfair and unkind.

The statement that Dr. Quimby practised Christian Science or that his mental method contained some of the essentials of Christian Science accounts for the further assertion that Christian Science is not Christian. Professor Jastrow deserves credit for discerning that Dr. Quimby's methods were adverse to Christ's teachings, but just how the good Professor determines the finality of what has defied eighteen centuries of time and scholastic theology is a mystery; to wit: the Doctrine of Christ. Why, ages have wrangled and fought over this subject until history points with scarlet finger to unchristly deeds and impotent creeds, all in His name; and even yet the lack of unity among Christian denominations and the utter want of that power and glory which characterized the founder of Christianity and the early Christians puts to shame the theological labor of the centuries.

Professor Jastrow is not an authority on Christianity, yet he pronounces Christian Science unchristian. Let me quote some authority on this subject: Rev. Edward T. Hiscox, D. D., of Brooklyn, in the *Christian Enquirer*, a Baptist organ, says: "The modern Church would be elevated to a much higher plane of Christian living than it now occupies if it were to follow them. I am profoundly convinced that the great need of all our churches is more of the religion I have seen in the lives of the Christian Scientists whom I know." Rev. Dr. E. C. Bowls, of New York City, President of the State Convention of Universalist Ministers, in speaking of Christian Science, says: "There is certainly a perception here of the true foundation of Christianity." I might quote from Phillips Brooks and many theologians of like note, but *quantum sufficit.* Who will venture to assert in face of the evidence given that Professor Jastrow's argument on this point has any force at all?

Professor Jastrow also says Christian Science is not a science, and that Materia Medica is a science. This first assertion is most wanting in reason or proof, for if Christianity is not scientific it is not true. Anything which has a demonstrable principle is said to be science. If Christianity lacks a principle, it is nothing but theory or belief; on the other hand, if the Christian religion has a principle, it is a scientific religion or a Christian science. The second assertion that Materia Medica is a science challenges the wisdom of experienced men who are authority on this subject, while Professor Jastrow is not. The 'Standard Dictionary' says of Materia Medica: 'It is the most empirical and tentative of all sciences.' Many eminent medical teachers and practitioners do not agree with Professor Jastrow's views on Materia Medica. Of these I will mention Dr. Rush, the famous Philadelphia teacher of medical practise; Dr. Waterhouse, Professor in Harvard University; Dr. Mason Good, a learned professor in London; Dr. Chapman, Professor of the Institutes and Practise of Physics in the University of Pennsylvania. Sir John Forbes, M. D., F. R. S., Fellow of the Royal College of Physicians of London, says: "No systematic or theoretical classification of diseases that therapeutic science has ever promulgated is true or anything like the truth, and none can be adopted as a safe guidance to the practise."

The above is to show the weakness of Professor Jastrow's argument, and not to depreciate the philanthropic efforts and labor of the noble multitude of M.D.'s who have alleviated much suffering and done much good in the world. We honor them for the noble lives and the good they have done and are still doing.

Professor Jastrow is no doubt a very clever and very learned man, but he has not proved himself capable of classifying the sciences nor of sitting in judgment on Christianity.

Mr. Jastrow acknowledged 'the popular preeminence of Christian Science' and advises reading *Science and Health*. Truth courts investigation, and when *Science and Health* is universally read, its abstract and metaphysical statements will be found simple compared with the tangled verbosity of human reason and human logic.

Logic is, indeed, the language of science, but scientific fact is based on principle, and principle—call it what you will, but I call it God.

J. Edward Smith.

[Professor Jastrow's article on 'The Modern Occult,' published in the September number of the Popular Science Monthly, has not unnaturally called forth a number of replies. As there seems to be some fairness in the claim of the 'Christian Scientists' that a sect counting its adherents by hundreds of thousands should be heard in its defense, and as Mr. Smith appears to have been delegated to make an official reply and has consented to do so briefly, we have pleasure in publishing his letter. It will be read with interest by many, and will undoubtedly confirm Professor Jastrow's statement that argument is impossible when people do not speak the same language. From the remote past men have worshiped strange gods in strange ways, and that there should be survivals and avatisms is in nowise surprising. We are not concerned with these, but when a religious sect trespasses on the domain of science it must be treated in accordance with due process of law. The Christian Scientists in their claims to treat all manner of disease have laid themselves open, not only to the charge of folly, but also of charlatanism. The writer of the above letter offered to produce before the editor of this journal a number of persons who had been cured of snake bites by Christian Science treatment. As people almost never die from bites of American snakes, and as there is no reason in this case why the Christian Science treatment should kill them, the production of the survivors was not a matter of scientific interest. It was, however, suggested to the gentleman that he permit himself to be a subject for inoculation experiments with snake venom, as his assurance that he could not be poisoned would in nowise interfere with the scientific results. To this proposal, however, he did not take kindly. It is on record that Mrs. Eddy not only suffered from toothache but took nitrous oxide gas when the teeth were extracted. But the inconsistencies of the leaders of Christian Science make no impression on its adherents. We do not speak the same language.—Editor.]

MR. TESLA'S SCIENCE.

To the Editor: In the *New York Sun* for January 3, Mr. Nikola Tesla has an article that deserves a word. The word is one of warning to all soberminded readers to remind them that Mr. Tesla's recently published utterances have discredited him in the eyes of competent judges. In the *Century Magazine* for June, 1900, Mr. Tesla printed a long article, superbly illustrated with cuts that had little or nothing to do with his subjects, which dealt with a few electrical matters, and also with philosophic and social problems upon which he freely expressed a jumble of trivial, ignorant, pretentious and erroneous opinions. This article was freely reviewed in the Popular Science Monthly for July, 1900, and in *Science* for September 21. These reviews were doubtless seen by Mr. Tesla, but no word of reply has been made public by him. Indeed, he says in the *Sun* that from adverse criticisms on his work he experiences 'a feeling of satisfaction.' Any one who desires a standing among men of science is called upon to defend his public utterances when they have been seriously questioned in reputable scientific journals. Until an adequate rejoinder is received Mr. Tesla has no standing among professed men of science. He will have none among intelligent readers from the moment that the case is understood by them. It is not profitable to again go over the ground covered by the articles just mentioned, but readers are referred to them in passing.

The article in the *Sun* of January 3 bears the marks of authenticity. Much of it is printed in quotation marks. It gives an account of Mr. Tesla's work in Colorado during a part of the year 1899. This work had, he says, three objects: first, to transmit power without wires, and second, to develop apparatus for submarine telegraphy. These two problems have a direct commercial value. When they are solved, by Mr. Tesla or another, we shall hear of them through the Patent Office. As we have not so heard of them it is permissible to wait for results. We wish Mr. Tesla every success in these investigations. He is entitled to all the time he needs—a lifetime if necessary. If his experiments forward our present knowledge in any material degree he will be entitled to the gratitude of all mankind, and he will receive it. Until they do pronunciamentos from him and comments from us are not required.

The third problem upon which Mr. Tesla was engaged 'involves,' he says, 'a still greater mastery of electrical forces.' He will 'make it known in due course.' In the meanwhile, however, he states that he has noted "certain feeble electrical disturbances . . . . which by their character unmistakably showed that they were neither of solar origin nor produced by any causes known to me on the globe." These he supposes may have been signals from intelligent beings on Mars or some other of the 'twenty or twenty-five planets of the solar system.' Mr. Tesla obviously wants to figure in the newspapers. Every one would be greatly interested if it were true that signals are being sent from Mars. Unfortunately for Mr. Tesla's scientific standing, he has not adduced a scrap of evidence to prove it. It is of a piece with the 'twenty or twenty-five planets' he ascribes to the solar system. It would be interesting if there were so many. There is no evidence of it save Mr. Tesla's assertion, and assertions—Mr. Tesla's or another's—do not count in science. There is no further space for a notice of Mr. Tesla's latest extravagant vagary. For men of science no notice at all is needed. Any intelligent reader who will consult the reviews already mentioned and compare them with Mr. Tesla's own words will see that his vivid writings must be read with extreme caution. His electrical experiments being directed towards commercial uses must be judged by proved commercial success. His speculations on science are so reckless as to lose an interest. His philosophizing is so ignorant as to be worthless.

X.

SCIENTIFIC LITERATURE.

ENGINEERING.

AMERICAN books on surveying have heretofore been prepared primarily as texts for class use, rather than for the use of the field engineer. This point of view is reversed in the volume of 900 pages, by Herbert M. Wilson, entitled 'Topographic Surveying, including Geographic, Exploratory and Military Mapping,' recently issued by John Wiley & Sons. It sets forth, in the main, the practise of the U. S. Geological Survey, and many of the illustrations have been derived from the publications of that bureau, the colored ones being printed from copper plates owned by the Government. Field work, with the plane table, the transit and stadia, the level and office methods of mapping occupy nearly one-half of the volume; about 300 pages are devoted to geology and astronomy, and the remainder to photography, camping, and the subsistence and health of field parties. In no book heretofore issued are the practical details of topographic work discussed with such fulness as here, and the numerous tables will be found of great assistance in facilitating computations. Indeed, a special effort seems to have been made in the direction of tables, some of which might well have been omitted; for instance, the space devoted to the table of Peirce's criterion for the rejection of observations would have been better filled by elementary matter on the method of least squares, and the table for the values of 0.046*d*, when *d*=10, 20, 30, etc., seems a reflection on the mathematical knowledge of the reader. The book is in general clearly written, although the frequent use of italics seems to indicate that the author was often apprehensive that he might be misunderstood. It is a valuable supplement to the text-books of the engineering colleges.

'ROAD MAKING AND MAINTENANCE,' by Thomas Aitken (London, Griffin & Co.), deals largely with European practise in street construction. The country roads of England are as a rule better than those of the United States, having been earlier built and more systematically repaired, while great attention is paid to securing uniformity of surface. An instrument called the viagraph is described by the author, which takes an automatic record of the inequalities of the street surface and gives the sum of all the vertical depressions found in paving over a mile. A road having 15 feet of such depressions per mile is called excellent, while a fair road has 40 or 50 feet per mile, and a passable one 60 or 80 feet per mile. The cost of this viagraph is moderate, and it is only necessary to drag it along the street in order to obtain the authentic record. It is surprising to learn that wooden pavements still continue to be laid in English towns, while brick pavements are practically untried. On questions of city streets American practise seems fully abreast of that of England now that the necessity of good foundations of concrete is fully recognized. 'Street Pavements and Paving Materials,' by George W. Tillson (New York, Wiley & Sons), sets forth modern American practise in an exhaustive manner, giving specifications in use in different cities for different kinds of pavements. The first asphalt pavement laid in the United States was in 1870; great difficulties were met in adapting asphalt to climate and traffic, but these have gradually been overcome, and to-day we have hundreds of miles of these excellent pavements. The first brick pavement of the United States was also laid in 1870, and to-day the total number of miles is nearly a thousand, of which more than one-tenth are in Philadelphia. The cost of road construction and street paving appears to be now slightly less in the United States than in England, and hence there is little doubt but that in another half century our roads and streets will be brought into a condition fully equal to that found in Europe. These two books show that road building can no longer be left to farmers, and street construction to town councilmen, but that economic results can only be secured when they are placed under the charge of experienced civil engineers.

'Irrigation and Drainage,' by F. H. King, published by the Macmillan Company, is not strictly an engineering book, it having been mainly prepared for the farmer and gardener, but it is difficult to find a technical work which so clearly exemplifies the fundamental principles and minor details of the subject. The conditions that make irrigation imperative or desirable, the proper amount of water to be used, the methods of supplying and distributing the water, the laws of flow of ground water, and the reasons, objects and methods of draining land are set forth in a correct and lucid manner. As a text-book for use in agricultural colleges the volume appears to be well adapted, while engineering students will find that its discussions throw new light on their view of the subject. The irrigation of the arid regions, formerly known as the Great American Desert, is now a matter of great importance to both engineers and agriculturists, and the author deals fully with the peculiarities of its alkali soils and with the results thus far attained. In this connection note may be made of a recent Bulletin of the U. S. Geological Survey, entitled 'Storage of Water on Gila River, Arizona,' by J. B. Lippincott. This is a topographic and engineering study for an irrigation scheme made under a law authorizing that bureau to carry on surveys for possible reservoir sites in the arid regions. Powerful influences are at work to induce Congress to appropriate money for the construction of such reservoirs and for building canals to deliver water to irrigable areas. On the Gila River watershed it has been found that several reservoir sites are available, that the Buttes dam may be built at a cost of $2,600,000, the San Carlos dam at a cost of $1,039,000, and others for smaller amounts. It is gravely urged in this Bulletin that the Government should build one of these dams, in order to accommodate certain Indians from whom white men have already diverted water to which the tribe has a legal right. As these lines are written an effort is being made to push this philanthropic scheme through Congress by means of an amendment to the River and Harbor bill!

The literature of engineering now covers so vast a field that a person can become acquainted only with a part of the portion relating to his specialty Catalogues and indexes are indispensable, in order that he may know what has been printed and where to find it. The 'Catalogue of the Library of the American Society of Civil Engineers' is a valuable aid in this direction, although that library is far from complete. This volume, which contains seven hundred and four closely printed pages, arranges the books and pamphlets under twenty-five principal classes, each of which is divided into several sub-classes, thus rendering it easy for the engineer to ascertain exactly what the library contains on any topic. This method of arrangement has decided advantages over the usual author and subject catalogues of books whose publication is rarely advisable. The engineering literature in periodicals is, however, not represented in this catalogue, except in the titles of the journals. A 'General Index to Engineering News from 1890 to 1899' has just been issued, which supplies the want as far as the files of that journal for those years is concerned. This is a volume of three hundred and twenty-four pages, alphabetically arranged after the manner of a subject catalogue; it is an excellent example of good indexing, which may profitably be followed by other periodicals with advantage to themselves and their readers.

'Water Power,' by Joseph P. Frizell, published by Wiley & Sons, is the first engineering book to bear the date of the twentieth century. It is a book for the practitioner rather than for the student, practical rather than theoretical, descriptive rather than argumentative. Of the five hundred and sixty pages, about two hundred are devoted to dams, about one hundred and fifty to canals and water wheels, and the remainder to the construction of power plants and the transmission of power. Much of the extended experience of the author is here recorded in a form which is likely to be useful to the enginering profession, and it is certain that as the coal deposits become exhausted the energy of waterfalls must more and more be utilized. It was a marked characteristic of the engineering books of the nineteenth century that they were adapted for the use both of students and practitioners, the same works that were studied in the class-room being the manuals for field and office work. There now seems to be a tendency to issue books, embodying the experience of engineers, which are mainly useful in practise and which are needed in engineering colleges only for consultation. One reason for this is that the number of engineers is now so great that such books can be published with profit, and another is that many details of practise have become so systematized that scientific classification of them is now possible. The economic side of engineering practise has, in fact, become of utmost importance, and the multiplication of books and periodicals is necessary in order that each designer may see the good points of the designs of others, avoid their faults, and thus make his own construction of greatest stability and usefulness at the minimum cost.

MYCOLOGY.

A book on 'Edible and Poisonous Mushrooms,' by Prof. George F. Atkinson, of Cornell University, has been published by Andrus & Church, Ithaca, N. Y. The author's 'Studies and Illustrations of Mushrooms,' issued as Bulletins 138 and 168 of the Cornell University Agricultural Experiment Station, have been so well received, and there has been such a demand for literature on the subject, that he prepared this large octavo book, containing over two hundred half-tone illustrations. Of these, seventy are used as full-page plates, and there are, besides, fifteen species in color. Nearly all the genera of North American agarics are illustrated, and many of the important genera, such as *Amanita*, *Agaricus (Psalliota)*, *Lepiota*, *Mycena*, *Paxillus*, etc., have a number of illustrations, while the genus *Amanita*, containing several of the most poisonous species, represented by about fifteen species, fully illustrated with the development and differential characters, described at length. In all, about two hundred species are described, and more than three hundred names are accounted for. Mrs. Sarah Tyson Rorer writes a special chapter on recipes for cooking mushrooms, and Mr. J. F. Clark one on the chemistry, toxicology and food value of mushrooms. There are also chapters on the collection and preservation of mushrooms, how to avoid the poisonous ones, and keys to the genera of the agarics.

FOLK-LORE.

In the 'History of the Devil and the Idea of Evil from the Earliest Times to the Present Day' (The Open Court Publishing Company), Dr. Paul Carus has produced an interesting and a convenient manual of a certain aspect of the anthropological history of religions, and of certain of the moral conceptions and the aids to their realization which these religions embody. The scope of the work is more various than the title would suggest, for it includes the consideration of the outlying topics that are indirectly but not inherently connected with the idea of evil and its personal embodiment. It thus loses in its systematic character, but gains somewhat in its acceptability as a popular presentation. The author has made good use of the extensive literature of his special topic and of the themes with which it is associated; but the compilation can not and presumably does not lay claim to any marked originality of contribution or presentation. In one aspect the volume shows commendable industry, namely, in the collection of illustrations, which give an unusually realistic account of the vagaries of the human mind, and especially the human imagination, in dealing with the mystery of good and evil. In five hundred pages of text we have three hundred illustrations, ranging from savage and Assyrian and Chaldean and Egyptian and Classic and Medieval and modern pictures of the incarnation of evil, to the acts of sacrifice and worship instituted in his honor, to Faust legends and the fate of the damned, to demon-possession and exorcism, to the scenes at the stake and the persecution of witches, to the portrayal of the devil in art and literature, in folk-lore, and finally his degradation in the caricature and drama of the day. This panoramic unfoldment of the changes of attitude towards the monarch of evil affords an interesting corollary to the conquests of culture over the terrifying realms of the imagination. The flight to evil that we know not of has in all ages been made by the fancy of the religious devotee, the ascetic, the churchman, and through them as well as by reason of the inherent necessity for a fear of consequences as an incentive to moral action, has the devil continued to live and exert his influence over the affairs of men. "The Devil of the Salvation Army," says Dr. Carus, "proves that there is still need of representing spiritual ideas in drastic allegories; but though Satan is still painted in glaring colors, he has become harmless and will inaugurate no more witch-persecutions. He is curbed and caged so that he can do no more mischief. We smile at him as we do at a tiger behind the bars in a zoological garden."

The scope of the work may be briefly indicated. An introductory consideration of the nature of good and evil as religious ideas leads to a general account of demonolatry; this cult and its various expressions in ancient Egypt, in Persia, among the Jews, in Brahmanism and Buddhism, are then described; the new era introduced by the spread of Christian conceptions is portrayed, and its combination with the conceptions of Greece and Rome, its later encounter with the traditions of Northern mythology are further characterized; the successive periods of inquisition, witch-persecutions, reformation, constitute the zenith of the diabolical epoch; the reconstruction of the notions in regard to Satan is well illustrated in the literature, while the philosophical problem of good and evil still remains for discussion, even after science and the progress of civilization have crowded the personal devil out of his occupation.

The main value of this volume is the service which it is capable of performing as a work of reference, and again as an interesting presentation of a range of ideas with which many scholars with various purposes have to deal, and which forms a significant chapter in the history of culture.

THE PROGRESS OF SCIENCE.

Criticism of the Government is a cherished prerogative of a democratic people. Shortcomings that would be regarded as inevitable in the conduct of a private institution, when discovered under Government control, are ápt to be the target of very free speech. We believe that the scientific work at Washington is, on the whole, carried on as economically and efficiently as in our endowed universities, but no human institution is perfect, and just now the U. S. Naval Observatory is being subjected to a good deal of criticism by the astronomers of the country. There is a general consensus of opinion that, while researches and discoveries of the highest order have been made at the Naval Observatory, there has been a lack of the far-reaching and long-continued fundamental work which should be the chief end of a national institution of this character. It is also pretty generally agreed that one chief difficulty is the division of control, the Observatory having for superintendent a line officer of the Navy, with no knowledge of astronomy and a scientific director with no real authority. Last year a board of visitors was appointed by Secretary Long, consisting of the Hon. William E. Chandler, the Hon. Alston G. Dayton, Prof. E. C. Pickering, Prof. George C. Comstock and Prof. George E. Hale, who made a careful report, their chief recommendation being that the Observatory be under the control of a permanent board of visitors, who should prescribe the work to be undertaken and fill vacancies on the staff, the astronomers so appointed to be no longer officers of the Navy. The naval officer who happens to be superintendent of the Observatory has just now made a rather acrimonious reply to the report of the board of visitors, calling its recommendations 'preposterous' and 'ridiculous,' and maintaining that the work done at Washington is equal to that of the Greenwich Observatory.

It must be confessed that there is small likelihood that the recommendations of the board of visitors will be carried into effect. The naval officers at Washington have great and well-deserved influence, and they must be persuaded either to consent to the transfer of the Observatory to another department or else to conduct the institution under the Navy in the way that will be most creditable to it and to the country. We regard the latter alternative as the more feasible. There may ultimately be a national department of education and science with a secretary in the cabinet, but the time for this has not yet come. In the meanwhile scientific work is distributed to different departments, and the Department of the Navy can conduct the Observatory, as is the case in Great Britain and France, as well as another department, even though the work of the Observatory and the Nautical Almanac are not exclusively, and perhaps not chiefly, of concern to the Navy. The stars—so long as they are not annexed—may logically belong to the department having to do with foreign affairs, but in this world logic is of less concern than making the best of existing circumstances. What we regard as essential is to convince the Department and the officers of the Navy that there should be a single head of the Observatory, selected as the man most competent by scientific attainments and executive ability to administer the institution. The promotion of the officer longest in the service to the scientific directorship and his retirement at the age of sixty-two years will certainly not always secure the best man possible or for a sufficiently long term of years. The director of the Observatory should be appointed by the President, on the recommendation of the Secretary of the Navy, and the latter should select one of two or three candidates nominated by some expert body such as the National Academy of Sciences. If such a plan were properly brought before the Secretary of the Navy, we believe that it would secure his approval and also the support of the officers of the Navy, who take pride in the Observatory. They would also probably agree that it would be more appropriate to change the name from 'Naval' to 'National' Observatory, it being administered by the Navy for the Nation.

THE scientific students of the country have two general gatherings in the course of the year. In the summer the American Association for the Advancement of Science holds a migratory meeting, and with it assemble a number of special societies. During the Christmas holidays the American Society of Naturalists serves as a center for societies devoted to the natural sciences—morphology, physiology, anatomy, bacteriology, botany, psychology and anthropology. The meetings of these societies were held this winter at the Johns Hopkins University, Baltimore, from the 26th to the 29th of December. There was no general registration of members, but the attendance was estimated at about three hundred, and as it consisted exclusively of working men of science, the number of papers presented was nearly equal to the attendance. The scientific work of the Society of Naturalists consists of a discussion on some subject of common interest, a lecture preceding the usual reception, and an address by the president, given at the annual dinner, while the special papers are presented to the groups of experts who make up the special societies. The discussion this year was on the relations of the Government to scientific research. It was opened by Prof. H. F. Osborn, of Columbia University, the American Museum of Natural History and the U. S. Geological Survey, who was followed by Prof. William B. Clark, of the Johns Hopkins University and the Maryland Geological Survey; Dr. L. O. Howard, Chief of the Division of Entomology of the U. S. Department of Agriculture; Dr. B. T. Galloway, Superintendent of Experimental Gardens and Grounds, U. S. Department of Agriculture, and Prof. William T. Sedgwick, of the Massachusetts Institute of Technology. The evening lecture on 'Indians of the Southwest,' elaborately illustrated, was given by Dr. Frank Russell, of Harvard University. The address of the president, Prof. E. B. Wilson, of Columbia University, was entitled 'Aims and Methods of Study in Natural History.' While the naturalists were meeting at Baltimore, the Geological Society of America held its thirteenth winter meeting at Albany, and the American Chemical Society held its twenty-second general meeting at Chicago. The American Physical Society and the American Mathematical Society held their sessions as usual in New York, while a branch of the latter society met at Chicago. There was also in Chicago a meeting of the Naturalists of the Western and Central States, with an attendance of one hundred members and a program containing about forty papers. The academies of a number of the Central and Western States, including Ohio, Iowa, Kansas, Wisconsin and Nebraska, also held their annual meetings. When it is stated that about five hundred scientific papers were presented before these societies, it will be seen how impossible it is to give a report of their great and far-reaching activity. We may, however, illustrate the character of their work by three or four examples.

As an example of the scientific work carried on by morphologists at the present time, we may note two important papers presented by Prof. E. B. Wilson, of Columbia University, at Baltimore. One of the most interesting biological results of recent years is the discovery of Loeb that the eggs of the sea-urchin may be caused to develop, without the influence of the male element, by treatment with solutions of magnesium chloride or other substances added to the sea-water. Wilson has now examined the internal processes occurring in these eggs. Phenomena of this character had been earlier studied by Richard Hertwig and Morgan, whose work paved the way for that of Loeb; but neither of these observers succeeded in obtaining complete embryos, the eggs only having passed through the initial stages of development. Wilson's observations bring the decisive proof that the eggs, developed under these conditions, have not been accidentally fertilized. It is well known that in the fertilization of the egg an equal number of chromosomes are contributed by the egg and the spermatozoon, this number being in every known case one-half that characteristic of the tissue cells of the species. If, therefore, the magnesium eggs really develop without union with a spermatozoon, we should expect to find them showing but one-half the number of chromosomes occurring in fertilized eggs. Such is, in fact, the case in the magnesium eggs (of *Toxopneustes)*, the number of chromosomes being here 18, while in normal fertilization it is 18 plus 18, or 36. Every doubt is thus removed regarding the accuracy of Loeb's general result. Interesting light is thrown by the observations on many features of the process of normal fertilization. According to Boveri's well-known theory, the egg is induced to develop through the importation of a centrosome carried by the spermatozoon. In the magnesium eggs this is obviously out of the question; and Wilson's studies, supplementing the earlier ones of Hertwig and Morgan along the same lines, give strong evidence not only that the importation of a centrosome is not necessary to development, but also that the centrosomes of the dividing magnesium eggs are formed *de novo* out of the egg-substance. As observed by Morgan, these eggs often become filled with large numbers of asters, each of which contains a centrosome. One of the most interesting results of Wilson's work is the discovery that these asters may multiply by division and form centers of cytoplasmic division, even when they have no connection with nuclear material. The important point was determined also that similar asters and centrosomes, likewise capable of division, are formed in non-nucleated egg-fragments obtained by shaking the eggs to pieces—a fact which shows that the formation of a centrosome may be wholly independent of the nucleus.

In a second paper Wilson described experiments on etherizing normally fertilized eggs at various stages, the results of which bear nearly on some of the questions suggested by the magnesium eggs. The principal result of these experiments was to show that division of the nucleus and that of the cell-body, though parallel, are in considerable measure independent processes, which is in accordance with earlier studies by Hertwig, Demoor and others. The results give, further, considerable ground for the conclusion that the rays of the radiating systems or asters in dividing cells cannot be regarded as fixed, fibrillar structures, as is assumed by most of the prevailing views, but are tracts of protoplasmic flow, as was many years ago maintained by Fol and Bütschli. It was shown also that by suitable etherization of the eggs and subsequent transfer to sea-water, the type of fertilization characteristic of the sea-urchin may be artificially changed into that normally occurring in the starfish, and in many worms and mollusks; and, in like manner, that the cleavage of the egg may be transformed into a mode that is typical of many of the cœlenterates and arthropods. These observations show that many new and interesting conclusions bearing on the early stages of development may be looked for by further experimental studies along the lines marked out fourteen years ago by O. and R. Hertwig, which have been too much neglected by later observers.

The geologists were especially interested in a paper by Prof. Frank D. Adams, of McGill University, which gave the results of an investigation on the flow of rocks when subjected to pressure in the laboratory under conditions which reproduce those obtaining in the deeper portions of the earth's crust. Marble was the rock on which most of the work was carried out, but harder rocks, such as granite, are now being studied. Small columns of marble were carefully turned, polished and accurately fitted into heavy wrought iron tubes, constructed on the plan of heavy ordnance by wrapping strips of wrought iron around a core of soft iron and welding the whole together. The core of iron was then bored out and the marble substituted for it. Heavy steel pistons were fitted into each end of the tube, and the rock was submitted to very high pressure, often for several months continuously, in especially constructed machines capable of developing pressures reaching nearly a hundred tons to the square inch. Under high pressures the marble was found to flow, bulging out the iron tube that enclosed it on all sides. When the iron tube was cut away a solid block of marble was obtained, which had completely altered its shape. It was found, however, that the marble in these cases was only about half as strong as the original rock. Other columns of marble were heated to temperatures of 300° C. and 400° C., and while thus heated the pressure was applied as before. Under these conditions the rock was found to flow readily and to retain its strength much better, being nearly as strong as the original rock. In the third series of experiments, the marble was not only heated to the temperatures before mentioned, but at the same time water under a pressure of 460 pounds to the square inch was forced through it while it was being compressed. Under these conditions, the marble, after being molded, was found to be as strong as it was originally. A microscopical study of the structure of the deformed marble shows that in these two latter cases the crystalline grains composing the marble had glided on one another.

Among the papers presented before the Bacteriological Society one of the most interesting was by H. L. Russell and S. F. Babcock, of Madison, Wis., upon the causes effective in the production of silage. The very great influence of bacteria in natural processes has led in the last few years to an assumption on the part of bacteriologists that these micro-organisms are agents in nearly all the general processes of nature involving chemical change. Among other phenomena connected with agriculture, it has been claimed that the changes which take place in corn fodder in the farmer's silo are the result of the growth of bacteria. These changes are accompanied by a rapid heating of the material when first placed in the silo and, later, by the production of peculiar flavors and aromas. These phenomena are so similar to those which bacteria are known to produce that it has been a very natural assumption that they are caused by micro-organisms. Russell and Babcock have been of the opinion that bacteriologists have gone too far in ascribing natural phenomena to bacterial agencies, and that it is necessary to look in different directions for the explanation of some of them. The production of silage, for example, they insist, is not the result of bacterial action. By carefully performed experiments they succeeded in producing normal silage under conditions in which bacterial growth was prevented. They conclude that the changes occurring in silage are produced partly by a continuation of the respiratory activities of the plant cells, which, for a time, are stimulated rather than checked when the plants are cut to pieces for storing in the silage, and partly as the result of the action of certain chemical ferments or enzymes, which are eliminated from the plant cells after the death of the plant. These two factors the authors regard as the efficient cause of these changes in silage which have hitherto been attributed to the growth of bacteria, and they believe that bacteria have nothing to do with the process when it takes place in a normal manner.

THE outcome of the experiments in growing Sumatra tobacco in the Connecticut Valley, recently reported by the National Department of Agriculture, is something more than a successful attempt at plant introduction. It is a tribute to the efficiency which has been attained in the methods of conducting soil survey, and a notable illustration of the scientific and practical value of such a survey as a basis for judging of the adaptation of agricultural plants. Two years ago the Division of Soils, in connection with its soil surveys in the Connecticut Valley, located areas about Hartford which it believed were suited to the growth of Sumatra tobacco. At that time it had never been grown in the region, and was not supposed to be adapted to it. During the past season the experiment was undertaken, in co-operation with the Connecticut State Experiment Station, on about a third of an acre. This was shaded from the sun by erecting a framework upon which cheese-cloth was stretched at a distance of about nine feet above the ground, and inclosing the sides as well. The tobacco grew well, and in due time was harvested and fermented as is customary. The quality of the finished product was pronounced excellent, and hardly to be distinguished from the imported article. As a substantial proof of this the crop has just been sold to a dealer at an average price of 71 cents per pound, including tops, butts and trash, along with the choicer leaves. As much as $1.25 per pound was received for some of the unsorted product. The average price received for the regular tobacco crop grown in the locality is about 20 cents. The Sumatra tobacco gave a net profit at the rate of nearly $900 an acre, exclusive of the expense of erecting the shade. The framework will last several years, but the cheese-cloth will have to be renewed each year. The object of shading this tobacco is to produce a thin leaf with small veins and a more luxuriant growth. Shading simulates the natural conditions under which it grows by making the atmosphere more humid and less subject to sudden changes. The Sumatra leaf is used for cigar wrappers, and is especially valued because it is elastic, free from objectionable taste and aroma, has small veins, which reduce the waste, and the leaf cuts up to better advantage than the ordinary wrapper leaf on account of its shape. About six million dollars' worth of Sumatra tobacco is imported annually, upon which a duty of $9,000,000 is paid. The experts in the Division of Soils estimate from their surveys that there is sufficient soil adapted to its growth in Connecticut and Florida to produce all that is demanded. This year's success will undoubtedly stimulate attempts to grow it regardless of the adaptation of the soil, so that there are likely to be many failures and disappointments another season, unless the advice of the Department is followed.

AN interesting chapter has been added to the knowledge of the inert gases of the atmosphere by Dr. Ramsay, the co-discoverer of argon, and Dr. Travers. A little more than two years ago they announced the discovery of krypton and neon, and at the same time obtained indications of two other gases, to which they gave the names of met-argon and xenon. They now find that the presence of the so-called met-argon was due to carbon in the phosphorus used for removing the oxygen. By the use of large quantities of liquid air they have, by fractional distillation, obtained sufficient amounts of krypton and xenon to study their properties and measure their physical constants. They are all monatomic gases, and in their inertness completely resemble argon and helium. The spectra of these elements have been examined and will shortly be published. The neon tube is extremely brilliant and of an orange-pink hue, and its spectrum is characterized by a multitude of intense orange and yellow lines. The krypton tube is pale violet, while that of xenon is sky-blue. The atomic weights of krypton and xenon are, respectively, 82 and 128, and the inert elements thus form a regular group lying between the halogens and the alkalies. The atomic weights are as follows: Helium, 4; neon, 20; argon, 40; krypton, 82; xenon, 128. Their physical properties also correspond with this grouping.

The daily papers have during the past month exploited with nearly equal prominence Mr. Tesla's pretended communications from the planets, the alleged discovery by Professor Loeb of an elixir of life, and Professor Pupin's important discovery improving the telephone and the telegraph. These three cases pretty well represent the different methods of newspaper science. Mr. Tesla likes to be advertised, and the arraignment of his vagaries by our correspondent, published in another column, is none too severe. Professor Loeb and Dr. Lingle have carried out valuable researches on the action of salts on muscular contraction, published in the 'American Journal of Physiology,' and these have been exaggerated and distorted in the daily press. We are requested by Professor Loeb to state that this has been done without his knowledge, and continued in spite of his earnest protest. Professor Pupin's discovery is reported with substantial accuracy as regards its nature, its importance, and the large sum paid by the American Bell Telephone Company for the patent. Professor Pupin's discovery was made in the course of a long theoretical and experimental investigation, carried on solely to increase our knowledge of electrical phenomena and without any reference to the Patent Office. The researches were communicated to the American Institute of Electrical Engineers last spring, and published in their 'Proceedings.' The application consists in the use of self-induction coils at regular intervals along a wire which counteract its capacity and maintain the distinctness of the electric wave. It is thus possible to telephone to San Francisco as distinctly as can now be done to Chicago, and in the use of lighter wires to Chicago alone hundreds of thousands of dollars are saved in the cost of copper. Underground wires for telephony can now be used, and ocean telephony is made possible.

The scientific societies, whose midwinter meetings are described above, have elected the following presidents for the ensuing year: American Society of Naturalists, Prof. W. T. Sedgwick, of the Massachusetts Institute of Technology; American Morphological Society, Prof. J. S. Kingsley, of Tufts College; American Society of Bacteriologists, Prof. W. H. Welch, of the Johns Hopkins University; Society of Plant Morphology and Physiology, Dr. Erwin F. Smith, U. S. Department of Agriculture; Folk-lore Society, Dr. Frank Russell, of Harvard University; American Psychological Association, Prof. Josiah Royce, of Harvard University; American Mathematical Society, Prof. E. H. Moore, of the University of Chicago; American Chemical Society, Prof. W. F. Clarke, of the U. S. Geological Survey; the Geological Society of America, the Hon. Charles D. Wolcott, Director of the U. S. Geological Survey. —Porf. E. E. Barnard, of the Yerkes Observatory, has been awarded the Janssen prize of the Paris Academy of Sciences for his discovery of the fifth satellite of Jupiter.—Dr. G. A. Miller, of Cornell University, has been awarded the mathematical prize of the Academy of Sciences, at Cracow.—Prof. H. C. Bumpus, of Brown University, has been appointed curator of invertebrate zoology and assistant to the president in the American Museum of Natural History, New York.—We record with regret the death of Lord William Armstrong, inventor of the gun that bears his name and of hydraulic machinery, and of Mr. William Pole, an eminent engineer and man of science, best known, perhaps, to the general public as the author of the 'Evolution of Whist.'—Mr. John D. Rockefeller has made a further gift of one and a half million dollars to the University of Chicago.—Among the public bequests made by the late Henry Villard are $50,000 each to Harvard and Columbia Universities.—The Huxley Memorial Committee announces that the sum of about $17,000 has been subscribed for the statue now in the Natural History Museum, London, and for the Huxley gold medal to be awarded by the Royal College of Science.—The collection of minerals and meteorites made by Mr. Clarence S. Bement, of Philadelphia, has been acquired by the American Museum of Natural History, New York.—The Duke of the Abruzzi proposes to start from Buenos Ayres in 1902 on a voyage to explore the South Polar Seas. A ship is to be built in Italy for the purpose.—Drs. Sambon and Low have returned to England, after the summer spent in the mosquito-proof hut in the Roman Campagna. They are in excellent health, though it is said that the past summer was exceptionally malarious. For example, fifteen or sixteen police agents were sent to Ostia, and though they only remained a night in the place, they all developed fever.—The daily papers report that the Finlay theory of the propagation of yellow fever by mosquitoes has been further confirmed by the commission now studying the subject in Cuba. Cable despatches state that a monkey which had been bitten by an infected mosquito developed on the fourth day well-marked symptoms; that of six non-immunes bitten by mosquitoes which had previously bitten yellow fever patients five developed yellow fever, while subjects who slept in infected clothing and bedding, but were guarded from mosquitoes, were untouched.—

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CHAPTERS ON THE STARS.

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STATISTICAL STUDIES OF PROPER MOTIONS.

The number of stars now found to have a proper motion is sufficiently great to apply a statistical method to their study. Several important steps in this study have been taken by Kapteyn, who, in several papers published during the past ten years, has shown how conclusions of a striking character may be drawn in this way.

We must begin our subject by showing the geometrical relations of the proper motion of a star, considered as an actuality in space, to the

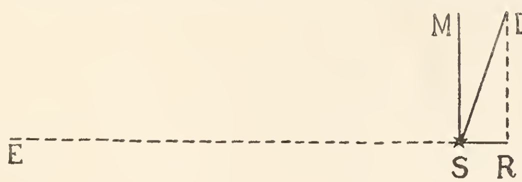

Fig. 1.

proper motion as we see it. The motion in question is supposed to take place in a straight line, with uniform velocity. Leaving out the rare cases of variations in the motion due to the attraction of a revolving body, there is nothing either in observation or theory to justify us in assuming any deviation from this law of uniformity. The direction of a motion has no relation to the direction from the earth to the star. That is to say, it may make any angle whatever with that direction.

Let E be the position of our solar system, and S that of a star moving in the direction of a straight line, S D. It must not be understood that the length of this line is taken to represent the actual motion; the latter would be infinitesimal as compared with its length; we use it only to show direction. We may, however, use the line to represent on a magnified scale the actual amount of the motion during any unit of time, say, one year. It may be divided into two components; one, S, in the direction of the line of sight from us to the star, which for brevity we shall call the radial line, and the other, S M, at right angles to that line.

It must be understood that, as the term 'proper motion' is commonly used, only the component S M, can be referred to, because the radial component, S R, does not admit of being determined by telescopic vision. As we know from the preceding chapters, it can in the case of the brighter stars be determined by spectroscopic measurement of the radial motion. At present we leave this component out of consideration.

The visible component, S M, can also be resolved into two perpendicular components, the one east and west on the celestial sphere, the other north and south. The former is the proper motion in right ascension (the measured motion in this coordinate being multiplied by the co-sine of the declination to reduce it to a great circle), and the other is the proper motion in declination. In star catalogues these two motions are given, so far as practicable. Thus, altogether the actual motion of a star in space may be resolved into three components: that of right ascension, that of declension, and the radial component.

An additional consideration is now to be added. The proper motion of a star, as observed and given in catalogues, is a motion relative to our system. It has been shown in a former chapter that the latter has a proper motion of its own. When account is taken of this, and the motions are all reduced as well as we can to a common center of gravity of the whole stellar system, we conceive the observed proper motion of the star to be made up of two parts, of which one is the actual motion of the star relative to the common center, and the other due to the motion of the sun, carrying the earth with it. The direction of the latter appears to us opposite that of the motion of the sun. The sun's motion being directed to the constellation Lyra, it follows that the component in question in the case of the stars is directed toward the opposite constellation, Argo. This component, as we know, is termed the parallactic motion, being dependent on the distance or parallax of the star.

As in the case of other proper motions, we may measure the parallactic motion either in angular measure, as so many seconds per century, or in linear measure, as so many kilometers per second. The relation of the two measures depends on the distance of a star. The simplest conception of the relation may be gained by reflecting that the parallactic motion of a star lying at right angles to the direction of the solar motion during the time that the sun, by its proper motion, is passing over a space equal to the radius of the earth's orbit, is equal to the parallax of the star. For this parallax is simply the angle subtended by that radius as seen from the star; and the same angle is the difference in direction of the star as seen from the two ends of the radius.

As yet, the actual amount of the sun's motion has not been well determined. Kapteyn's estimate is 16.7km. per second, which may be called 10 miles. But the results of additional determinations of radial motions make it likely that this result should be increased to perhaps 19 or 20km. per second, or 4 radii of the earth's orbit per year. Accepting this speed we shall have the following rule:

The parallax of a star lying in a direction nearly at right angles to that of the solar motion is equal to one-fourth of its parallactic motion in a year.

In the case of stars in other directions, the parallax would be greater in proportion to the cosecant of the angle between the direction of the star and the solar apex.

If the stars were at rest this rule would enable us immediately to determine the distance of any star by its proper motion, which would then be simply the parallactic motion itself. Unfortunately, in the case of any one star considered individually, there is no way of deciding how much of its motion is proper to itself and how much is the parallactic motion. But when we consider the great mass of stars, it is possible in a rough way to make a distinction between the two motions in a general average.

The direction or motion of any particular star having no reference to that of the sun is as likely to be in the direction of one of the three components we have described as of any other. Hence, in the average of a great number of stars we may conclude that these components are equal.

One of the simplest applications of this law will enable us to compute the mean parallax of the stars whose radial motions have been determined. As this application is, in the present connection, made only for the purpose of illustration, I shall confine myself to the 47 stars of which the radial motions have been measured by Vogel. The mean annual proper motions of these stars, taken without any regard to their signs, are:

	Including Arcturus.	Omitting Arcturus.
	"	"
In right ascension......	0.163	0.144
In declination..........	0.155	0.168

The difference of the mean motions in right ascension and declension is to be regarded as accidental. The velocity of Arcturus is so exceptionally great that we ought, perhaps, to leave it out in taking the mean.

Now, the mean of the radial motions as found by Vogel is 16 kilometers per second. By hypothesis the actual motion in the radial line is in the general average the same as in the other two directions. We have, therefore, to acquire what must be the parallax of a star in order that, moving with a velocity of 16 kilometers per second, its angular proper motion may have one of the above values. This result is by a simple computation found to be:

	″	″
From the mean motion in R. A.	0.049 or	0.043
From the mean motion in Dec.	0.064 or	0.035

The difference of these results shows the amount of uncertainty of the method. Our general conclusion, therefore, is that the mean parallax of the Vogel stars, which may be regarded as corresponding approximately to the mean parallax of all the stars of the second magnitude, is about 0″.04.

We have spoken of the two components of the apparent motion as those in right ascension and declination, respectively. But there is no particular significance in the direction of these coordinates, which have no relation to the heavens at large. For some purposes it will be better to take as the two directions in which the motions are to be resolved that of the parallactic motion and that of right angles to it. That is to say, taking the solar apex as a pole, we conceive a line drawn from it to the star, and resolve the apparent motion upon the celestial sphere into two components, the one in the direction of this line, the other at right angles to it. The former, which we may call the *apical motion,* is affected by the parallactic motion; the latter, which we call the *cross-motion,* is not, and therefore shows the true component of the motion of the star itself in the direction indicated.

Kapteyn has gone through the labor of resolving all the proper motions of the Bradley stars given by Auwers, in this way. His assumed position of the solar apex was:

Right ascension	276°=18h. 24m.
Declination*	+34°

The radically new treatment found in this paper embraces three points. The first consists in the distinction between the spectral types

*This work of Kapteyn is yet unpublished. The author is indebted to his courtesy for the manuscript copy, with permission to use it. Kapteyn's researches based on this material are contained in a paper on the 'Distribution of the Stars in Space,' communicated to the Amsterdam Academy of Science, January 28, 1893. An abstract in English is found in 'Knowledge' for June 1, 1893.

of the different stars and the separate study of the proper motions peculiar to each type. The next point is the reference of the motions to the solar apex. The third is the study of the relations of the stars to the galactic plane.

A remarkable relation existing between the spectral type of stars and their proper motions* was brought out by these investigations. The stars of Type I. have, in the general mean, smaller proper motions than those of Type II. The following table is made up from Kapteyn's work. First we give the limits of proper motion; then on the same line the number of stars of the respective Types I. and II. having proper motions within these limits:

Centennial Prop. motions. ″ ″	Number of Stars. Type I.	Type II.
0 to 5	786	474
6 to 9	203	194
10 to 19	159	223
20 to 29	25	86
30 to 49	13	71
50 and more	3	58
Total	1,189	1,106

It will be seen that in the case of stars having proper motions of less than 5″ per century a large majority are of Type I. In the case of proper motions between 6″ and 9″ the number is nearly equal. Between 10″ and 20″ there is a large majority of Type II. Between 30″ and 49″ the number of Type II. is nearly five times that of Type I. Finally, only three stars of Type I. have proper motions exceeding 50″, while 58 stars of Type II. have a proper motion exceeding this limit.

We may make two hypotheses on this subject: one, that the stars of Type II. really move more rapidly than those of Type I.; the other, that their actual motion is the same, but that the stars of Type I. are more distant stars. The last conclusion seems much more probable, and is strengthened by the much greater condensation of stars of Type I. toward the Milky Way.

Let us now consider the principles by which we may study a great collection of proper motions statistically. There are scattered around us in the stellar spaces, in every direction from us, a large number of stars, each moving onward in a straight line and in a direction which, with rare exceptions, has nothing in common with the motion of any other star. The velocities of the motion vary from one star to another in a way that can not be determined, some moving slowly and some rapidly. Is it possible from such a maze of motions to determine any-

*The author believes that Monck, of England, independently pointed out this relation, possibly in advance of Kapteyn.

thing? Certainly we can not learn all that we wish, yet we may learn something that will help us form some idea of the respective distances of the stars and the actual velocity of their motions. An obvious remark is that the more distant a star the slower it will seem to move. We must, therefore, distinguish between the linear or actual motion of a star, expressed as so many kilometers per second, and its apparent or angular motion of so many seconds per year, derived by measuring its change of direction as we see it with our instruments.

We shall now endeavor to explain Kapteyn's method in such a way that the reasoning shall be clear without repeating the algebraic operations which it involves. Let us conceive that Fig. 2 is drawn on the celestial sphere as we look up at the heavens. S is the direction of a star in the sky as we see it. Let us also suppose that the solar apex, situated in the constellation Lyra, lies anywhere horizontally to the left of the star, in the direction of the arrow-head marked *Apex*. Suppose also that, were the solar system at rest, we should see the star moving along the line S D. Let the length of the line S D represent the motion in some unit of time, say, one year. Next, suppose the star at rest. Then in consequence of the motion of the solar system, by which we are carried toward the apex, the star would seem to be moving with its parallactic motion in the direction S B, away from the apex. Let the length of this line represent the parallactic motion in one year. Then by the theory of composition of motions, the star moving by its real motion from S to D, and by the motion of the earth having an apparent motion from S to B, will appear to us to move along the diagonal S A of the parallelogram. Thus, the line S A will represent the annual proper motion of the star as we observe it with our instruments, and which can be resolved into the apical motion, in the direction S B, and is cross-motion in the direction Sτ.

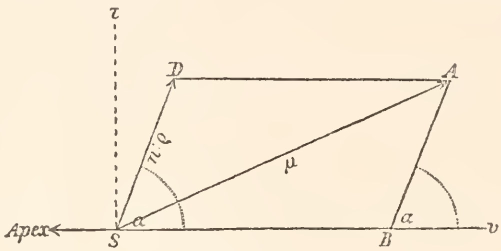

Fig. 2.

The apical motion consists of two parts, one the parallactic motion, equal to S B; the other real, and due to the motion of the star itself along the line S D, and equal to the distance of D from the line Sτ.

We have now to inquire how, in the case of a great number of stars, we may distinguish between the two parts.

We now make the general hypothesis that, in the average of a great number of stars, actual motions have no relation to the direction of our sun from the star. Then the components of the actual motion, S D, will in the general average have equal values, positive and negative canceling each other. Hence, if we take the mean of a great number of motions along the apical line it will give us the value of S B due to the motion of the earth, and, hence, the mean parallactic motion of all the stars considered.

The problem now becomes one of averages. We wish to form at least a rude estimate of the average speed of a star in miles or kilometers per second. To show how this may be done let us suppose that we observe the proper motions of a great number of stars at some distance from the solar apex, so that their parallactic motion shall be observable. Stumpe and Ristenpart, the German astronomers, as well as Kapteyn, have considered the relation between the two motions in the following way: We divide the stars observed into classes, taking, say, one class having small, but easily measured, proper motion; another having a proper motion near the average, and a third, of large proper motion. Sometimes a fourth class is added, consisting of stars having exceptionally large proper motions. From each of these classes we can determine, as already shown, the average motion from the direction of the solar apex; that is to say, the average parallactic motion. This will be inversely as the average distance of the stars.

Stumpe's three classes were: I., proper motions ranging from 16″ to 32″ per century; II., between 32″ and 64″ per century; III., between 64″ and 128″ per century; IV., greater than 128″. The average of the proper motions in each class, the average of the parallactic motions and the ratio of the two are these:

Class.	Prop. Mot.	Par. Mot.	Quotient.
	″	″	
I.	0.23	0.142	1.6
II.	0.43	0.286	1.5
III.	0.85	0.583	1.4
IV.	2.39	2.057	1.1

It will be seen that the ratio of the proper motion of the star to the parallactic motion diminishes as the former increases.

The same thing was found by Ristenpart from the proper motions of the Berlin zone, as shown below:

Class.	Prop. Mot.	Par. Mot.	Quotient.
	″	″	
Small	0.128	0.061	2.1
Medium	0.197	0.109	1.8
Large	0.374	0.279	1.3

The smaller value of the quotient from stars near to us than from the more distant stars was supposed to lead to the conclusion that the latter had a more rapid real motion than the former. A little thought will show that, while this is quite true of the stars included in the list, this does not prove it to be true for the stars in general. We can not, as already pointed out, determine the motion of any star unless it exceeds a certain limit. Hence, in the case of the more distant stars we can observe the proper motions only of those which move most rapidly, while in the case of the nearer ones we may have measured them all. We should, therefore, naturally expect that the more distant stars in our list will show too large a value of the proper motion, for the simple reason that those having small proper motion are not included in the average. There is, therefore, no evidence that the more distant stars move faster than the nearer ones.

An error in the opposite direction occurs through the method of selecting stars of given proper motion. We have already pointed out that in the case of any individual star we cannot determine how much of its apparent apical motion may be that of the star itself, and how much the parallactic motion arising from the motion of the earth. What we have done is to assume that in the case of a great number of stars the actual apical motions will be equal, and in the opposite directions, so as to cancel each other in the average of a great number, leaving this average as the parallactic motion. Now, to fix the ideas, suppose that two stars have an equal apical motion, say 3 radii of the earth's orbit in a year, but in opposite directions. The apical motion of the earth being 4 radii per year, it follows that the star which is moving in the same direction as the earth will have a relative apical motion of only 1, and will, therefore, not appear in our list as a star of large proper motion. On the other hand, the star moving with equal speed in the opposite direction will have a motion of 7 radii per year, and, will, therefore, be included among stars of considerable proper motion. Thus, a bias occurs, in consequence of which we include many stars having a motion away from the solar apex, while the corresponding ones, necessary to cancel that motion, will be left out of the count. Thus, the parallactic motion will, in the average, be too large in the case of the stars of large apparent proper motion. Now, this is exactly what we see in the above tables. As we take the classes with larger and larger proper motions, the supposed parallactic motion, which is really the mean of the apical motions, seems to increase in a yet larger degree. It is, therefore, impossible to determine from comparisons like these what the exact ratio is.

This error is avoided when we do not arrange and select the stars according to the magnitude of their proper motions, but take a large list of stars, determine their proper motions as best we can and draw our conclusions from the whole mass. This has been done by Kapteyn in the paper already quoted; and by a process too intricate to be detailed in the present work he has reached certain conclusions as to the ratio of the actual motion of the sun in space to the average motion of the stars. His definitive result is:

Average speed of a star in space
= Speed of solar motion × 1.86.

This I shall call the straight-ahead motion of the star, without regard to its direction. But the actual motion as we see it is the straight-ahead motion, projected on the celestial sphere. The two will be equal only in cases where there is no radial motion to or from the earth. In all other cases the motion which we observe will be less than the straight-ahead motion. By the process of averaging, Kapteyn finds:

Linear projected speed of a star
= Speed of solar motion × 1.46.

This projected motion, again, may be resolved into two components at right angles to each other. It follows that the average value of either component will be less than that of the projected motion. The components may be the motions in right ascension or declination, or the apical motion and the motion at right angles to it. In any case, the mean value of a component will be:

Speed of solar motion × 0.93.

I have used Kapteyn's numbers to obtain the same relation by a somewhat different and purely statistical method.

Imagine the proper motion of a star situated nearly at right angles to the direction of the solar motion. Although we cannot determine how much of its apical motion is actual and how much is parallactic, we can determine whether its motion, if toward the solar apex, exceeds that of the sun. In fact, all stars the apical component of whose motion is in the same direction and greater than that of the sun, whatever the distance of the star, appear to us as moving toward the apex, a direction to which we assign a negative algebraic sign. All stars moving more slowly than this, or in the opposite direction from the sun, will have apparent motions away from the apex, which we regard as algebraic positive. We can, therefore, by a simple count separate the stars moving in the same direction as the sun, and with greater speed, from all the others.

I have classified the stars in this way not only as a whole, but also with reference to their cross-motion—motion at right angles to that of the sun. That is to say, I have taken the stars whose cross-motion, τ, is 2″ per century or less and counted their apical motions as positive, negative and zero. Then, I have done the same thing with cross-motions of 3″ or 4″, then with cross-motions ranging from 5″ to 7″, and so on. All cross-motions above 13″ we put together.* The results of this work are shown, so far as described, in the first four columns of the table below. We have here for the various values of τ the number of positive, negative and zero apical motions.

Table showing the number of positive and negative apical motions for different values of the cross-motion.

Values of τ	Special Motions, σ					Percentage.	
	Pos.	Zero.	Neg.	P′.	N.	N.	P.
0, ± 1, 2	1,013	261	425	1,143	555	0.33	0.67
± 3, 4	360	56	160	388	188	0.33	0.67
± 5 to 7	285	37	107	303	125	0.29	0.71
± 8 to 12	215	7	52	218	55	0.20	0.80
± 13 +	216	2	61	217	62	0.22	0.78
Total	2,089	363	805	2,269	985	0.30	0.70

The first question that arises in connection with this table is how to count the motions that come out zero; that is to say, those which are too small to be certainly observed. The most probable distribution we can make of them is to suppose that they are equally divided between positive and negative motions. I have, therefore, added one-half of the zero motions to the positive and one-half to the negative column, thus getting the results given in columns P and N. The percentages of positive and negative motions thus resulting are given in the last column.

We see that there is a fairly regular progression in the percentage, depending on the value of the cross-motion. In the case of the small cross-motions, which presumably belong to the more distant stars, the percentage of negative motions is markedly greater than it is in the case of the nearer stars which have larger values of τ. The diminution in the number of zero motions is still more remarkable. This arises from the fact that in the case of the nearer stars the apical motions are necessarily larger, whether positive or negative.

In the preceding table all the stars were counted, without reference to their distance from the solar apex. The result of this will be that the mean of the apical motions is taken as we see it projected on the sphere, which does not correspond to the actual motion in space except when the direction of the star is at right angles to that of the apex. I have, therefore, made a second partial count, including only stars between 60° and 120° from the apex. These stars were selected in oppo-

*The author should say that the greater part of the work on these countings was done with great care and accuracy by Mrs. Arthur Brown Davis, to whom he is so much indebted for help of this kind through the present work.

site regions of the heavens, so as to eliminate any constant error depending on the right ascension. The result of a count of 733 stars is:

Number of positive motions	530
" " zero "	50
" " negative "	153

If we proceed as before, dividing the zero motions equally between the positive and negative ones, we shall find the respective numbers to be 555 and 178. The percentage of negative motions is, therefore, 24. This will still be slightly too large, owing to the obliquity under which many of the stars were seen. We may estimate the most likely percentage as 23.

We conclude, therefore, that when the motions of all the stars are so resolved that one component shall be that in the direction of the apex, 23 per cent. of the stars will be found moving toward the apex with a greater speed than that of the sun. It may, therefore, be assumed that in the general average an equal number are moving in the opposite direction with a greater speed than that of the sun. We conclude, therefore, that the resolved motion of 46 of the stars is greater than of the sun, leaving 54 per cent. less.

In the absence of an exact knowledge of the relation between the magnitude and the number of motions, we shall not be far wrong in assuming that one-half the stars move to or from the apex with more than the average speed, and one-half with less. Comparing this with the percentage found, we may conclude that the average motion of a star is less than that of the sun, in the ratio 46:50; or that it is found by multiplying the motion of the sun by the factor 0.92. This is almost exactly the number which we have quoted from Kapteyn.

We have already stated that the actual speed of the solar motion, still somewhat uncertain, may be estimated at 20 kilometers per second, or 4 radii of the earth's orbit in a year. For our present purposes the latter method of expressing the velocity is the more convenient. Multiplying this speed by the factors already found, we have the following results for the average proper motions of a star in space expressed in kilometers per second, and radii of the earth's orbit in a year:

Straight-ahead motion	37km. = 7.4r.
Projected motion	29km. = 5.8r.
Motion in one component	19km. = 3.7r.

The motion of 20km. or 4r. assigned to the sun is its straight-ahead motion. This is little more than half the average. It follows that our sun is a star of quite small proper motion.

THE DISTRIBUTION OF THE STARS IN SPACE.

We shall now bring the lines of thought which we have set forth in the preceding chapters to converge on our main and concluding problem, that of the distribution of the stars in space. While we cannot reach a conclusion that can claim numerical exactness, we may reach one that will give us a general idea of the subject. The first question at which we aim is that of the number of stars within some limit of distance. It is as if, looking around upon an extensive landscape in an inhabited country, we wished to estimate the average number of houses in a square mile. On the general average, what is the radius of the sphere occupied by a single star? If we divide the number of cubic miles in some immense region of the heavens by the number of stars within that region, what quotient should we get? Of course, cubic miles are not our unit of measure in such a case. It will be more convenient to take as our unit of volume a sphere of such radius that from its center, supposed to be at the sun, the annual parallax of a star on the surface would be 1″. The radius of this sphere would be 206,265 times that of the earth's orbit. We may use round numbers, consider it 200,000 of these radii, and designate it by the letter R.

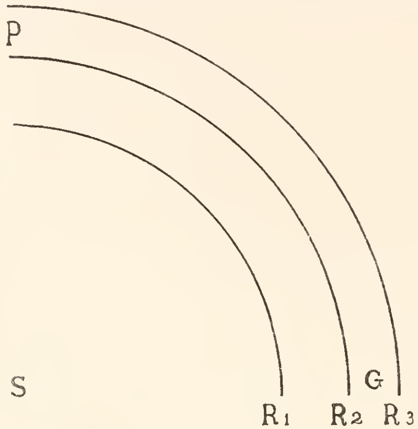

Fig. 3.

Now, let us conceive drawn around the sun as a center concentric spheres of which the radii are R, 2R, 3R, and so on. At the surfaces of these respective spheres the parallax of a star would be 1″, half a second, one-third of a second, and so on. The volumes of spheres being as the cubes of their radii, those of the successive spheres would be proportional to the numbers 1, 8, 27, 64, etc.

If the stars are uniformly scattered through space, the numbers having parallaxes between the corresponding limits will be in the same proportion.

The most obvious method of determining the number of stars within the celestial spaces around us is by measurement of their parallaxes. It is possible to reach a definite conclusion in this way only in the case of parallaxes sufficiently large to be measured with an approach to accuracy. In the case of a small parallax the uncertainty of the latter may be equal to its whole amount. In this case the star may be at any distance outside the sphere given by its measured parallax, or far within that sphere, so that no conclusion can be drawn. It is, on the whole, useless to consider parallaxes less than 0″.10; even those having this value are quite uncertain in most of the cases. The data at command for our purpose are the known individual parallaxes and the statistical summary given by Dr. Chase as the result of his survey, and quoted in our chapter on the parallaxes of the stars. This survey was confined to stars whose parallax was not already measured, and it brought out no parallax exceeding 0″.30.

The most careful search has failed to reveal any star with a parallax as great as 1″, and it is not likely that any such exists. It is, therefore, highly probable that the first sphere will not contain a single star except the sun in its center.

Within the third sphere, the parallax at the surface of which is 0″.33, we may place the following for stars with entire certainty:

	″
α Centauri	Par.=0.75
Ll. 21,185	0.46
61 Cygni	0.39
Sirius	0.37

There are two other cases in which the parallax is doubtful, though the measures as made bring the stars within the sphere 3R. They are:

	″
η Herculis	Par.—0.40
O. A. 18,609	0.35

In the case of η Herculis the proper motion is so small that the presumption is strongly against so large a parallax, and the doubtful parallax of the last star is so near the limit that it may be left out of the count. The doubt in its case may be set off against a doubt whether the parallax assigned to Ll. 221,185 is not too large. We assume, therefore, that four stars are contained within the sphere 3R, the volume of which is $3^3 = 27$. This would give, in whole numbers, one star to 7 unit spheres of space.

When we come to smaller parallaxes we find a great deficiency in the number measured in the Southern hemisphere. The policy of Gill, under whose direction or with whose support all the good measures in that hemisphere were made, was to make a few very thorough determinations rather than a general survey. Between the limits 0″.20 and 0″.33 are found:

In the Southern Hemisphere...............	4	meas.	(Gill)
" Northern "	2	"	(Chase)
" " "	12	"	(Others)
Total....................................	18		

Of the Northern results three are exactly on the limit, 0″.20, and several others are doubtful, and probably too large. The most likely number for the Northern hemisphere seems to be 12, and if we estimate an equal number for the Southern hemisphere we shall have 24 in all. Adding the four stars within the sphere 3R, we shall then have a total of 28 within the sphere 5R, of which the volume is 125. This gives between 4 and 5 space units to a star.

Let us now consider the space between the spheres 5R and 10R, including all stars whose parallax lies between the limits 0″.10 and 0″.20. Of these the numbers are:

Southern Hemisphere	6	(Gill)
Northern "	15	(Chase)
" "	15	(Others)

Reasoning as before, we may assume that the number of stars between the assigned limits is 60, making a total of 88 within the sphere 10R. The volume of space enclosed being 1,000 units, this will give one star to 12 units of space.

How far can we rely on this number as an approximation to the actual number of stars within the tenth sphere? The errors in the estimate are of two classes, those affecting the parallax itself and those arising from a failure to include all the stars within the sphere. The very best determinations are liable to errors of two or three hundredths of a second, the inferior ones to still larger errors. Thus, it may happen that there are stars with a real parallax larger than the limit of which the measures fall below it and are not included, and others smaller than the limit which, through the errors of measurement, are made to come within the sphere. As we have seen in the chapter on the parallaxes, it is quite possible that there may be a number of stars with a measurable parallax whose proximity we have never suspected on account of the smallness of the proper motion. We can only say that the nearer a star is to the system the more likely its proximity is to be detected, so that we are much surer of the completeness of our list of large parallaxes than of small ones. Hence, there may well be a number of undetermined parallaxes upon or just above the limit 0″.10.

The most likely conclusion we can draw from this examination seems to be that in the region around us there is one star to every 8 units of space; or that a sphere of radius, 2R, equal to 412,500 radii of the earth's orbit, corresponding to a parallax of 0″.50, contains one star. This is a distance over which light would pass in 8½ years.

We next see how far a similar result can be derived from statistics of the proper motions. It seems quite likely that nearly all proper motions exceeding 1″ annually have been detected. The number known is between 90 and 100, but it can not be more exactly stated because there is some doubt in the case of a number which seem to be just about on the limit. In this value, 1″, is included the effect of the parallactic motion, which, on the general average, increases the apparent proper motion of a star. To study this effect let us call the list of 90 or more stars actually found List A. Were it possible to observe the proper motions of the stars themselves separate from the parallactic motion, we should find that, when we enumerate all having a proper motion of more than 1″, we should add some to our List A and take away others. The stars we should add would be those moving in the same direction as the sun, whose motions appear to us to be smaller than they really are, while we should take away those moving in the opposite direction, whose motions appear to us larger than they really are. On the average, we should take away more than we added, thus diminishing slightly the number of stars whose motion exceeds 1″. Making every allowance, we may estimate that probably 80 stars have an actual proper motion on the celestial sphere of 1″ or more. We have found that the average linear proper motion of a star, as projected on the sphere, is about 6 radii of the earth's orbit annually. A star having this motion would have to be placed at the distance 6R to have, as seen by us, an angular motion of 1″. The parallax corresponding to the surface of this sphere is 0″.167. The volume of the sphere is 216, and according to our estimate from the parallaxes it would contain only 27 stars. It will be seen that these results give a greater density of the stars than the result from the measured parallaxes; that is to say, they indicate that there are still an important number of measurable parallaxes to be determined, while the number of stars is less than would be derived from their proper motions. But the fact is that the number of stars estimated as within a given sphere by the proper motions will be in excess, owing to the actual diversity of these proper motions, which may range from 0 to a value several times greater than the average. In consequence of this, our list of stars with a proper motion exceeding 1″ will contain a number lying outside the sphere 6R, but having a proper motion larger than the average. We are also to consider that within the sphere may actually lie stars having a proper motion less than the average, which will, therefore, be omitted from the list. Of the number of omitted and added stars the latter will be the greater, because the volumes of spheres increase as the cubes of their radii. For example, the space between the spheres 6R and 9R is more than double that within 6R, and our list will include many stars in this space. The discrepancy between the parallaxes and the proper motions probably arises in this way.

Let us see what the result is when we take stars of smaller proper motion. The most definite limit which we can set is 10″ per century. We have seen that Dr. Auwers, in his zone, found 23.9

stars per 100 square degrees having a proper motion of 10″ or more. This ratio would give about 10,000 for the whole heavens. The sphere corresponding to this limit of proper motion is 60R. On our hypothesis as to star density this sphere would contain 27,000 stars, nearly three times the number derived from Auwers's work. But it is not at all unlikely that even this sphere in question contains twice as many stars as have been detected. Great numbers of the more distant stars will not have been catalogued, owing to their faintness, because a star at the distance 60R will shine to us with only one per cent. the light of one at distance 6R. This corresponds to a diminution of five magnitudes; that is to say, a star of the sixth magnitude at distance 6R would only be of the eleventh magnitude at distance 60R, and would, therefore, not be catalogued at all. There is, therefore, no reason for changing our estimate of star density, which assigns to each star around us 8 units of volume in space.

This fact suggests another important one. Owing to the great diversity in the absolute magnitude of the stars, those we can observe with our telescopes will naturally be more crowded in the neighborhood of our system than they will at greater distances.

Some further results as to the mean parallax of the stars may be derived from a continuation of the statistical study of the proper motions. Kapteyn's investigation in this direction includes a determination of the mean parallactic motion of the stars of each magnitude for the first and second spectral types separately. From this he obtains the following mean parallaxes for stars of the different magnitudes:

Mean parallaxes of stars of different magnitudes, and of the two principal types, as found from their parallactic motions:

Mag.	Type I.	Type II.
	″	″
2.0	.0315	.0715
3.0	.0223	.0515
4.0	.0157	.0357
5.0	.0111	.0253
6.0	.0079	.0179
7.0	.0056	.0126
8.0	.0039	.0089
9.0	.0028	.0063
10.0	.0020	.0045
11.0	.0014	.0032

Using the value 4 for the solar motion, instead of 3.5, found by Kapteyn, all these parallaxes should be diminished by one-eighth of their amount.

Unfortunately, owing to the great diversity in the absolute brightness of the stars, and the resulting great difference in the distances of stars having the same magnitude, these numbers can give us only a vague idea of the actual parallaxes. Let us take, for example, the stars of the sixth magnitude. A few of these are, doubtless, quite near to us and have a parallax several times greater than that of the table. Excluding these from the mean, an important fraction of the remainder will have a parallax much smaller than that of the table.

We get a slightly more definite result by studying another feature of the proper motions. We may consider the Bradley stars, whose motions have been investigated, as typical, in the general average, of stars of the sixth magnitude. By a process of reasoning from the statistics, of which I need not go into the details at present, it is shown that the parallactic motion of a large number of these stars, probably one-eighth of the whole, is about 1″ per century or less. To this motion corresponds a parallax of 0″.0025, corresponding to the sphere of radius 400R.

The statistics of cross-motions lead to a similar conclusion. One-half the Bradley stars have a cross-motion of less than 2″.5 per century. To this motion would correspond a sphere of radius 200R and a parallax of 0″.005. Stars at this distance must be hundreds of times the absolute brightness of the sun to be seen as of the sixth magnitude. Yet the conclusion seems unavoidable that the sphere of lucid stars extends much beyond 400R.

Granting the star density we have supposed, a sphere of radius 400R would contain 8,000,000 stars. As we see many more than this number with the telescope, we have no reason to suppose the boundary of the stellar system, if boundary it has, to be anywhere near this limit.

All the facts we have collected lead to the belief that, out to a certain distance, the stars are scattered without any great and well-marked deviation from uniformity. But the phenomena of the Milky Way show that there is a distance at which this ceases to be true. Let S be the sun, R a portion of the surface of the outer sphere of uniform distribution, and R2 and R3 two contiguous spheres passing through the galactic region G, of which the pole is in the direction P. It is quite certain that the star-density is greater around G than around P. This may arise either from the density at G being greater, or from that at P being less, than the density within the sphere R. From the enormous number of stars collected in the galactic regions, we can scarcely doubt that the former alternative is the correct one. But there must be a sphere at which the second alternative is also correct, because we find the number of stars, even of the lucid ones, to continuously increase from P toward G.

Can we form any idea where this difference begins, or what is the nearest sphere which will contain an important number of galactic stars? A precise idea, no; a vague one, yes. We have seen that the galactic agglomerations contain quite a number of lucid stars, and that, perhaps, an eighth of these stars are outside the sphere 400R. We may, therefore, infer that the Milky Way stars lie not immensely outside this sphere. More than this, it does not seem possible to say at present.

So far as we can judge from the enumeration of the stars in all directions, and from the aspect of the Milky Way, our system is near the center of the stellar universe. That we are in the galactic plane itself seems to be shown in two ways: (1) the equality in the counts of stars on the two sides of this plane all the way to its poles, and (2) the fact that the central line of the galaxy is a great circle, which would not be the case if we viewed it from one side of its central plane.

Our situation in the center of the galactic circle, if circle it be, is less easily established, because of the irregularities of the Milky Way. The openings we have described in its structure, and the smaller density of the stars in the region of the constellation Aquila, may well lead us to suppose that we are perhaps markedly nearer to this region of its center than to the opposite region; but this needs to be established by further evidence. Not until the charts of the international photographic survey of the heavens are carefully studied does it seem possible to reach a more definite conclusion than this.

One reflection may occur to the thinking reader as he sees these reasons for deeming our position in the universe to be a central one. Ptolemy showed by evidence which, from his standpoint, looked as sound as that which we have cited, that the earth was fixed in the center of the universe. May we not be the victims of some fallacy as he was?

THE LAW OF SUBSTANCE.

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IN Haeckel's new and remarkable monistic book, 'The Riddle of the Universe at the Close of the Nineteenth Century,' which has just been translated by Joseph McCabe and published by the Harpers, the accepted laws of the persistence of matter and the persistence of energy are enunciated and their unity insisted upon; the union constituting what is denominated 'The Law of Substance.' Substance, 'Stoff,' in other words, being in fact what we are familiar with as matter, including all its physical attributes, as essential parts of it, as a person's character and his material parts are one and, failing either of those attributes, is no longer the same. It is only by these characteristics that we can recognize or define either the person or the molecule; without them, so far as we can see, there would be neither person nor matter.

The principle and the law of substance are unquestionably now incorporated into the scientific code permanently and positively; but the time of recognition and the dates of discovery of the two elements of that law are not, in the opinion of the writer, precisely as stated by Haeckel; the discoverers are not given credit by this author in correct proportion. He accords to Lavoisier the discovery of the persistence of matter and the proof of that principle, undoubtedly, as generally believed, correctly. He gives Robert Mayer (1842) credit for the discovery of the principle of the persistence of energy and assigns to Helmholtz (1847) its more general application.

It was, in fact, Benjamin Thompson (Count Rumford), the American philosopher, who, in 1796-97, experimentally proved the equivalence of the two forms of energy, thermal and dynamic. He read the paper describing his work in 1798, before the Royal Society of Great Britain; while Sir Humphry Davy confirmed it and added further proof immediately afterward.

It must be carefully noted that there are at least three quantities to be observed, studied and quantitatively measured: (1) substance or matter; (2) the forces which affect matter; (3) energy. Matter can perhaps be conceived of as destitute of any designated force and possibly even of any known attributes, such as the physical forces; forces can possibly be conceived apart from any specific matter; energy involves both matter and motion, and infers the action of forces in its production or variation. Nevertheless, our only method of acquiring a knowledge of matter is through the action of its attribute forces upon our senses; it is indeed possible that matter only exists through that quality which makes it the residence of the physical forces; it is extremely probable that all natural forces affect all matter and originate in matter.

There are just three corollaries to the general 'Law of Substance,' the Law of Persistence of all Existences; these are:

1. The Law of the Persistence of Matter *per se*.

2. The Law of Persistence of Force as an Attribute of Matter.

3. The Law of Persistence of Energy, whether as affecting a mass of matter or in process of transfer or of transformation; affecting varying quantities and kinds of matter; passing from one quantity of matter to another; changing, in inverse direction, the quantity of matter affected and the velocity-component of the energy; the product of mass and mean velocity-square remaining constant for the whole universe.

The distinction between force and energy was not, in earlier times, very exactly observed; but it is easy to perceive in the context to the enunciation of either corollary to the fundamental law the fact that writers usually well understood the principle which they sought to state. It had, by Faraday's time, come to be well understood by many scientific men that matter is persistent, that its characteristic forces cling to it persistently and that energy is the product of forces and motion, and is consequent upon inertia.

The writer took occasion, in a paper read before the American Society of Civil Engineers (December 9, 1873), criticizing Professor Tait's 'Sketch of Thermodynamics,' his assignment to Sir Humphry Davy of a prior place and his depreciation of the work of Mayer, to show that Rumford is entitled to a larger credit than is ordinarily assigned him even by those who admit his first appearance in this line of investigation at the close of the eighteenth century. It is easy to show that, not only was Rumford the first to exhibit by experimental research the fact of the equivalence of thermal and dynamic energy, but that he was the first to establish with some degree of approximation their quantivalence. In fact, he secured data giving a much closer determination of the 'mechanical equivalent of heat' than did Joule, or any other investigator of later years up to the middle of the century; at which date, while an approximate value had been hit upon, so great was the variety of constants published that the real value was still exceedingly uncertain. Professor Tait, however, was the first to call attention to the fact that Rumford actually gave data sufficient to afford a basis for computation of the equivalent, but he made the resultant figure 940 foot-pounds, assuming the horse-power at 33,000 foot-pounds per minute, and failing to note the fact that the engineer's 'horse-power' is considerably larger than the power of the average horse.

Taking the generally accepted and fair mean value for the power of the animal, and accepting Rumford's statement that the work was that which could be readily performed 'by a single horse,' the writer showed that the quantity of heat developed in Rumford's experiments, compared with the accepted datum, 25,920 foot-pounds per minute as the power of the horse, as given by Rankine, for the average case, or better, say 25,000 for the average Bavarian horse of the last century, we obtain as the 'mechanical equivalent,' 783.8 foot-pounds, differing from 778, the accepted figure of Rowland and later authorities, by but six units, less than 1 per cent. of its own value and vastly nearer than any figures obtained up to our own time.

Thus, as the writer claimed in 1873, we may state the achievement of that great philosopher and engineer in the following terms:

1. Rumford was the first to prove experimentally the immateriality of heat.

2. He was the first to indicate and directly to prove it to be a form of energy; publishing his proof a year before Davy.

3. Rumford first, a half-century before Joule, determined by experimental research the quantivalence of thermal and dynamic energies, and secured data giving the value of the factor of equivalence with almost perfect accuracy.

4. He is entitled to the sole credit of the experimental discovery of the true nature of heat, of its equivalence with mechanical energy and its measure of quantivalence.

The work of Sir Humphry Davy was of great importance; but it was in confirmation of the deductions previously announced to the Royal Society by his contemporary and colleague, Rumford.

"Benjamin Thompson, of Concord, New Hampshire, commonly known as Count Rumford, the Bavarian, should be accorded a higher position and a nobler distinction than has yet been given him by writers on thermodynamics."*

Rumford, above all others, ancient or modern, is entitled to the credit of not only laying down an experimental foundation for the 'Law of Substance' and the principle of persistence of energy, but also for actually making it a physical, rather than as previously a metaphysical, topic; for proving the falsity of the older views of the nature and origin of heat in thermodynamic systems, for proving by direct test and experimental investigation the immateriality of heat and its real character as a 'mode of motion,' as Tyndall called it, as a form of energy more properly. He furnished a method and means of estimating the 'mechanical equivalent of heat'; he originated by actual work of research a true statement of the principle of the quantivalence of the two forms of

* Transactions of the American Society of Civil Engineers, 1873. 'Note relating to Rumford's Determination of the Mechanical Equivalent of Heat.'—Thurston.

energy and, inferentially, of the quantivalent relations of all energies. He originated the now usual method of determining the quantivalence of heat and thermal and dynamical forms of energy by the storage of the heat of friction in a mass of water, and, by the churning of liquids, of similarly storing the heat of fluid-friction. He adopted the view that the energy developed in the animal system is the measure of a certain proportion of the stored energy of the food thus utilized. Thus he extended the principle of persistence to the organic world and to living creatures, opening the way to the final generalizations and conclusions of the enunciator of the so-called 'Law of Substance.'

Thus Rumford was the first to prove by experimental investigation the transformability of the energies, to exhibit the principle in its most important example and to derive, by physical research, the principle of the thermodynamic equivalence of energies and the fact of heat being simply a form of energy and a mode of motion of substance.

Mayer seems to have been the first to recognize a now well-understood fact: that, if we are to gain a more effective development of the energies, potential in our fuels, which are practically our only sources of commercially useful energy, we must find a way to transform the potential energy of chemical union directly into some other form than the thermal and by some other than the thermodynamic process. He says* that 'the evident wastes of the thermodynamic process as illustrated in our best steam engines justify us in seeking other methods of energy-transformation,' more particularly by the transformation into motion of electricity obtained by chemical means.

Mayer was probably the first to write under the definite title 'The Mechanical Equivalent of Heat.'† He was the first to declare, in so many words: 'the *vis viva* of the universe is a constant quantity.'‡ He stated that 'the heat produced mechanically by the organism must bear an invariable quantitative relation to the work expended in producing it.'

This he deduced from his 'physiological theory of combustion.' He anticipates the idea of the permanence of the universe in its present general aspect by the suggestion that this redistribution of energy, 'degraded' by other phenomena, may be effected 'by the falling together of previously invisible double stars' or equivalent phenomena.§ He finds by computation that the energy transformed through such collisions 'would considerably exceed that which an equal weight of matter could furnish by the most intense process of chemical action'—in other words: it would resolve the solid mass into its elementary atoms; which is pre-

*'Forces of Inorganic Nature; 'Liebig's Journal,' 1842.

† 'The Mechanical Equivalent of Heat,' 1851.

‡ 'Celestial Dynamics,' 1848.

§ 'The Mechanical Equivalent of Heat,' 1851.

cisely the idea now held by Haeckel and other contemporary men of science.

Mayer accepted the principle and, basing his computations on the then accepted values of the specific heat of air, determined an equally approximate mechanical equivalent. Joule followed, in 1845-49, and later, determining this equivalent by admirable direct experiment. English writers have sometimes insisted upon assigning all credit to the latter for this determination; but Tyndall is less insular in his attitude and frankly and cordially gives Mayer the credit to which he is undoubtedly entitled. Both are certainly to be credited with important original work, and the method of Mayer gives a more accurate and certain measure of the constant sought than did any of the earlier experiments of the English physicist, the more exact measures of specific heats as now known being employed. Had Mayer known of Regnault's work, or had that work been completed before Mayer attempted his computations, the latter would have obtained more accurate figures than Joule secured years afterward. It was only when Prof. Henry A. Rowland took up the task and performed his marvelously fine work that an acceptable valuation was secured.

Meantime, Helmholtz had accepted and applied the law of equivalence of the energies broadly, as holding in all physical phenomena; but he was distinctly anticipated by Grove, the English physicist, who in January, 1842, in a lecture before the London Institution, asserted that 'Heat, light, electricity, magnetism, motion and chemical affinity are all convertible material affections' and that 'all these affections are resolvable into one, namely motion.'* This thesis he enforced then and thenceforward continuously. In 1862, he summarized his work in a published study of 'The Correlation of the Physical Forces,' later reprinted by Youmans in his famous collection of similar papers of 1864. His paper concludes with an excellent bibliography, in which he shows the origin of the now unquestioned view of authority in the minds of the old Greeks, and its gradual establishment by observation, experience and, finally, by experiment in the nineteenth century.

Helmholtz's lecture 'On the Interaction of the Natural Forces' was delivered at Königsburg, in 1854; he at the time holding the professorship of physiology at that university. In this lecture he states his first ideas to have been published in a pamphlet, in 1847, 'On the Conserva-

* Perhaps the best presentation of the work of the earlier men of science, recognizing these great and fundamental truths, is that of Prof. Edward L. Youmans, the founder of the Popular Science Monthly and one of the most broad-minded and far-seeing men of his time, who, in his 'Correlation and Conservation of Forces,' published by the Appletons in 1865, brought together the records of the great pioneers in this evolution of the scientific basis of all natural science, including the papers of Grove, Helmholtz, Mayer, Faraday, Liebig and Carpenter.

tion of Force,'* in which he 'endeavored to ascertain all the relations between the different natural processes.' In his lecture of 1854, he credits earlier writers on the subject, in the following order: Carnot (1824), Mayer (1842), Colding (1843), Joule (1843), and states that he was awakened to this work by the last-named.

To the Carnot law, Helmholtz gives the following expression: 'Heat only when passing from a warmer to a colder body, and then only partially, can be converted into mechanical work.'

This is obviously no other than the essence of the principle as not only asserted, but actually proved, a quarter of a century before Carnot by Benjamin Thompson and Humphry Davy, by direct experiment, so far as it is an assertion of the convertibility of the two energies. Helmholtz acknowledges the indebtedness of the scientific world to Mayer, whose paper 'On the Forces of Inorganic Nature' had been printed in 1842, that 'On Organic Motion and Nutrition' in 1845, and that 'On Celestial Dynamics' in 1848; while his paper 'On the Mechanical Equivalent of Heat' was not published until 1851.†

Helmholtz concludes: 'Thus the thread which was spun in darkness by those who sought a perpetual motion has conducted us to a universal law of nature which radiates light into the distant nights of the beginning and to the end of the history of the universe.'

Dr. W. B. Carpenter, in a lecture before the Royal Society, published later in their Transactions for 1851, summarized the work in this field, to his date, under the title 'The Correlation of the Vital and Physical Forces,' and showed, probably for the first time in this field, the unity of the principle of equivalence of energies in organic and vital, as well as in inorganic and lifeless nature. He attributes to Dr. Mayer, of Heilbronn, the first annunciation of the great principle of 'Conservation of Force,' in its then broadest form, in his paper of 1845, already mentioned; while Carpenter considers his own paper of 1850 'On the Mutual Relations of the Vital Physical Forces, as the first announcement of the extension of the law beyond the latter class of phenomena into the range of vital energies. It is in his lecture on this subject that Carpenter states the fact, since recognized perhaps most explicitly, among contemporary writers, by Haeckel, that 'what the *germ* supplies is not the force but the *directive agency.*' 'The actual constructive force is supplied by heat.' Even 'the life of man, of any of the higher animals, consists in the manifestation of forces of various kinds, of which the organism is the instrument,' and, further: " during the whole life of the animal, the organism is restoring to the world around it both the *materials* and the *forces* which it draws from it.'

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* It will be noted that it was very usual among these earlier writers to employ 'force' synonymously with 'energy,' as we now define the latter.

†All these papers may be found in Youman's collection, already alluded to.

"But there is this marked contrast between the two kingdoms of organic nature in their material and dynamic relations to the inorganic world: that while the vegetable is constantly engaged in raising its component materials from a lower plane to the higher, the animal, whilst raising one portion of these to a still higher level by the descent of another portion to a lower, ultimately lets down the whole of what the plant had raised; in so doing, however, giving back to the universe, in the form of heat and motion, the equivalent of the light and heat which the plant had taken from it."

Thus, as Tyndall later wrote: "As experimental contributors, Rumford, Davy, Faraday and Joule stand prominently forward; as theoretic writers (placing them alphabetically) we have Clausius, Helmholtz, Kirchoff, Mayer, Rankine, Thomson," and he distinguishes sharply between the two classes, as the world of science always must, without denying to either credit for that practical genius which makes the work of the one party useful or for that genius of foresight and insight which often leads the other far in advance of the investigator, giving quantitative values to relations thus earlier recognized.

Thus, also, the ideas now taking expression as scientific statements of nature's laws originated in a distant age, grew into form with experience and observation and restricted experimental research, until, with the opening of the XIXth century, and with the enormous development of scientific method and of experimental systems, and with the production in marvelous exactness and perfection of every form of instrument of research, quantities came to be exactly measured and the law of persistence of energy could be stated positively and quantitatively.

When the idea of equivalence of thermal and dynamic energies and of the formation of a thermodynamic science had come to be familiar to the leaders of scientific thought, the extension of the idea to embrace all the physical forces and energies was a simple and inevitable matter. The comprehension of all physical energies within the stated law naturally and promptly, and just as inevitably, led to the suggestion of the extension of the law to the so-called vital energies and forces and to its enunciation in that general form which permitted its application by Carpenter to the vital forces and its introduction by the biologists into their department of life and work. It was in the extension of such apparently obvious deductions to the seeming limit, and without a thought of the fact having originality at the time, that the writer, in the Vice-President's address before the American Association for the Advancement of Science, at St. Louis, in 1878, made that extension in an enunciation of the principle now called by Haeckel the 'Law of Substance.'* The de-

* At that time there were two Vice-Presidents in the organization of that Association, both of whom were expected, annually, to present addresses before the whole Association at special meetings held for that purpose.

duction from all previous experience, and the inference from all experimental work to that date, seemed entirely obvious. But, so far as the writer is aware, this expression of the 'Law of Substance,' thus enunciated in August, 1878, is unanticipated. It was then stated as follows:*

"The facts revealed by the researches of Rumford, Davy and Joule have been grouped and systematically united by Rankine, Thomson, Clausius and other scarcely less eminent men and the science of thermodynamics, which has been thus created, has been applied and put to the proof by Hirn and other distinguished engineers of our own time. Finally, it has now become evident that this last is but another branch of the universal science of energetics, which governs all effective forces in all departments of science. The man is still to be found who is to combine all the facts of this latest and most comprehensive of all sciences into one consistent and symmetrical whole and to illustrate its applications in all methods of exhibition of kinetic energy.

* * * *

"The grand principle which we are just beginning to indistinctly perceive, and to recognize as underlying every branch of knowledge and as forming the foundation of all positive science, seems, when stated, to be simply an axiom. The Scriptural declaration that the world shall endure until its Maker shall decree its destruction by Omnipotence is but a statement of a principle which is more and more generally admitted as a scientific truth, viz.:

"The two products of creation, matter and force, and the fruit of their union, energy, are indestructible.

"The grand underlying basis of all science is found in the principle:

"All that has been created by infinite power—matter and its attribute, force, and all energy—is indestructible by finite power and shall continue to exist, so long as the hand of the Creator is withheld from its destruction."

"This 'Law of Substance,' as Haeckel proposes to call it, the writer then stated, has "been admitted almost from the time of Lavoisier, so far as it affects matter; it has been admitted as applicable to physical energies since the doctrine of the correlation of forces and of the persistence of energy became accepted by men of science and we are gradually progressing toward the establishment of a *Law of Persistence of all Existence*, whether of matter, of force and energy, or of organic vitality, and perhaps even to its extension until it includes intellectual and soul-life."

*Proc. A. A. A. S., Twenty-seventh Meeting, at St. Louis, Mo., 1878; Sec. A, Mathematics, Physics and Chemistry; Address of the Vice-President, p. 43. *Vide* also Thurston's 'Manual of the Steam Engine,' Vol. I., 1st Ed., 1891, Chap. III., p. 241.

"The truths of science are thus coming into evident accord with those doctrines of religious belief which are common to all creeds. We are, however, as far as ever from the determination of the question whether those higher forms of force and energy have quantivalent relations and intertransformability; although a belief that mind and matter have a certain identity, and that in matter can be discerned 'the promise and potency of all terrestrial life,' has been avowed, explicitly or implicitly, by more than one great thinker when wandering into the realms of speculation."

In this, Tyndall long anticipated our contemporary writers.* Lavoisier showed to the satisfaction of the scientific men of his time that matter is indestructible, whatever the apparent result of chemical action. Faraday, and probably many among his predecessors, recognized that the forces are indestructible, and that great investigator wrote:

"To admit that force may be destructible, or can altogether disappear, would be to admit that matter could be uncreated; for we know matter only by its forces."†

Liebig fully recognized the distinction between the proper use, of the term, force and energy, and usually called the latter 'power,' as when he says:

"Man by food not only maintains the perfect structure of the body, but he daily inlays a store of power and heat, derived in the first instance from the sun. This power and heat, latent for a time, reappears and again becomes active when the living structures are resolved by the vital processes into their original elements."‡

Carpenter clearly saw these distinctions and recognized the nature of energy, as distinguished from force, when, in his discussion of the action of the vital forces, he asserted:

"What the germ really supplies is not the force but the directive agency; thus rather resembling the control exercised by the superintendent builder, who is charged with working out the designs of the architect, than the bodily force of the workmen who labor under his guidance in the construction of the fabric."§

Carpenter says explicitly:

"Hence we seem justified in affirming that the correlation between heat and the organizing forces of plants is not less intimate than that

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* See his 'Heat Considered as a Mode of Motion,' N. Y., D. Appleton & Co., 1864, for an admirable statement of this point and for his splendid championage of Mayer.

† 'The Conservation of Force.'

‡ 'The Connection and Equivalence of Force.'

§ 'The Correlation of Vital and Physical Forces.'

which exists between heat and motion." He includes both animal and vegetable vitality in his generalization.

"The life of man, or of any of the higher animals, essentially consists in the manifestation of forces of various kinds, of which the organism is the instrument."

All organic life involves the direction of nature's forces and their utilization by direction of the energies; but this striking and important distinction is observed, as Carpenter first definitely asserted: The animal employs energy derived by the disintegration of vegetable growth to its will-directed, and to its internal automatic, work; while the vegetable directs the energy of the sun's rays and of chemical action to the building up of new organic matter into its life-forms. A cycle thus transfers and transforms energy radiated to the earth from the sun, building up the vegetable, sacrificing the structure in the building of the animal organism, breaking down the animal structure again, and setting free the circling energy to continue its progress along other paths into other organic matter, or elsewhere, as directing agencies may compel.

Thus, in all nature and in all manifestations of natural law and of motion, general experience has satisfied us that matter is persistent, that it is endowed with inalienable properties which include the so-called physical forces, similarly persistent in their character and methods of action and their intensities, and that energy, a property of matter in motion, is also persistent, but not also permanently affecting any given mass; its total quantity is invariable, but it may be distributed indefinitely, transferred in any manner and transformed to any extent, irrespective of other than quantitative measures of matter affected. Matter not only permanently retains its characteristic forces, but, reciprocally, the forces permanently require and maintain matter as their residence. No exception to this constancy of union of matter and forces is yet known, and the only question now remaining to be fully answered is: How far may such relations be traced into the more intangible realms of nature and life and consciousness.

Herbert Spencer has stated the fundamental idea of science in this field most concisely, accurately and clearly. He says in 'First Principles': "We cannot go on merging derivative truths in these wider truths from which they are derived without reaching at last a wider truth which can be merged in no other or derived from no other. And whoever contemplates the relation in which it stands to the truths of science in general will see that this truth, transcending demonstration, is the *Persistence of Force*." Indeed, Faraday had already, years before, asserted this law to be the highest that our faculties can appreciate in physical science. In fact, as we may perhaps still more strongly put it: The Law of the Persistence of Substance, including its every attribute, must necessarily underlie every permanent existence and the universe itself.

The number of world-riddles, as Haeckel says, is diminishing rapidly, and our scientific knowledge has come to be so far-reaching that if we cannot resolve every minor problem of the universe, we have at least gone far toward the solution of the mightiest among the larger questions. One 'comprehensive question,' as he calls it, remains: What is the foundation of the 'Law of Substance,' the law of the persistence of matter and its attribute, force?

"What is the real character of this mighty world-wonder that the realistic scientist calls Nature or the Universe, that the idealist philosopher calls Substance or the Cosmos, what the pious believer calls God?"

"We must admit that we know as little of its essence, as did the ancients or the philosophers of the later centuries, up to our own. The mystery deepens as we probe it; there remains beneath all and behind all an apparently 'unknowable,' to-day, as in all earlier times." Haeckel throws no new light upon this eternal sphinx-life. He claims that the eternity of matter, with its inalienable eternity of unchanging attributes, its eternally persistent motion and energy, means eternal life of the universe, with never-ending renewal of such movements as we are now conscious of and in this probably all men of science are ready to agree with him. But he goes on to assert that the necessary conclusion is the destruction of 'the three central dogmas of the dualistic philosophy—the personality of God, the immortality of the soul and the freedom of the will.' He finds few philosophers willing to go with him to the end of his logic and thinks that 'consecutive thought is a rare phenomenon in nature.' The majority of philosophers are desirous of clinging to the old beliefs on the one hand, while taking hold of the monism of the newer time on the other, seeking to ride both the differently moving steeds and usually ending by dropping from the younger at the limit of their powers of holding on.

This has undoubtedly been true in the past and will probably remain true in the future and as long as man retains his apparently eternal and immortal convictions relating to a higher power; but, admitting Haeckel's accusation and going with him to the ultimate of his deduced facts and law, it seems extremely probable that, arrived at its end, they will all be found much in the position of Haeckel himself, confronting the deduction of Clausius and Lord Kelvin, and will still ask the unanswerable question:

What lies beyond? Who or What inaugurated this eternity? What or Who originated matter? What or Who marked the limits of the universe? If limitless: Who and What filled it with matter and motion and life?

There will still within the soul of every thinking human being remain the conviction, apparently implanted at the origin of things, of some real 'First Cause,' of some necessary beginning of our time, space and life, and a conviction that what we call eternity affords time and the universe space for all the evolution of higher life that imperfect human nature aspires to. It will be admitted that, as Goethe says:

> 'By eternal laws of Iron Rules,
> Must all fulfil the cycle of their destiny.'

All can see that

> 'The times are changed, old systems fall,
> And new life o'er their ruins dawns;'

yet, as in all past times, new interpretations and adjustments of the beliefs and the creeds of the fathers will be found to reconcile fundamental principles in religion and in morals with the older inspirations and the newer readings of the Book of Nature, and we may unquestionably hope that, in the future as in the past, the newer readings will tend toward evolution of higher thought, nobler life, more perfectly ideal and spiritual philosophy. We may all go with Haeckel and the greatest interpreters of the laws of Nature, and yet may find it possible to look beyond the limits of things seen into 'The Unseen Universe' with no loss of the spiritual.

Haeckel is one of the few, even among scientific men, who accept the necessary, or apparently necessary, conclusions coming of his logic to the very extremity and, in this case, he finds them carrying him to the deduction that there can be no immortal life of the individual soul. Whether this conclusion must follow or not, he is more far-reaching in his deductions relating to physical phenomena, as consequences of the 'Law of Substance,' than any among his predecessors; for he accepts the conclusion that there cannot be a dead eternity and that there must be some return from that swing of the pendulum which, with Sir William Thomson (now Lord Kelvin), left a cold and still universe to eternal death. This he finds absurd and admits the probability that the backward swing will come, during the eternities, through the occasional collision of suns, suns and planets, planet with planet, of binary systems and meteoric masses and star-dust, such as have been actually, not infrequently, seen during our own historic period, by the astronomer at his telescope, and by his ancestor, the astrologer, and even occasionally by the unobservant people of all times. Such a collision is sufficient in its development of thermal energy to reduce the colliding bodies into vapor and to disperse it throughout space in nebula and meteoric matter, and to renew the cycle.

As Haeckel says: The law of the persistence of force proves, also, that the idea of a 'perpetuum mobile' is just as applicable to, and as significant for, the cosmos as a whole, as it is impossible for the isolated action of any part of it. Hence the theory of '*entropy*' is likewise untenable. It is not the fact that the 'end of the world' is to come as supposed in the theories of entropy and with the degradation of energy to a uniform and unchanging lifelessness. Sooner or later—and time is nothing, 'a thousand years are but as a day'—sooner or later, the collection of masses will return mass-energy to the form of molecular and atomic energy, now here, now there, throughout the universe, and the round of eternities will be unceasing. "The eternal drama begins afresh—the rotating mass, the condensation of its parts, the formation of new meteorites, their combination into larger bodies, and so on."*

* 'The Riddle of Existence'; pp. 239-248.

THE HEIGHT AND WEIGHT OF THE CUBAN TEACHERS,

WITH COMMENTS ON THEIR PHYSICAL STATUS COMPARED WITH THE AMERICANS.

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WHEN the Cuban teachers were in Cambridge last summer, it was commonly observed that they seemed to be smaller in size and stature than our own American teachers and students. This impression was undoubtedly favored by the peculiar manner in which some of the Cubans wore their clothing. Many of the men had their coats cut in at the waist, and wore them tightly buttoned about the waist and chest, while the trousers were large and full, especially at the knee. This gave the bodies of the men a lean and slender appearance. Most of the women went without their hats when going to and from the recitation halls, and, although many wore high-heeled shoes, the diminutive stature was very apparent.

In order to determine the facts as to the physical status of the Cuban teachers, about a thousand (973) of them were measured and weighed at the Hemenway Gymnasium at Harvard University during the first week in August, 1900. As this work was undertaken in connection with the regular work of the Harvard Summer School of Physical Training, the time that could be given to the measurements was necessarily limited, and the height and weight were the only physical observations taken and recorded. In order to facilitate the work, each teacher was given a card to fill out, upon which were blank spaces for his number, date of measurement, name, date of birth, and his own and his parents' nationality. The cards distributed to the women were pink in color; those given to the men were green. These cards were brought to the gymnasium by the persons who desired to be measured, and the height and weight, taken in inches and pounds, were entered upon the cards, which were then left to be tabulated. Contrary to the usual custom with American students, the height and weight of the Cubans were taken with the clothing and shoes on. Three-quarters of an inch were allowed for the height of the heel of the shoe, and six per cent. of the total weight of each woman and seven per cent. of the total weight of each man was allowed for the weight of the clothing. The subtraction of the height of the heel of the shoe and the weight of the clothing from the original height and weight as taken, make these factors in the measurement of the Cubans comparable with the students and teachers of several of the colleges for men and women in the United States. This comparison seems to me altogether desirable, not only that we may learn something of the physical characteristics of the Cubans, in order to help them in their efforts to attain a national independence, but in order that we may learn something of our own strength and weakness, and be able to govern ourselves accordingly.

The ages of the American students measured, which we present for comparison, ranged from 16 to 30, while the ages of the Cuban teachers ranged from 16 to 60. As the growth in stature is usually completed about the twenty-second year, the number beyond this age who were measured would have little influence in raising the average height. The weight, however, may increase up to the fiftieth or sixtieth year, and if any considerable number of persons beyond the age of 30 or 40 are included in this observation, the average weight would be considerably increased. In the factor of weight, therefore, the Americans and Cubans were hardly comparable, because there were so many of the Cubans who were older than the Americans, and consequently might be expected to weigh more. The effect of this increased weight due to age shows itself in a peculiar way, as will be observed by reference to Chart 2.

After the cards were collected from the Cubans they were tabulated according to the percentile grade method advocated by Francis Galton. By this method the medium weight and height which 50 per cent. surpassed and 50 per cent. failed to reach, were determined, also the values which smaller and larger per cents. exceeded or fell short of.

In referring to Table No. 1 it will be observed that there were 973 Cuban teachers measured. Four hundred and seventy-nine of these were men and 494 women. The youngest man was 16 years of age, and the oldest 64, while the youngest woman was 13, and the oldest 59. The medium age, *i. e.*, the age which 50 per cent. surpassed and 50 per cent. fell short of, was 27 years for the men and 24 years for the women. Ten per cent. of the men were more than 44 years of age, and 10 per cent. of the women were 38 years and over. The table of American college students with whom the Cuban teachers were compared was made up from the measurements of about 3,000 men and 2,000 women, taken more than fifteen years ago. It is only fair to state that the average height and weight in several of these institutions for both sexes has increased somewhat since then. Of this number comprising the American table, the youngest man was 16, and the oldest 45, while the youngest woman was 15, and the oldest 40. The medium age of the male student was 20 years, and the medium age of the female student was 18.8 years. Ninety-five per cent. of the American male students were under 26 years of age, which was the age surpassed by

TABLE I.

No.	Above.	95	90	80	70	60	50	40	30	20	10	5	Above.	
	Below.	5	10	20	30	40	50	60	70	80	90	95	Below.	
	Minimum												Maximum	
Nationality.						*Age.*								*Number*
Cuban Men	16	18	19	21	23	24	27	30	34	39	44	49	64	479
Cuban Women	13	17	18	19	20	22	24	26	28	33	38	46	59	494
American Men	16	17	18	18	19	19	20	20	21	22	24	46	45	3000+
American Women	15	16	16.5	17	18	18.2	18.8	19	20	21	23	25	40	2000+
						Height.								
American Men	54.7	63.9	64.6	65.7	66.5	67	67.7	68.2	69	69.8	70.9	71.7	75.6	3000+
Cuban Men	55.9	60.2	61	62.2	63.1	63.8	64.3	65.1	65.7	66.5	67.7	68.5	75.6	479
American Women	53.2	59.1	59.8	60.6	61.4	61.8	62.6	63.1	63.8	64.6	65.5	66.2	71.3	2000+
Cuban Women	54.7	57.2	57.9	59.1	59.5	59.9	60.3	61	61.5	62.2	63.4	64.2	68.9	494
						Weight.								
American Men	72.8	110.3	114.7	121.4	125.8	130.2	134.5	138.9	143.3	147.8	156.6	165.3	229.3	3000+
Cuban Men	85	94	99	104	108	112	114	119	123	129	138	150	202	479
American Women	77.2	92.6	97	102	108	111	114.6	119	122	129	137	145	218	2000+
Cuban Women	74	80	85	91	95	99	102	106	110	117	128	138	220	494

over 50 per cent. of the Cuban male teachers. Although the Cuban female teachers were younger than the Cuban male teachers, 60 per cent. of the former had attained an age which was only surpassed by 5 per cent. of the American female students. Almost all the extra attainments in stature and in weight that may be attributable to age are, therefore, in possession of the Cubans.

In comparing the distribution of height and weight among the two nationalities (see Table No. 1 and Charts Nos. 1 and 2), some interesting and suggestive facts are brought to our attention. Among the American male students measured, the shortest was 54.7 inches and the tallest was 75.6 inches. Among the Cuban male teachers the shortest was 55.9 inches and the tallest was 75.6. Although there is but little difference in the extremes represented by the two nationalities, the difference in the stature attained by the greatest number in the two groups is very striking. The medium height of the American male student is 67.7 inches, while only 10 per cent. of the Cuban male teachers attain this stature. The medium height of the Cuban male teachers was found to be 64.3 inches, but this height is surpassed by over 90 per cent. of the American male students.

Upon referring to the figures giving the height of the women, it will be observed that the American female students have a greater range of extremes, as would naturally follow from their larger numbers, the tallest American being 71.3 inches and the shortest 53.2, while the tallest Cuban female teacher was 68.9 inches and the shortest 54.7 inches. The medium height of the American female student is 62.6 inches, and the medium height of the Cuban female teacher is 60.3 inches. Over 80 per cent. of the American female students surpass the stature attained by 50 per cent. of the Cuban female teachers, or only 20 per cent. of the latter attain a stature of 62.2 inches, which is surpassed by 50 per cent. of the former.

The distribution of weights (see Table No. 1) in the two groups is equally striking and suggestive. The heaviest American male student in the group weighed 229.3 pounds, and the lightest weighed 72.8 pounds. The heaviest Cuban male teacher weighed 202 pounds, and the lightest 85 pounds. The medium weight of the American male student was 134.5 pounds, and the medium weight of the Cuban male teacher was 114 pounds. More than 90 per cent. of the American male students surpass in weight the 114 pounds attained by only 50 per cent. of the Cuban males, and only 5 per cent. of the latter exceeded 150 pounds.

The heaviest American female student in the group weighed 218 pounds, and the lightest 77.2 pounds. The heaviest Cuban female teacher weighed 220 pounds and the lightest 74 pounds, which surpasses the American females in the two extremes. The medium weight of the American female student was 114.6 pounds, and the medium weight of the Cuban female teacher was 102 pounds. Eighty per cent. of the American female students surpass the medium weight of the Cuban female teachers, but on the other hand, 10 per cent. of the Cuban women surpass 128 pounds in weight, which is exceeded by only 20 per cent. of the American women students.

Many other interesting comparisons may readily be made. Upon referring to Table 2, some of the differences in the several percentile grades of the two sexes and nationalities readily become apparent.

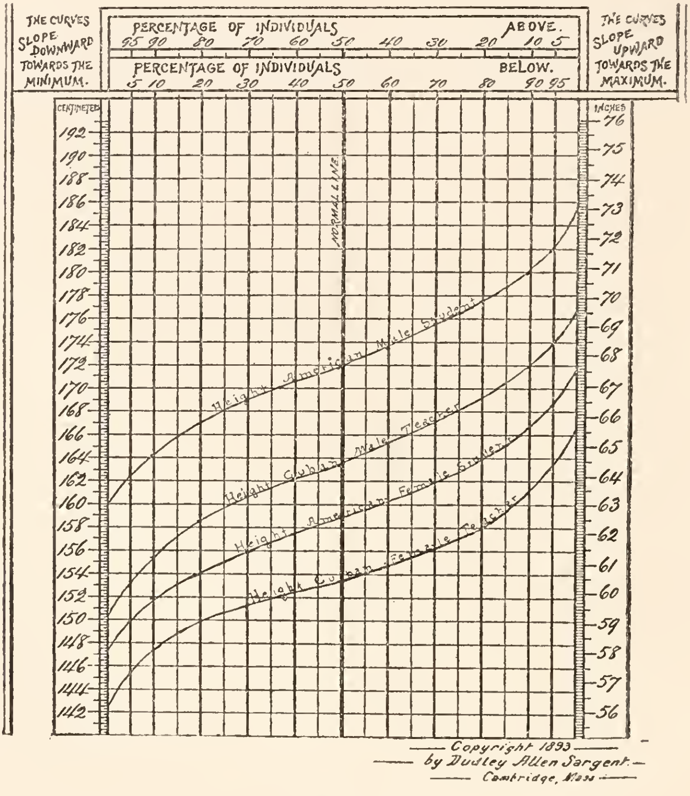


CHART 1.

The medium Cuban man is 12 pounds heavier than the medium Cuban woman, but the smaller Cuban men are 13 or 14 pounds heavier than the smaller Cuban women, while the larger Cuban men are only 2 and 6 pounds heavier than the larger Cuban women. This would seem to indicate that the Cuban women tend to take on flesh as they grow older much more readily than the Cuban men, or that through some selective agency the larger and stronger type of Cuban man is not well represented among the teaching force. In all probability, the stronger and heavier men would have entered the army or engaged in some more vigorous occupation than teaching school.

Among the many things that interested the Cubans in our people was the freedom of our women and the opportunities they enjoyed for growth and development, both mentally and physically. But what shall we say to the fact that the medium American woman is 19.9 pounds lighter than the medium American man, and that the difference increases in the man's favor all through the different percentile grades.

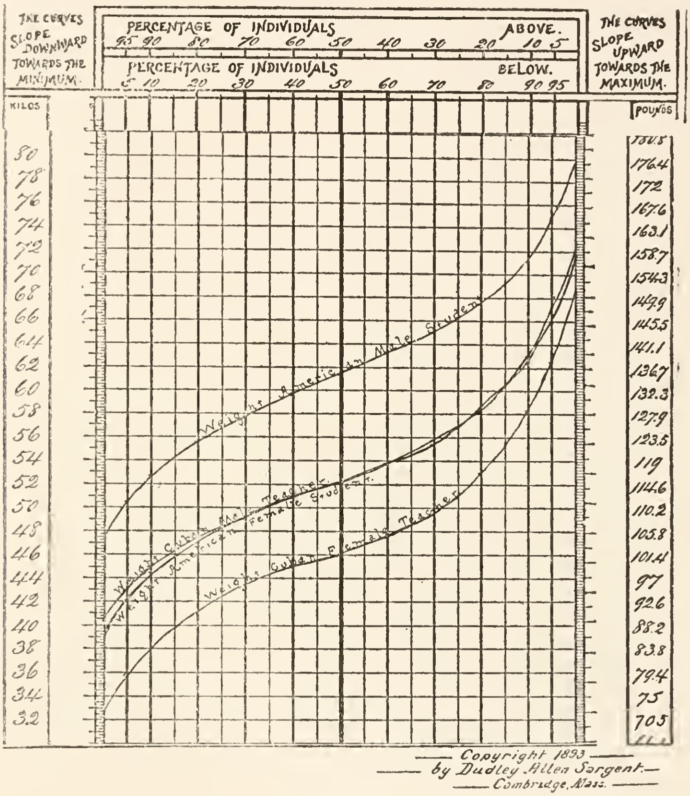


CHART 2.

If our American women have better opportunities for growth and development than the Cuban women, why do they not compare more favorably with the American men, in weight and height, than the Cuban women do with the Cuban men? Is it due to the inferiority of the American woman, or the superiority of the American man? Has the heavier and more buxom type of woman been selected, and left her leaner and lighter sister to wed the arts and sciences? Have the admirable opportunities for physical training and athletics, af-

TABLE II.

	Above.	95	90	80	70	60	50	40	30	20	10	5	Above.
	Below.	5	10	20	30	40	50	60	70	80	90	95	Below.
	Minimum												Maximum
Difference in Weight.													
Cuban Men and Cuban Women..............	11	14	14	13	13	13	12	13	13	12	6	2	—18
American Men and American Women...	—4.4	17.7	17.7	19.4	17.8	19.2	19.9	19.9	21.3	18 8	19.6	20.3	11.3
American Men and Cuban Men..........	—12.2	16.3	15.7	17.4	17.8	18.2	20 5	19.9	20.3	18.8	18.6	15.3	27.3
American Women and Cuban Women......	3.2	12.6	12	11	13	12	12.6	13	12	12	5	—3	—2
Difference in Height.													
Cuban Men and Cuban Women..............	1.2	3	3.1	3.1	3.6	3.9	4	4.1	4.2	4.3	4.3	4.3	6.7
American Men and American Women...	1.5	4.8	4.8	5.1	5.1	5.2	5.1	5.1	6.2	5.2	5.3	5.5	4.3
American Men and Cuban Men..........	—1.2	3.7	3.6	3.5	3.4	3.2	3.4	3.1	3.3	3.3	3.2	3.2	0
American Women and Cuban Women......	—1.5	1.9	1.9	1.5	1.9	1.9	2.3	2.1	2.3	2.4	2.1	2	2.4

forded our male students, begun to show the expected results by a general increase of weight and stature, that has not yet been attained by our college women? Can it be true that our American women are beginning to show the material cost of attempting to build a highly organized brain and maintain their special physiological function at the same time? Although in primitive races the two sexes are almost always more nearly alike physically, perhaps the little contrast between the Cuban male and female teachers as compared with the contrast between the American male and female students, may be due to the superiority of the physique of the Cuban women in comparison with the physique of the Cuban men. This supposition is greatly strengthened by again comparing the difference in the medium weight of the Cuban male teacher with that of the American student. The latter is 20.5 pounds heavier than the former, which is even in excess of the amount which the American male exceeds the American female in weight. On the other hand, we find that the medium American female student exceeds the medium Cuban female teacher by 12.6 pounds, which is more than the average Cuban man exceeds the average Cuban woman. The weight of the Cuban man and the American woman is very nearly the same in all of the percentile grades, as will be observed in noticing the close proximity and correspondence of the curves in Chart No. 1.

The differences in height follow the same general trend as those in weight. (See Table No. 2.) There is a difference of 4 inches in the medium height of the Cuban man and the Cuban woman, while the difference between the American man and the American woman is 5.1 inches. In both nationalities there is less comparative difference between the small men and the small women and the large men and the large women, in point of height, in the various percentile grades, than there is difference in weight. The difference between the medium height of the American man and the Cuban man is 3.4 inches, while the difference between the medium height of the Cuban women and the American women is 2.3 inches. Here, again, in all the grades, the comparative differences in height were much less than the comparative differences in weight. In this respect it is interesting to note that most of the Cubans gained steadily in weight all the time they were in Cambridge, and many returned to Cuba in a better condition of health than when they came to the United States.

If we would inquire into the real cause of the diminutive stature and weight of the Cuban teachers of both sexes when compared with our student type, we must begin with the question of race. The agencies, conditions and environment that have been working for generations upon a people stamp their almost indelible effects upon them, and give them the physical characteristics which we readily recognize in the different national types. Upon looking up the nationality of the Cuban teachers as recorded on their cards, we find that of the men 74 per cent. had Cuban fathers and mothers, 17 per cent. had Spanish fathers and Cuban mothers, while 2 per cent. descended from parentage of mixed Cuban, Spanish, Portuguese, French, German, Negro and American origin.

Among the women, 71 per cent. had Cuban fathers and Cuban mothers, 22 per cent. Spanish fathers and Cuban mothers, 3 per cent. Spanish fathers and Spanish mothers, while 4 per cent. had mixed descent of Cuban, American, French and Mexican origin. In both the men and women the descent is so largely Cuban and Spanish that the influence of the other nationalities would hardly be appreciable. We must look, then, to Spanish and Cuban ancestry and to the conditions under which they have lived to account in a large measure for the poor physique of their descendants as we see them to-day.

Looking up the physical status of the Spaniards, as shown by their height and weight, we find the height of the average Spaniard to be 65.64 inches, according to the report of the Anthropometric Committee of the British Association for the Advancement of Science, and Baxter's report of the soldiers entering the U. S. Army during the Civil War. In the latter report, the men from Italy, Spain and Portugal, in the order given, are shown to have had the lowest average stature of all the recruits that entered the service. Assuming that the Spanish soldiers were built on the same lines as the Cuban teachers, that is, weighing about 1.77 pounds to every inch in stature, it would make them average about 116.18 pounds. This is a very low standard of physical attainment, and ranks the Spanish immigrants who come to this country with the Portuguese, Hungarians, Hindoos, Bavarians, Chinese and North American Esquimaux.

Concerning the causes that have led to Spain's physical, mental and moral deterioration, it is hardly necessary to speak. When we consider that during the dark days of the Inquisition, from 1481 to 1808, more than 340,000 persons were punished for their religious convictions, and 32,000 of these were burnt alive, and that thousands who represented the nation's best blood fled from the country—what other result could have been expected? Let us turn now to the island of Cuba. Columbus described the native Cubans as 'loving, tractable and peaceable; though entirely naked, their manners were decorous and praiseworthy.' Another authority says 'the early Cubans seem to have been men of medium height, broad shoulders, brown skinned, flat-featured and straight-haired.' Into this native element has been poured an infusion of Spaniards, Creoles, Negroes, Chinese and other foreign blood, with its inevitable tendency to mix races.

From a physical point of view, the Cubans of to-day are inferior to their Spanish forefathers. This fact is attributed principally to the enervating effect of the climate, but there are other causes. The Cubans being naturally a domestic and affectionate people seek to form marital relations at a very early age. Many a young man is a father before he is eighteen years of age, by a wife a couple of years younger. Girls are considered women at the age of thirteen or fourteen, and many of them are mothers of a considerable family before they are twenty. When we consider that the human organism is not fully developed until the age of twenty-one or twenty-two, even in a tropical climate, a large number of these premature marriages and all that they imply might easily account for the physical inferiority of the race. Another custom which I understand is practised more or less extensively among the best of Cuban families, can not but have a damaging effect upon the life and health of the child, and consequently upon the adult physique. This is the pernicious habit of bandaging infants in swaddling clothes. (See 'Cuba, Past and Present,' by Richard Davey.)

The object, in all probability, is to give the child what is termed by some persons a fine figure; but, inasmuch as every attempt of this kind tends to cramp the vital organs and eventually to stunt growth and development, it would seem to be one of the customs which the Cuban ladies might well afford to abandon if they hope to rear a vigorous people. Another custom, which, however, is not confined to Cuba, is the excessive use of tobacco. But in that country, I am informed, almost every man, woman and child appears to be addicted to the habit of smoking. (See 'Cuba, Past and Present.') Tobacco may be a solace to the aged, a force regulator for many, and even a food to some persons, through the property it possesses of lowering organic activity. But this is the very reason why it should not be used by aspiring youth who wish to attain a vigorous manhood. Excessive smoking produces disturbances in the blood, mucous membranes, stomach, heart, lungs, the sense organs and in the brain and nervous system. When indulged in freely by the young, the habit of smoking causes impairment of growth, premature development and physical prostration. This custom alone, if universally practised by one or two generations, would certainly tend to dwarf the people who become enslaved by it.

A tropical climate does not invite one to active exercise, and the Cubans as a people may well be excused for not indulging in the violent athletic games now so popular with the Northern races. But it has always seemed to me strange that they do not avail themselves of the opportunities present for swimming and bathing. I understand that there are ample bathing places, but the people of either sex seem to have a prejudice against their free use. When one recalls that the South Sea Islanders of the Pacific are among the tallest and best-formed people in the world, averaging 5 feet 9.33 inches in height, it is natural to associate their fine physiques with their passionate fondness for swimming, which is one of the best of known exercises for giving one an all-round development.

The Cubans, as a class, have been reported by different American authors to be uncleanly, and some of the Cambridge people feared that this personal neglect might prove troublesome during the Northern sojourn of their visitors. Passing over the right of the Americans to make this criticism, who were themselves criticized by Dickens and other English travelers, not so many years ago, for this same defect, and who are not even now a water-loving people—I wish to say that bathing for cleanliness, with free use of perfumed soap, etc., is of little value from a hygienic point of view, compared to the bathing that follows a profuse perspiration produced by physical exercise. If, in connection with the use of water in the summer season, the skin is frequently exposed to the direct rays of the sun, and immediate contact with the air, it will be greatly improved in its functional power. In my personal contact with young men in the examining room, I am more and more impressed with the importance of keeping the skin in good condition, not only as a means of maintaining health and preventing disease, but of adding to one's nervous and muscular power. Since custom has decreed that the body shall be altogether covered, even in the tropics, the skin has lost much of its beauty, as well as its health-preserving qualities.

A dark complexion is the result of living for a long time in a tropical climate, and is not indicative of racial inferiority, as is too frequently assumed where the white and black races come together. The habit which many Cuban women have of plastering their faces with rice powder until they look almost ghastly, seems to us very singular, in view of the fact that so many of our own well-bred youth of both sexes spend their summer vacations at the seashore or in the mountains, earnestly endeavoring to acquire a tanned skin and a bronzed or olive-brown complexion.

Another custom which prevailed among many of the Cuban women who were in Cambridge was that of wearing narrow-toed, high-heeled shoes. The Cubans have naturally small hands and feet, and perhaps it is pardonable for a people to affect to exaggerate a little the thing upon which they pride themselves. Here, again, we see something of Spanish blood and the traditions of slavery. Those who toil for a living have large hands and feet: slaves toil for a living; therefore, slaves have large hands and feet. Those who do not have to work for a living have small hands and feet: ladies do not have to work for a living; therefore, ladies have small hands and feet. It is only necessary to carry this line of reasoning a step farther to see why the Chinese aristocrat bandages the feet of his daughter until they become so small and crippled that she cannot walk, or the prospective Spanish aristocrat crowds her feet into pointed-toed shoes, with heel in the middle of the foot, with the same result. This inability to walk with ease and comfort was made very apparent among the Cuban teachers in their historical and geological excursions about Cambridge. Upon investigation, it was found that the Cuban women were wearing narrow, pointed-toed shoes, with high heels, numbering in sizes from two to four, and that the Cuban men were wearing the same style shoe, numbering in size from three to six. These are the sizes usually worn by our American boys and girls ranging in age from ten to fourteen. Our women wear shoes ranging in size from No. $2\frac{1}{2}$ to 8, and our men shoes ranging in size from No. 6 to 10.

Of course, a smaller stature on the part of both Cuban men and women implies smaller feet, but in order that the feet, though small, should be of service, the toes and joints must be allowed freedom of movement. This they cannot obtain if the feet are crowded into small, tight-fitting, stiff-soled, high-heeled shoes.

Our American men and women, after enduring years of pedal infirmities, have at last learned the value of common-sense shoes. The interest in tennis, golf, cross-country walking and other forms of physical exercise has done much to bring about a needed reform in America in caring for the feet. It is a recognized fact that conquering armies often depend as much upon their ability to march as they do upon their ability to fight. So, in more senses than one, it is necessary for a people to get a footing in the world before they think of competing with rivals or maintaining their independence as a nation.

While we all rejoice in the efforts of the Cubans to improve the condition of their schools, and admire their interest and enthusiasm for intellectual attainments—let it be remembered that every nation that has risen to eminence in this respect has always had a strong physical foundation to build upon. My observations among the Cubans have led me to believe that they are not so far behind the Americans in point of mental ability and acumen as they are in lack of physical vigor, and some moral aim or purpose to strive for. This condition is partly due to the effects of a tropical climate, and the corrupting influence of an effete civilization like that maintained in the Island of Cuba so many years by the Spanish Government. But I have already pointed out some of the physical defects of the Cuban people that are the outcome largely of faulty habits of living—short stature, light weight, flat chests, slender waists, small hands, little, narrow feet and emaciated limbs. These are fundamental defects, and are usually associated with a relatively feeble digestion, weak heart and incapacious lungs.

The remedies I would suggest are equally fundamental. Restraint from conjugal relations and the breeding of children until both sexes have completed their growth and development. Eating more food and drinking less coffee. Abstinence from the use of tobacco during the period of adolescence. Proper clothing for infants and children, and freedom from the restrictive and cramping influence of coverings for the trunk, limbs and feet at all times. The establishment of systematic habits of exercising and bathing from early youth to adult life, in view of attaining greater physical beauty and perfection. Arouse an ambition in young men to be strong, active and courageous, and incite them to the practise of such sports and games as tend to cultivate these qualities. Kindle among the young women an admiration for large, vigorous and manly men, in preference to little men, with effeminate airs and graces. A few years of strenuous living with these simple ideals in view will not only make the future Cubans larger and stronger than the present generation, but will go a long way towards enabling even the present Cubans to realize some of their higher ideals and nobler aspirations.

THROWING A HIGH EXPLOSIVE FROM POWDER GUNS.

By Hudson Maxim.

THERE is now at Sandy Hook a battery of pneumatic torpedo guns, and another at the port of San Francisco, the largest of which have a caliber of fifteen inches and are capable of throwing a maximum charge of 500 pounds of nitro-gelatin about a mile. Even to attain this range, it is necessary to fire at a very high angle. The projectile has no power whatever of penetration, being only a thin casing, about an eighth of an inch thick.

The purpose of these guns was to drop dynamite upon the deck of war vessels, or into the water to explode near them. These batteries are necessarily provided with a large plant of engines, boilers and air compressors, which, together with the long and cumbersome pneumatic guns and mountings, present unusual difficulties in their protection from the fire of an enemy, while the range is so short that a modern battleship could approach within what, for it, would be a comparatively short range, and destroy the entire outfit, without in turn being in the least exposed to the fire of the pneumatic tubes. Even should a battleship, in order to enter the Channel, be obliged to pass within range of the pneumatic guns, it would be by mere chance that one of the torpedo bombs could be dropped anywhere near it.

We will grant, however, that should these guns score a hit, with 500 pounds of nitro-gelatin, the stanchest battleship would have cause to tremble, especially should the bomb drop into the water and explode near the unprotected hull.

The pneumatic gun owes its existence to a misconception of the nature and possibilities of high explosives and of the requirements of a system for their successful projection from ordnance. Congress appropriated the money for the construction of the pneumatic batteries now in service from the same misapprehension of their utility. The 'Vesuvius,' with its pneumatic guns, was also the child of error. The shots fired by her at the fortifications of Santiago resulted in nothing more serious than the production of loud reports, which possibly frightened the enemy. Her projectiles had no power of penetration, and, therefore, were useless against fortifications.

It must be borne in mind, however, that the modern powder gun, with its small caliber and ponderous weight, throwing a heavy steel projectile, with but a small bursting charge of black powder, or with none at all, and the unwieldy armor-clad battleship are also only the children of experiment and have not yet passed the experimental stage. These constitute one extreme of the problem, while the pneumatic torpedo gun is the other. In the belief of the writer, the large-bored cannon for throwing high explosives at high velocity, propelled by smokeless gunpowder, instead of by compressed air, is a mean between the extremes, which is destined to solve the problem; while the present form of cannon and the armor-clad warship, on the one hand, will be relegated to the rear, and the pneumatic gun, on the other hand, will fall into oblivion.

It was with a view to the solution of the problem of successfully throwing high explosives from powder guns that the writer developed the progressive smokeless powder, which has been adopted by the United States Government, and by the use of which higher velocities with lower pressures are secured than would be possible by any other means. A special form of multi-perforated powder grains, invented by the writer, for throwing aerial torpedoes from guns, makes it possible to so control the pressures, even when full charges are employed, as to warrant the use of guns having a very large caliber and comparatively thin walls. I found that several high explosives could be made sufficiently insensitive to withstand the shock of acceleration in powder guns necessary to any desired velocity.

There was, however, at that time, no means known for making a fuse which should carry a sufficient quantity of detonative material, such as fulminate of mercury or a similar compound, in order to detonate effectually the insensitive high explosive charge on reaching the target. When such a quantity of fulminate was employed, there was danger of its being exploded by the shock of the propelling charge of gunpowder, and in turn setting off the high explosive charge of the shell and bursting the gun.

I designed and patented a fuse in 1895, in which the detonator was positioned at the rear of the shell, and completely outside of the high explosive charge, with the whole strong wall of the shell base between it and the high explosive, in which position, should the fuse go off prematurely from shock in the gun, the detonator would blow out at the rear and no damage would be done, as the high explosive would be beyond its reach. When, however, the projectile with its fuse struck the target, the body of detonative compound was thrown violently forward in a guide tube and into the high explosive bursting charge, due to the retardation of the projectile.

To carry out the foregoing experiments, I built two powder mills at Maxim, near Lakewood, N. J. It was there that the Maxim-Schüpphaus smokeless powder was produced, and there I conducted a large number of experiments with a long four-inch gun, having pressure gauges at different points along the whole length of the barrel, by which it was possible to ascertain not only how much pressure was exerted behind a projectile at the instant of firing, but how well the pressure was maintained behind it all along the bore. From this gun a torpedo shell, made thin and filled with Maximite and having a very heavy base portion filled with lead to act as tamping, was fired against an armor plate three and one-half inches thick and four feet square, demolishing it completely. The quantity of high explosive carried was only two pounds.

After the completion of the experiments at Maxim, N. J., and the successful testing of the Maxim-Schüpphaus powder by the United States Government, followed by its adoption, I went to England, with a view to the disposition of the foreign patent rights. On the 24th of June, 1897, I delivered a lecture before the Royal United Service Institution of Great Britain, on 'A New System of Throwing High Explosives from Ordnance.'

I explained and illustrated how a torpedo gun could be constructed which would weigh no more and cost no more than the ordinary twelve-inch seacoast rifle, but which should have a caliber twice as great, and which would stand a chamber pressure sufficiently high to throw a projectile carrying half a ton of high explosive at as great a velocity as that imparted to the usual 1,000-pound shell thrown from the 12-inch gun, and which carries only 37 pounds of black rifle powder.

I showed diagrams giving the range of destructiveness of such aerial torpedoes when striking in the water adjacent to a battleship, and claimed that such a quantity striking on board or against the armored side, under high velocity, would, without question, throw the vessel out of action.

This lecture was very widely commented upon in both the general and the scientific press, and it was stated in the House of Parliament, by one of the members who was opposing the appropriations for so many large battleships, that it would be necessary, in the event of war, and after the aerial torpedo was introduced, to keep battleships snugly in harbor and roof the harbors over to protect them.

THE GATHMANN GUN.

The Gathmann Gun Company, last year, secured an appropriation from Congress for a large torpedo gun, which was constructed by the Bethlehem Ironworks, and now lies at the Sandy Hook Proving Grounds, awaiting tests.

This gun is very like that proposed by me in the above-mentioned lecture, excepting that the caliber is not quite so large for the weight, although the caliber, which is eighteen inches, will doubtless prove sufficient to enable the gun to give a good account of itself.

In the trials of this gun, made by the builders with a charge of Maxim-Schüpphaus smokeless powder, a projectile weighing a ton was hurled at a velocity of 1,900 feet per second with a pressure of only 19,000 pounds to the square inch. As the gun will safely stand a pressure of 25,000 pounds to the square inch, a velocity of more than 2,000 feet per second can obviously be readily obtained, as against the velocity of from 2,000 to 2,250 feet per second for the 1,000 pound shell from the 12-inch gun, with a pressure of 35,000 pounds to the square inch. We must note here that the weight of the Gathmann gun is only 59 tons, against 52 tons for the 12-inch seacoast rifle.

A bill now before Congress calls for an appropriation for the efficient testing of this weapon. The service projectile, which will be thrown from this gun in the coming test, will carry about 475 pounds of wet, compressed guncotton, or 700 pounds of Maximite. Maximite being 50 per cent. heavier than guncotton, the shell will hold 225 pounds more of that material. There are to be 24 shots at full velocity, some for range and accuracy, and others to show the effect on powerful structures erected on the land. The last and final test will be against a steel barge anchored off shore, presenting a side fully armored and supported, so as to offer even greater resistance than would be afforded by the side of the strongest battleship now afloat.

Although Mr. Gathmann is my competitor, I feel much gratified at his success in procuring from the Government the necessary appropriations for building and testing this gun, and I am of the opinion that the results of these tests will prove a source of gratification to all the taxpayers of the country, who, unless the gun proves successful, will be called upon to contribute hundreds of millions of dollars for building and arming a fleet of monster battleships, which will not be required after one shot has been fired against the steel barge which will be provided for the purpose.

The war vessel that must follow as a natural result of the success of the aerial torpedo will be an unarmored, or only partially armored, gunboat or cruiser of small dimensions, capable of traveling at very high speed. It will be a sort of floating gun-platform, and will cost only a fraction of what the battleship costs, while a single one of these gunboats will afford far more protection than the most powerful battleship.

MAXIMITE.

The United States Government has, during the last two years, been putting forth especial efforts to thoroughly investigate the qualities and merits of high explosives, with a view to finding the best bursting charge for shells. A large number of explosive compounds have been submitted by various inventors and tested by the Ordnance Department of the United States Army at the Sandy Hook Proving Grounds.

Some of the explosive compounds submitted have given very satisfactory results. Perhaps half a dozen of them would serve fairly well, if nothing better could be found. The Government, however, has placed its standard of excellence very high, with the hope of finding, if possible, something better than is possessed by other countries.

The United States Government was one of the last to adopt a smokeless powder, notwithstanding the fact that it was one of the first to experiment with these new explosives. But the Departments then having the matter in charge were very conservative, taking nothing for granted, were uninfluenced by the example of other countries and were determined that nothing but the best would be good enough for Uncle Sam. The result is that this Government to-day possesses a smokeless powder superior to that adopted by any other country. The same policy has been manifested in the search for a high explosive suitable as a bursting charge for shells.

The tests through which a high explosive must pass before there is the least hope of its meeting the requirements of the Government are very severe. The inventive Yankee, having an ambition to serve the Government by producing for its use a satisfactory high explosive, has a difficult task before him. In the first place, the compound must be perfectly stable, and to determine this it is submitted to a severe heat test for a period of fifteen minutes. If it fails to stand this test it is condemned at once, and goes no further. If it passes the heat test satisfactorily, a quantity is then placed under a falling weight or hammer to test its sensitiveness or its ability to resist shock. This is determined by the height from which it is necessary for the hammer to fall in order to explode the material. If the explosive proves sufficiently insensitive to indicate that it will stand the impact or shock of penetrating armor plate, it is then tested to determine its explosive power. A forged steel armor-piercing shell is filled with the material and armed with a very powerful exploder, which is set off by electricity. The force of the explosive is shown by the number and character of the fragments. Small shells are burst for fragmentation in a steel-walled chamber; larger shells are buried in the sand and exploded, the fragments being recovered by sifting the sand.

If the number of fragments indicates a sufficiently high explosive power, an armor-piercing shell is filled with the compound and fired through a nickel steel plate, so thick as to almost stop the shell in passing through, leaving just velocity enough to carry it a few feet into a sand butt back of the plate, where it may be dug out and recovered, provided the explosive proves to be sufficiently insensitive to stand the shock of impact, and does not explode on the instant of striking the plate. This is a very severe test—the severest of all. An explosive which will stand this impact on the plate, where the entire velocity of the projectile is overcome, while moving its length through the plate, is proved to be so insensitive that there can be no danger in its projection from ordnance at any desired velocity. That is to say, there will be no danger of the explosive going off in the gun, because the shock of acceleration in the gun is necessarily very much less than the shock of retardation when the projectile strikes the armor-plate.

Maximite has passed all of the above tests satisfactorily. When it was subjected to the heat test and no change was manifested at the

Fig. 1.

Twelve-inch forged steel armor-piercing shell, weighing 1,000 lbs., before and after exploding the Maximite. There are about 7,000 fragments shown in the photograph from which this illustration was made.

end of fifteen minutes—the required time—the material was allowed, at my request, to remain under the test for a period of two hours, and there were no signs of decomposition even then.

A 12-inch forged steel armor-piercing shell, weighing 1,000 pounds, and provided with a detonating fuse, having electrical connections for firing, was filled with Maximite. The shell was buried in the sand and exploded. So terrific was the detonation that 7,000 fragments were actually recovered and photographed.

The accompanying illustration, Fig. 1, shows the shell before exploding. On the right of the shell are 7,000 fragments which were recovered. It will be observed that the fragments do not have the usual broken appearance, but are much distorted by the violence of the explosion.

A five-inch armor-piercing projectile was next filled with Maximite and fired through an armor plate, as above described, the projectile being afterwards recovered intact. It was found that the shock had in no way affected the explosive. The shell was then armed with a fuse and fired by electricity. The number and character of the fragments showed that the same force was developed in proportion to the weight of the shell, as in the case of the large 12-inch shell above mentioned, which was exploded in the sand. The five-inch shell is shown in Fig. 2. The fragments recovered after the explosion are shown on the right of the shell.

The next test was with projectiles filled with Maximite fired against

FIG. 2.

Five-inch forged steel armor-piercing projectile, weight 45 lbs., before and after exploding the Maximite. This shell, after filling with the explosive, was first fired through a four-inch nickel steel plate into a sand butt, where it was recovered intact. It was then exploded for fragmentation. There are a little over 800 pieces of the shell shown in the photograph, the average weight of the pieces being, therefore, about one ounce.

a concrete wall, with results which demonstrate that the power of the explosion was superior to that of any other high explosive ever thrown from a gun.

Projectiles loaded with Maximite were then fired through a wooden screen, after passing which they exploded, and the fragments went into the sea. The fragmentation was such that the appearance of the water was similar to that which would be produced by the simultaneous fire of a regiment of musketry. On this occasion, a result was produced hitherto unknown, and which, perhaps, illustrated the violence of the explosive better than anything else. The projectiles, at the instant of explosion, were probably going at a velocity of about 2,000 feet per second. Pieces of the base plug of one of the projectiles were thrown back with such violence as to not only overcome the forward movement, but to throw them backward with a velocity estimated to be at least 1,000 feet per second.

This shows that a projectile filled with Maximite and exploded in a state of rest would have its fragments hurled at a velocity of about 3,000 feet per second, a much higher speed than that of a rifle ball, and that the forward-moving fragments, when a projectile is exploded in flight, will be hurled at a velocity something like 5,000 feet per second, or more than twice the speed of a rifle ball.

For the same reason that a large number of small bullets thrown at a high velocity are more effective and deadly than the large, heavy, slow-moving bullets formerly employed, a shell filled with such an

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 3.

The fragments, natural size, of the point of a forged steel armor-piercing shell, exploded with Maximite, showing the ragged and shredded state of the metal produced by the explosive, with the hardened tip of the projectile broken off by the impact.

Fig. 4.

Side view of a fragment from the body of a 12-inch armor-piercing forged steel shell, exploded with Maximite. On the left of the fragment, which was the inner surface of the shell, is seen the flattening and stretching effect of the blow which it received from the explosion, as though it had been heated and then struck with a sledge-hammer, the force of the blow being so sudden and severe that the whole outer surface of the shell, except a small piece seen hanging to the fragment on the right was knocked off by the force of the impact.

Fig. 5.

View of opposite side of fragment seen in Fig. 4, showing where this piece was jammed upon a neighboring fragment with such force that its surface was made to flow like wax.

explosive as Maximite has an enormous advantage over explosives heretofore in use.

CURIOUS PROPERTIES OF MAXIMITE.

Maximite cannot be exploded by ignition. If a store-house filled with this material were set on fire, there would be no danger of explosion. Melted cast iron may be poured upon a mass of Maximite without the least danger of exploding it. When heated, it melts, and if the heating be continued, it will evaporate like water, without producing an explosion. Lyddite, the high explosive adopted by the British Government, is said to be simply picric acid. This substance is melted for filling the shells, which are preliminarily heated to about the fusion point of the material to prevent too rapid setting. The melting point of picric acid is 122° C. The melting point of pure Maximite is exactly one-half of that of picric acid. That is to say, it is 61° C. The low melting point of Maximite enables it to be fused over the ordinary water bath, but owing to the impossibility of exploding it by heat, the water bath is not used, for it may be melted over an open fire in the same manner that asphalt is melted in the street cauldrons, and with equal safety. It is not necessary to heat the shells beforehand when filling them with Maximite.

On the other hand, great care has to be taken in the fusion of picric acid, because, if it becomes ignited in quantity before fusion, while in granular form, it will detonate, and also if it be heated very much above the fusion point, it will detonate.

The high fusion point of picric acid renders it necessary to employ a special lining material for protecting the shells against the erosive effect of the acid, while Maximite has very much less erosive action upon metals, and owing to its low fusion point an ordinary coating of shellac or similar substance is all that is necessary to protect the shells.

It has been found from the experiments made by the Government that, although a high explosive may be so sensitive as to safely withstand the shock of acceleration in the gun, it may still be dangerous to fire, owing to the rapid rotation given to the projectile by the rifling of the gun, which is a rate of about 7,000 turns a minute. As a result, the projectile revolves upon the explosive before the latter has time fully to participate in its rotation. The great heat generated by this friction is apt to set fire to the explosive, causing a detonation.

Maximite requires so little heating for fusion that there is but slight contraction of the molten substance in reaching the point of solidification or freezing point. Maximite, furthermore, possesses the peculiar quality of expanding on solidifying, in the same way that water does on freezing. This causes it to set very firmly upon, and to adhere tightly to, the walls of the shell, so that it is quite impossible for the charge to shift in the shell. In the event, however, of the shell rotating upon the Maximite charge, the surface of the substance exposed would simply melt, producing a fluid and perfectly frictionless bearing. In the Transvaal War many Lyddite shells exploded prematurely, either from shock in the gun or from the rotation of the shell upon the charge. Such prematures would be impossible with Maximite.

Fig. 6.

Three 3-inch shells, which were filled with Maximite and primed with 50 grains of fulminate of mercury. The points of the shells were blown off with the fuse without exploding the Maximite. The confinement and the force of the exploder were not sufficient to detonate the Maximite. This is a good illustration of the extreme insensitiveness of this material. (See small piles of unexploded Maximite below the fragments of the shells.)

When wet compressed guncotton is used as a shell charge, there is always some danger of a premature from the rotation of the shell upon the charge, especially when the percentage of water is not great.

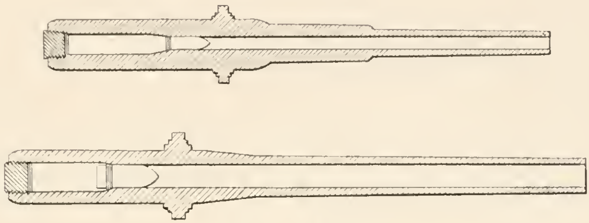
VALUE OF HIGH EXPLOSIVES IN ARMOR-PIERCING SHELLS.

Maximite is the first high explosive, satisfactory in other respects, which could be fired through armor plate of such thickness as to render it available for armor-piercing shells.

In a recent test at the Sandy Hook Proving Grounds, a 12-inch armor-piercing forged steel shell, carrying a bursting charge of 70 pounds of Maximite, was fired through a 7-inch Harveyized nickel steel plate. This is the maximum thickness of such a plate for which this shell is adapted; hence Maximite has shown itself capable of withstanding the shock of penetration of armor plate as thick as the armor-piercing shell itself will stand, and furthermore, in the maximum quantity which the largest shells are capable of carrying.

In the 12-inch shell for piercing still thicker armor, the charge space is considerably smaller and the length of column of explosive very much shorter, so that, although the shock upon the projectile would be greater, still the shock upon the explosive would not be any more severe than that exerted upon the Maximite in the above test.

The writer has developed a fuse which will carry 100 grains, or even more, of a fulminate of mercury compound, together with more than 2,000 grains of a picrate, through the thickest armor plate, without going off prematurely, and which will act promptly to explode the bursting charge of Maximite immediately it gets through the plate.



Figs. 7 and 8.

A section of the common 12-inch seacoast rifle, and a section of torpedo gun proposed by the writer in a lecture before the Royal United Service Institution of Great Britain, June, 1897.

The problem of successfully throwing high explosives from powder guns may be said to be already solved. Not only this, but the far more difficult problem has been solved, of successfully firing high explosives through armor plate to explode inside of a war vessel.

An equally important feature of the problem has also been met, and that is the safety in storage of high explosives in quantity, especially in the magazines of a battleship. The refractory character of Maximite is such that it is rendered absolutely safe under such circumstances. Furthermore, it is so insensitive that projectiles filled with it could not be exploded by other projectiles striking them and exploding among them.

In a recent test by the Government, three 3-inch shells were filled with Maximite and armed with a point fuse filled with fifty grains of fulminate of mercury, and the fuses fired by electricity. As a result, the forward ends only of the shells were blown off by the fuse, leaving the whole rear portions of the shells unbroken, and filled with unexploded Maximite. The fragments of the forward ends, which were recovered, had the Maximite adhering to them like mortar to a brick. Another 3-inch shell was filled with picric acid, fused and fired in exactly the same manner as were the Maximite shells. The picric acid detonated with great violence, breaking the shell into small fragments. This test determined the superior insensitiveness of Maximite, and its absolute safety against even very severe shocks.

In order to effectually detonate Maximite, it must be confined in a very strong steel shell, and set off with not less than 100 grains of fulminate of mercury, reinforced with not less than 1,000 grains of some form of picrate, dry guncotton or similar substance.

In the recent tests made by the British government upon the old battleship, the "Belleisle," great havoc was found to have been wrought by the Lyddite shells whenever they penetrate through the ship's side at unprotected points, but all such shells which struck upon the armor plate exploded on impact, and did no damage. Had Maximite shells been used in this test, they would have passed through the armor plate and exploded inside the vessel.

Maximite is an entirely new chemical compound. Nothing like it, to my knowledge, has ever before been produced. Its production is based upon an entirely novel theory of detonation, which, together with the formula for the material itself, is kept a Government secret.

PYRAMID LAKE, NEVADA.

BY HAROLD W. FAIRBANKS, PH.D.
BERKELEY, CAL.

NOT much more than fifty years ago the Great Basin region, lying between the Rocky Mountains and the Sierra Nevadas, was almost unknown. Previous to 1840, a few daring men had penetrated west of the Rocky Mountains. The route to Oregon had been traversed, and one party had crossed the southern portion of the Great Basin, but the main portion was unexplored.

The maps made of the country lying west of the Rocky Mountains previous to the explorations of Fremont are most interesting, as showing the strange conceptions which men had formed of the geographic features of the region. The great Sierra Nevada range of California is entirely absent, and a number of rivers are marked as rising in the Rocky Mountains and flowing west into the Pacific.

One of these maps was used by Fremont, who first made known the real character of the region, and the journal of his wanderings in this desert waste is most interesting reading. Enabled as we are now to cross the deserts in a few hours in comfortable cars, with good maps at hand, and plenty to eat and drink, it is hard to place ourselves in the position of the early explorers of a vast and unknown region, where each day the problem of food and water has to be solved anew.

We owe much to Fremont for his daring explorations in the arid regions of the West. It was during his first expedition that he discovered Pyramid Lake, the subject of this sketch, but in trying to extricate himself and his party from the deserts, they nearly perished upon the snowy summits of the Sierra Nevada Mountains.

In the year 1843 Fremont conducted an exploring expedition to Oregon. As winter approached he turned southward from The Dalles, expecting to return to Salt Lake by way of Nevada. But upon getting into the deserts and fearing that he would not be able to cross them, he turned westward and, in the very heart of winter, attempted to cross the Sierras into California. This plan was based upon a misconception of the geography: for his map showed him no Sierra Nevada, but instead a great river called the Buenaventura, which was supposed to rise in the Rocky Mountains and flow westward into San Francisco Bay. Day after day as his party became more wearied, and food for the animals became scarcer, he watched for this river, thinking that every stream which they came to must be the one sought, but found invariably that

Fig. 1. Pyramid Island, Pyramid Lake.

Fig. 2. Tufa Deposits by Pyramid Lake, showing Concentric Structure.

the streams flowed in the wrong direction and emptied into lakes without outlets or into the desert sands.

As the party traveled southward into Nevada, they came upon one of the largest and most interesting of the lakes of the Great Basin. Fremont says in his journal: "Beyond, a defile between the mountains descended rapidly about 2,000 feet; and filling all the lower space was a sheet of green water some twenty miles broad. It broke upon our eyes like the ocean. The waves were curling in the breeze and their green color showed it to be a body of deep water. For a long time we sat enjoying the view. It was like a gem in the mountains which from our position seemed to enclose it almost entirely." Thus runs the narrative of the first white man who ever saw this great body of water. Of its source and general relations he knew nothing, but he hoped that it had an outlet and that the stream would lead him westward to California.

Traveling southward along the eastern shore of the lake, the party came in sight of a great rock rising from it, and camped upon the shore opposite. Fremont says: "It rose according to our estimate 600 feet above the water, and from the point we viewed it, presented a pretty exact outline of the great pyramid of Cheops. This striking feature suggested a name for the lake and I called it Pyramid Lake."

The lake thus discovered and named has had an interesting geological history, and is surrounded by many remarkable scenic features. It occupies the deepest portion of the basin of a much greater lake which once covered much of northwestern Nevada. This extinct lake has been named Lahonton, after an early French explorer.

It must be understood that the Great Basin, as its name signifies, is an extensive region with no outlet to the ocean. It is made up of innumerable faulted crust blocks, the elevated ones giving rise to the north and south ranges of mountains and the depressed ones to the desert basins lying between. Each local basin or valley has its own watershed limited by the mountains which surround it, but if for any cause the water supply from these mountains is in excess of the evaporation in the valley, a lake results, and if the supply is sufficient the lake will overflow its own basin and spread into the adjoining basins, rising to a height at which the water lost by evaporation exactly balances the inflow.

In this manner it was that the great Lake Lahonton spread over the valleys of northwestern Nevada during the glacial period. The Walker, Carson and Truckee rivers, with many smaller ones, all heading in the glacier-covered Sierras, were supplied with a great amount of water during the heavier precipitation of that period. In addition, the heat was not so great and consequently evaporation was less.

The ancient boundaries of this lake have been traced and carefully studied, and we know that during its high-water stage it was second, in size, only to Lake Bonneville, another great lake of the same period which occupied the basin of Great Salt Lake. The total length of Lake Lahonton from north to south was not far from 250 miles, with a width from east to west of 180 miles. Its area was more than 8,000 square miles. It was an exceedingly irregular lake, however, for it was broken up by mountain ranges into many long and narrow arms, with deep bays and long peninsulas. At the time of its greatest expansion it still had no outlet, although one arm reached far westward into Honey Lake valley, California, and another one extended into southern Oregon.

As time passed on and precipitation decreased, the supplying streams became smaller and the lake began to shrink. The basins which had been connected at high water again were separated and so there at last resulted the conditions of the present day. Many of the lakes are still

FIG. 3. TERRACES OF LAKE LAHONTON, NORTH OF PYRAMID LAKE.

shrinking, and it is difficult to tell how much of the ancient lake will eventually remain. Walker Lake, Carson Lake, Humboldt, Honey and Pyramid lakes are the remnants of the once far-reaching Lake Lahonton. The great valleys which the lake left bare are now among the most arid portions of Nevada. Notable among these is the Black Rock desert, where for many miles, and in some directions as far as the eye can reach, the barren clay floor of the old lake stretches away.

As the waters of Lake Lahonton receded they did so by stages and at every stopping-place left a well marked beach. These old beach terraces are among the most striking features of this region. One may travel for days over the desert with the old wave-cut benches circling the mountains far above him.

Pyramid Lake occupies the deepest of the basins of Lake Lahonton. It has a depth now of about 360 feet, but the waters of the ancient lake rose 500 feet higher, making its greatest depth at the time of maximum expansion nearly 1,000 feet. Pyramid Lake has a length of thirty miles and a maximum width of ten miles. It is fed by the Truckee River, which has its source in Lake Tahoe in the high Sierras. The lake is, of course, alkaline, as are all the lakes of the Great Basin, but the water is not as strongly impregnated as some of them. It is well supplied with large trout, as well as several other kinds of fish. The water is unfit for people to drink, although it answers for stock.

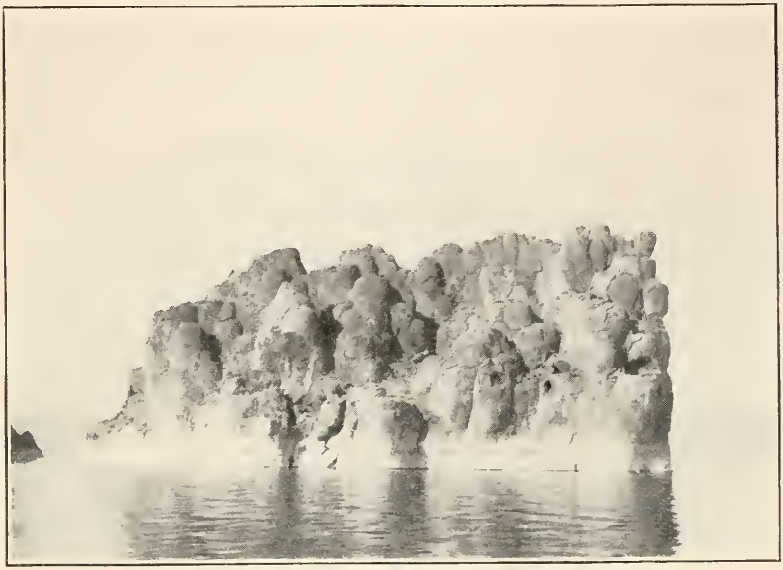


FIG. 4. TUFA DEPOSITS, NORTH END OF PYRAMID LAKE.

High mountains come down to the lake, leaving in places scarcely room for a road, and although the waters are quiet as a rule, yet they are subject to sudden and violent storms.

At many points within the basin of the former lake, Lahonton, there are strange-appearing deposits of calcareous tufa, either encrusting the rocks or rising in curious and fantastic towers and domes. The waters of the lake were richly impregnated with calcium carbonate, derived in part from the incoming streams, but more largely probably from calcareous springs. As the lake waters receded, the salts in solution became more concentrated and soon began to form chemical precipitates upon projecting rocky points. In the portion of the basin now occupied by Pyramid Lake the springs were more numerous and the water consequently more richly impregnated with lime. As a result, we find to-day in and about this lake the most interesting and remarkable tufa deposits known in all the Great Basin.

The tufa deposits are of various sorts and appearances, the differences being due to changes in the chemical properties of the water at various stages. Some of the forms are merely encrusting, and apparently structureless. Others show beautiful dendritic and interlacing figures, lapping over each other like the successive branches of some organic growth. The great deposits in Pyramid Lake have been built up in the form of towers, domes and pinnacles. The smaller ones bear a most striking resemblance to great thick mushrooms with a concentric

Fig. 5. Tufa Domes, East Shore of Pyramid Lake. Mushroom-like Form.

structure. These mushroom-like growths start from some projecting point or pebble and increase in size by precipitation from the surrounding water, until, massing together, the great domes and pinnacles have been built up, rising hundreds of feet in the air.

While these deposits are still being formed in Pyramid Lake, the large ones which rise so picturesquely from the water must, of course, have been formed before Lake Lahonton had entirely disappeared, and it has been only through the continued recession of the water that the deposits have become exposed to our observation.

Following the road northward along the west side of the lake, we pass many curious forms assumed by the tufa. Here is one upon a projecting point of the shore like an old ruined castle, there by the road-side a cluster of nearly spherical domes, partly broken down and showing the concentric inner structure. But upon the far side of the lake, standing out clearly in the desert air, rises the most attractive feature of all. It is Pyramid Island, and we do not wonder at Fremont's naming it as he did.

Hiring a boat at a little ranch by the shore, we rowed across the clear and quiet waters of the lake to Pyramid and Anaho islands. The latter island is completely encrusted with the dendritic tufa, which from a distance appears like the overlapping scales upon some gigantic animal.

FIG. 6. MUSHROOM ROCK, ANAHO ISLAND.

Upon the eastern side of the islands, rising from the edge of the water there is a most picturesque deposit, known as the mushroom rock and shown in the accompanying photograph. Rising from a firm base, the deposit becomes smaller, and then at the top swells out in a spherical head.

Pyramid Island next demanded attention, and a row of a mile farther brought us close under its towering cliffs. It rises almost vertically from the water, but its sides soon become more sloping and terminate in a point nearly 300 feet high. Its shape is almost symmetrical from whichever side it is viewed. Its surface is of a very light color, and consequently it is a conspicuous landmark from all points about the lake.

Fig. 7. One of the Pinnacles, North End of Pyramid Island.

Fig. 8. Tufa Crags, North End of Pyramid Lake.

It is but a short distance from the island to the eastern shore, where Fremont camped and made the sketch which accompanies his narrative. This is a favorite camping spot for the Indians while engaged in fishing. Upon a projecting point near here there is a large cluster of very perfect tufa domes. They are among the finest about the lake. Several of them stand out from the others and exhibit finely their manner of growth. Starting from a point upon the rocks, the mushroom-like form spreads out until eight or ten feet in diameter and is then completed by a perfect hemispherical upper surface.

Long before we reached the northern end of the lake our attention was attracted by a long line of sharply pointed crags and islands, extending out more than a mile into the lake. The most of these can be reached only by water, so securing a boat from an Indian, we pulled across the three miles of water intervening.

This group of tufa domes and crags is by far the most interesting of any about the lake. Exceedingly picturesque is the effect as one rows among them, gliding over the quiet waters, from whose clear depths rise these fantastic forms. Some are low and rounded, their mammillary or botryoidal surfaces made up of an aggregation of domes. Others are more angular, rising sharply from the water's edge to a height of 300 feet. Beautiful beaches of clean sand stretch between those nearer the shore, sand marked most regularly by the waves of the lake at different stages, as it slowly recedes through the summer months. Upon a warm summer's day when the lake glistens in the sunlight, the caves in the tufa offer most inviting retreats, and the clean gently shelving beaches and comfortably tempered water are irresistible. One enjoys a bath in the mineral waters, but must be careful not to stay in them too long, for they are so strongly impregnated with alkalies that the skin is soon affected.

During the high-water stages of the lake these picturesque towers grew up beneath its surface from numerous warm springs carrying lime in solution. Springs still issue at various places, and the tufa can be observed in process of formation. It is soft and spongy, crushing under one's feet as one walks over the surface, but slightly above the summer level of the lake.

These rocks, as well as those at the southern end of the lake, are the resort of thousands of sea birds, many of which nest here. Pelicans, sea gulls, terns, geese, ducks, etc., abound. The pelican rookeries are large and particularly interesting, with the great uncouth birds swimming about in large numbers and the downy young waddling around the nests. The cavities and nooks in the tufa offer especially convenient nesting places for many of the birds. Then, too, they are seldom molested in this remote place.

Another interesting feature about the life of these rocks is the multitude of spiders. One cannot climb over them without being covered with the webs and distributing hundreds of the little insects. But few bushes grow upon the tufa, for the rainfall here is very slight, and they are clearly revealed in all their nakedness.

Exceedingly barren are the shores of this great lake, except at two points where springs furnish water for irrigation. The Truckee River has rich bottoms along its lower course, occupied by Indians who seem to be fairly well civilized.

Although the lake is so isolated, its scenery is remarkable in the extreme, and it deserves to be better known. More plainly than is usually the case, the history of the ancient lake which occupied these valleys is recorded on the slopes of the surrounding mountains and in the strange tufa deposits which rise out of the waters of its modern representative, Pyramid Lake. Rising and falling with the different seasons, the lake seems to have slight hold upon life. If the Truckee River should be entirely diverted to Winnemucca Lake, the waters of Pyramid Lake would undoubtedly shrink to insignificant proportions. The same effect would be brought about if the aridity of the Great Basin region should increase, and the precipitation upon the Sierra Nevada become less than at present.

Let us hope that, in the swinging of the pendulum from arid to more moist conditions and back again, the lakes of the Great Basin are not doomed to extinction, but that they may again increase in size, repeating the conditions of the past.

THE GEOLOGIST AWHEEL.

By Professor WILLIAM H. HOBBS,
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IN no country of the world does the government distribute to its people with so lavish a hand as in our own the published results of scientific investigation. One example among many that might be given is furnished by the reports of the United States Geological Survey, which for abundance of material, for scientific value and for beauty of illustration are not approached by the geological publications of any European state. Of the many who see the beautifully colored geological maps which accompany these magnificent reports, or the only less elaborate and expensive maps prepared by certain of the individual States, doubtless few have the faintest notion of the studies on which they are based.

No comprehensive study can be made of the geology of any region until some sort of geographical map of the region makes it possible to represent the exposed rock masses in approximately their true positions relative to one another. If the geology be other than of the very simplest character—and this will generally be true of mountainous regions —it is not only necessary to fix the geographical positions of rock masses, but their elevations as well. In other words, the map must not only be a plan, but special elevations must be represented, known as geological sections. The most satisfactory representation—and this will be essential for all difficult areas—will be one which shows not only special elevations, but the topographic relief of every point in the area. A proper preparation for detailed geological work in a difficult area involves, therefore, the making of a relief or topographic map based on correct triangulation, and of a scale and an accuracy of delineation of relief forms commensurate with the complexity of the geological structure. For large areas of the eastern United States such maps have been prepared by the United States Government, sometimes in cooperation with the State governments, and these maps may be obtained in the form of beautifully engraved atlas sheets by any one and at merely nominal prices. On these maps are shown in black the railroads, highways, houses, etc. (the culture); in blue, the lakes, streams, swampy areas, etc. (the hydrography); and in brown, the lines of approximately equal altitude (the topography).

With such a map the field geologist can begin intelligently his geological work. This work will consist first of all in the collecting of his data, that is, the visiting and examination of a great number of rock exposures well distributed over the area, and the careful location of each upon his topographical map, with observations indicated by special characters and colors. Where the region is thinly settled and roads are few, access will be difficult and the location of exposures doubly so, since no well determined points upon the map will generally be found near at hand from which to fix direction or to measure distance. In the comparatively thickly populated Atlantic section of the United States there will, however, be found large areas within which the highways form an elaborate network, and the location of outcrops will here be comparatively easy; a road corner, a sharp bend of a highway, a house, or other characteristic landmark being generally near enough to furnish a basis of measurement. It is for a study of such areas that the present paper is especially intended.

In the past the field geologist engaged in areal and structural work has depended either upon his own power of locomotion or upon the use of a saddle horse or a team. In the northeastern United States the numerous fences restrict his use of a horse to the highways themselves, and the difficulty of hiring suitable saddle horses has practically eliminated them from consideration. When teams are used they must very frequently be left while rock exposures are sought or examined, and the time thus lost in hitching in suitable places is very considerable. Further, a horse requires food and water, protection from flies, etc., and its hire varies from one to three dollars per day.

The advent of the bicycle has greatly facilitated the study of regions where roads are frequent, though geologists seem to be slow to appreciate its advantages. The increasing number of official government or State geologists, of university professors, and of teachers and students generally who engage in geological work may well excuse one for urging the advantages in effectiveness, in cheapness and in comfort of a properly equipped bicycle for this and similar forms of scientific work. One of the greatest of these advantages arises from the attached cyclometer, which if read and recorded at road corners and other landmarks affords one at all times either a perfect location (in case an exposure is found on the highway), or a convenient base (if an excursion must be made away from the road).

The most convenient form of cyclometer for geological work is one which can be attached to the axle of the forward wheel of the bicycle between the prongs of the fork. The slight disadvantage of being compelled to bring the wheel to a definite position before reading the cyclometer is small when compared to the danger of injuring the usual form through the falling of the wheel or from contact with objects by which the wheel is left supported. It is, moreover, frequently desirable to ship the wheel as baggage on railway trains, and it is generally better on these occasions to remove the ordinary type of cyclometer lest it be broken or injured in handling. All this danger is avoided in the improved form of cyclometer which is attached to the center of the axle.

The equipment of the geologist will generally consist of a collecting bag with separate compartments for note book, maps, and rock specimens; a hammer, compass and aneroid barometer. In regions of low relief the aneroid is of little service and may be dispensed with, but the best method of carrying the other articles of the geologist's equipment is a question of considerable importance.

The collecting bag which is in use by government parties operating in the northern Atlantic States may be deserving of a special description, inasmuch as it is an evolution of many years. It is made of the best grade of russet leather and has four compartments. The map compartment is merely a double back within which the maps, properly protected, are slipped. The note book compartment is sewed on the front of the bag and shaped to the book. In the main central compartment of the bag the specimens are stowed and in a wide but shallow pocket sewed to its back near the top are kept the black and colored pencils, the eraser, horn protractor, and small ebonite triangle, for use in the making of notes and in plotting the observations upon the map. The cover of the bag is a flap fastened by a strap to a buckle on the front and near the bottom of the note book compartment. When carried on the person the bag is supported by a wide strap passing through loops on the sides and bottom so as to carry the weight from below. On the wheel the bag is supported by a light framework of strong galvanized iron wire, which by means of three leather straps is securely fastened to the handle bar and the head of the machine. The bag fits loosely into the frame, even when filled with specimens, and it is kept in place on rough roads by being attached by two straps furnished with snaps to the handle bar of the bicycle. The bag can thus be almost instantly attached to the wheel or removed from it and slung by the carrying strap over the shoulder.

The topographic map sheets which are used for the base in the geological work are cut in half and each of these halves is again divided so as to be mounted on the inside of two cloth covered and hinged boards, as is the lining to a book cover. This method of mounting secures a smooth surface and a firm support to the map, gives a large area always at hand so that geological relationships may be easily appreciated, and furnishes moreover the best possible protection to the records of the work. Hardly less important is the protection which these stiff boards afford to the leather back of the bag when they are slipped within its map compartment, and also to the body of the geologist when the bag is loaded with heavy specimens and carried from the shoulder.

The best form of compass is doubtless the four-inch aluminum dial compass with clinometer attachment, which is manufactured by Gurley for the United States Geological Survey, but cheaper and simpler instruments can be made to serve almost as well. This instrument is best carried in a leather box worn upon the belt. The aneroid, if used, is carried in a leather case slung from the shoulder and passed under the belt so as to be shaken as little as possible. The hammer is most conveniently carried upon the person by slipping the handle through the belt, a 'pick' or prospector's form being specially secure in this position because of its long head. When riding the hammer is slipped under a strap on the side of the carrying frame of the rock bag.

Where observations must be frequently taken, as in detailed areal mapping, considerable time may be lost in finding a suitable support against which to rest the wheel. Bicycle manufacturers should be able to devise a light and simple support which can be carried with the wheel and quickly adjusted. In a region adapted to bicycle work, such as much of the Piedmont Plateau and the Coastal Plain of the eastern United States, as well as large areas in Europe, it is believed that a bicycle outfit such as is here described makes it possible to reduce greatly the expense and to divide by at least one-half the time necessary for mapping over that required if older methods of locomotion and transportation are employed. The inertia of long-established practise is, however, considerable, and geologists have been somewhat slow to adopt the newer methods. The small expense of such an equipment and the accessibility of the beautiful government maps make it possible for private and essentially amateur geologists, with the advantages of only a brief geological training and a moderate amount of experience, to collect valuable data within the area surrounding their homes, especially if these chance to be in a thickly settled part of the country.

THE FORMATION OF HABITS IN THE TURTLE.*

By ROBERT MEARNS YERKES,
HARVARD UNIVERSITY.

HABITS are determinants in human life. It is true that we are free, within limits, to form them; it is also true that, once formed, they mold our lives. In the life of the brute habit plays an even more important rôle than it does in man. The ability to survive, for example, frequently depends upon the readiness with which new feeding habits can be formed. So, too, in case of dangers habitually avoided, those individuals which form habits most quickly have the best chances of life. But it is unnecessary to emphasize the importance of habit to all living beings, for it is obvious. We have now to ask, What precisely is a habit?

A habit proves in analysis to be nothing more or less than a tendency toward a certain action or line of conduct—a tendency due to structural and functional modifications of the organism which have resulted from repetition of the action itself; for nothing can be done by the animal mechanism without resultant changes in its organization. These changes it is which influence all subsequent activities and constitute the physical basis of habit. Repetition of an act apparently leads to the formation of a track for the controlling nervous impulse—a line of least resistance, so to speak—along which the current therefore *tends* to pass. A duck when thrown into the water does not have to stop to think what to do to get out, how to move this leg and then that; it instinctively, we say, meets the situation with that combination of movements called swimming. But the duck swims almost, if not quite, as well the first time it is put into the water as it ever does. There is little profiting by experience. This simply means that the structural basis of the swimming habit is present at birth, and does not have to be formed by repetition of the action thereafter. The habit is, in other words, inherited. For man swimming is not an instinctive act; he has to learn every detail of the complex muscular process by trial; he has to establish by repetition of the

* This article is based upon an experimental study of the associative processes of turtles made at the Marine Biological Laboratory, Woods Holl, Mass., during the summer of 1899, under the direction of Dr. E. L. Thorndike. My thanks are due Dr. Thorndike and Prof. C. O. Whitman, the director of the laboratory, for their kindness.

activity the basis of the habit. Finally, however, the man will be able to meet the situation—water, a distant shore, and a desire to be on the shore—as the duck does—that is, habitually.

Since habits make an animal what it is in great part, the study of their formation, of the manner and rapidity of their growth, and of their permanence must be of practical as well as of scientific importance. We are rapidly realizing, as the increasing interest in animal psychology clearly indicates, that the mental life of all animal types must be understood before we can attain to a satisfactory science of psychology or give a history of the evolution of mind. To watch the progress of a habit's growth is exceedingly interesting, whether the subject be a man or one of the lower animals. Ordinarily the chief difficulties in the way of such a study are the great length of time and the constancy of observation necessary. But these obstacles may readily be avoided by making observations under artificial or experimental conditions—that is, by adapting conditions to the needs of the experiment, instead of trying to adapt one's self to natural conditions. The account which follows presents, as an example of this kind of work, observations on habit formation in the common 'speckled turtle' *(Chelopus guttatus)*. It has been my aim to give a brief account of the way in which a particular turtle profited by experience.

The work was undertaken to determine to what extent and with what rapidity turtles can learn; to measure as accurately as might be their intelligence. Reptiles are usually considered sluggish and unintelligent creatures, and there can be no question about the general truth of this opinion. Turtles certainly appear to be very stupid—so much so, indeed, that one would not expect much in the way of intelligent actions. Just how stupid, or better perhaps, just how intelligent they are, we shall be better able to judge after studying the habits of the animals more carefully, and collecting more evidence like the following:

The finding of the way through a labyrinth to a nest was chosen as the habit to be studied. The motives employed to get the subject to try to find its way to the nest were: first, the desire to hide in some dark, secluded place; secondly, the impulse to escape from confinement; and lastly, the desire to get to a place of comfort. Dr. Thorndike,* in studying the associative processes of cats and dogs (of which a brief account appeared in the Popular Science Monthly for August, 1899), used hunger as the chief motive for escape. This is unsatisfactory in the case of turtles, because they frequently do not eat well in confinement, and at best their feeding or

*'Animal Intelligence, an Experimental Study.'

desire for food is very irregular and hard to control as a motive in experimental work.

The method of experimentation was simple. A box three feet long, two feet wide and ten inches deep was divided into four portions by partitions, also ten inches deep, arranged as shown in Fig. 1. In each partition was a hole four inches long and two inches deep, just large enough to permit the turtle to pass through easily. The box is shown in ground plan by Fig. 1.

A is the space in which the animal was placed to start, the starting-point being marked by a dot (.). The corner marked nest contained a mass of damp grass and was darkened. When everything was ready for an experiment the animal was placed in *A* at the dot and allowed to wander about until it found the nest by passing through the openings marked 1, 2 and 3.

On July 20 the animal, a speckled turtle about four inches long which was found in Woods Holl, Mass., was placed in *A* for

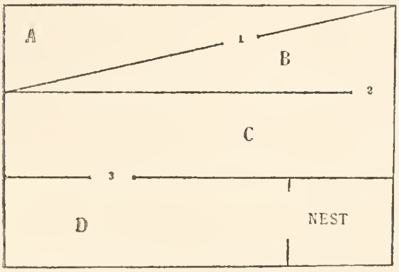

FIG. 1. PLAN OF LABYRINTH NO. 1.

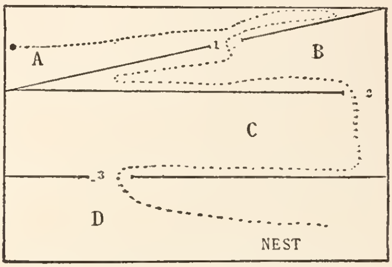

FIG. 2. COURSE FOR FOURTH TRIP.

the first time. After wandering about almost constantly for thirty-five minutes, it chanced to find the nest, into which it immediately crawled, there remaining until taken out for another experiment two hours later. The observations were made from one to two hours apart, in order to avoid fatiguing the animal, and also to leave it some inducement for seeking the nest, for if it were taken out each time as soon as it got back to the comfortable corner, the game would soon lose interest. The second time the nest was reached in fifteen minutes, with much less wandering. The time for the third trip was five minutes, and for the fourth, three minutes thirty seconds. During the first three trials the courses taken were so tortuous that it seemed foolish to try to record them. There was aimless wandering from point to point within each space, and from space to space. After the third trip the routes became much more direct, and accurate records of them were obtained. Fig. 2 gives the course taken in the fourth experiment. It is fairly direct, but shows that the animal lost its way in *A* and again in *B;* having passed through 2, it took the shortest path to the nest.

A record of the route in connection with the time of the trip is necessary as an index of the effect of experience, because if the animal takes a direct course, with no wrong turns, but makes several halts, the time may indicate no profiting by the former acts, whereas the route will at once show that there has been improvement. Thus one record supplements the other.

These experiments were made six or eight times a day until fifty trials had been given. The tenth trip was made in three minutes five seconds, with two mistakes in turning. The time of the twentieth journey was but forty-five seconds, and that of the thirtieth, forty seconds. In the latter experiment a direct course was taken; this was also true in the case of the fiftieth trip, which was made in thirty-five seconds. Fig. 3 represents graphically the times of the first twenty experiments of this series. The vertical

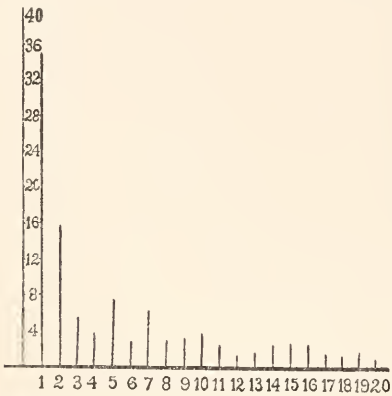

FIG. 3. TIMES OF EXPERIMENTS FROM ONE TO TWENTY.

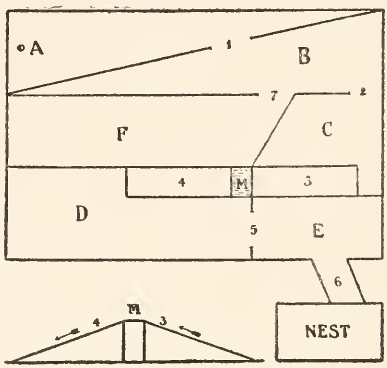

FIG. 4. PLAN OF LABYRINTH NO. 2.

column of figures at the left, 1 to 40, indicates minutes; the horizontal line of figures, 1 to 20, gives the number of trials.

That the turtle profited by experience, and that very rapidly, is evident from the figures. The average time for the first ten trips, from one to ten, was eight minutes fifty-four and a half seconds; the average time of the ten trips between thirty and forty was one minute three seconds. What at first took minutes, after a few trials required only as many seconds. There was remarkably little aimless wandering, crawling up the sides of the box and sulking in the corners after the third experiment. In fact, the animal soon began to behave as if it had the goal in mind and was intent on making directly for it. It learned with surprising quickness to make the proper turns and to take the shortest path. Three or four times I noticed it turn in the wrong direction, crawl into a corner and, as it seemed, become confused, for it then returned to the starting-point, as if to get its bearings, and started out afresh. In every case the second attempt resulted in a direct and unusually quick journey to the nest. Very frequently halts just in front of the holes were noticed. It looked as if the animal were meditating upon the course to be taken. Had one seen a man in a similar situation he would unhesitatingly have said that the person was trying to decide which way to go. There can be little doubt, however, that the mental attitude of the turtle was extremely simple compared with a man's under similar conditions. There are those who would claim that even the turtle was thinking about its environmental conditions, but it seems far more probable that it stopped in order the better to get those sensory data by which it was enabled to follow its former course. Smell and sight furnish the most important elements in the associative processes of lower animals. This interpretation of the action is sup-

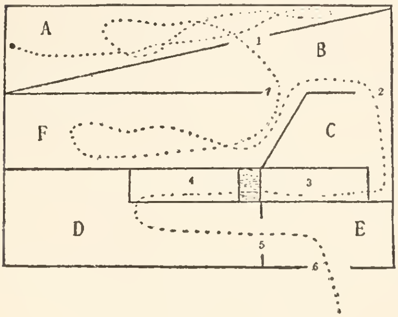

Fig. 5. Course for Fifth Trip.

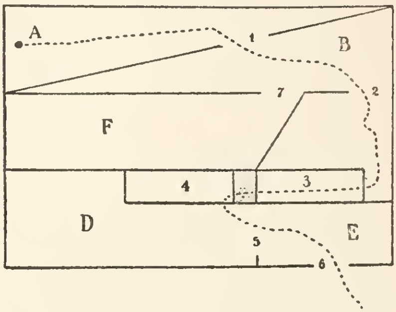

Fig. 6. Course for Thirtieth Trip.

ported by the fact that it occurred most frequently after the course had been gone over a few times.

A more complex and novel labyrinth was now substituted. Its new features were a blind alley (see *F*, Fig. 4) and three inclined planes (3, 4 and 6 of Fig. 4). A plan of the labyrinth is shown in Fig. 4. At the left of the nest a side view of the inclines 3 and 4 is shown. Each was one foot long, and the middle point *(M)* was four inches from the floor.

Labyrinth No. 2 was used in the same way as No. 1, the turtle being placed in *A* and permitted to seek the nest, which was this time a box filled with moist sand. The inclines at first baffled the little fellow, and it was an hour and thirty-one minutes before he reached the nest. *A* and *B* seemed to offer no difficulties, but the new features—the blind alley and the inclines—were puzzles. By the fifth trial, however, these had become somewhat familiar. The route taken in this experiment has been produced in Fig. 5.

The time of this trip was sixteen minutes. The times of some of the other trials were as follows:

10th trip	4 minutes.		
15th "	6	"	
20th "	4	"	5 seconds.
25th "	3	"	
30th "	3	"	20 seconds.
35th "	2	"	45 "
40th "	4	"	20 "
45th "	7	"	
50th "	4	"	10 seconds.

The route for the thirtieth trip was, as Fig. 6 indicates, almost direct.

The times of these experiments are generally longer than those of the first series because the inclines consumed considerable time.

During the formation of the habit of crawling up incline 3 and sliding down incline 4 a very interesting modification of the action occurred, namely, the shortening of the path to the sand-box by crawling over the edge of incline 4. At first the animal, after climbing up 3, would slide all the way to the bottom of 4 and would then turn toward the nest. Soon, however, it began making the turn toward the nest before reaching the bottom, thus throwing itself over the edge of 4. The turn was made earlier and earlier on 4, until finally it got to crawling over as soon as it reached the top of 3, or *M*. It always turned itself over the edge carefully, and landed, after a fall of four inches, usually on its head or back. By this process the path was shortened eight or ten inches. This action is a splendid illustration of the way in which an advantageous habit may grow by accretion, as it were, until it seems as if it must have been the result of reasoning. Some would, no doubt, hold that in this case the turtle chose the direct path because of inferences from judgments. Although this *may* be true, there is surely a sufficient explanation of the habit, as we have come to know it, in the profiting by chance experience. No one would say that the nest was at first found by inferences. It was reached because of the animal's impulse to move about, to seek escape or hiding. Had the turtle stopped to judge and draw inferences as to the way to escape, instead of persistently moving from place to place, it would probably be in the pen yet. No; the wandering impulse led by chance to the finding of satisfaction, turtle pleasure, in the nest. Because of this satisfaction, the action was impressed on the vital mechanism, so that there was a tendency (the beginning of a habit) toward repetition of it. Had the action failed to give satisfaction, the probability of its being repeated would have been merely that of chance, and not chance plus the influence of the former pleasure-giving activity. The turtle happened to crawl over the edge of the incline, and, finding that this enabled it to get to the nest quicker, it continued the act, thus forming a habit.

Such experiments as these give clear pictures of habit formation in animals. They also furnish a means of measuring with considerable accuracy the rapidity of the process, the degree of intelligence and the permanence of associations, thus making possible a comparison of the mental abilities of different animals.

THE SCIENCE OF DISTANCES.*

By Sir GEORGE S. ROBERTSON, K. C. S. I.

WHEN the British Association for the Advancement of Science honored me with an invitation to preside over this Section, I accepted the distinction, thoughtfully and with sincere gratification. The selection as your president at Bradford, this great and interesting center of commercial energy, of a student of political movements who was also deeply interested in the science of geography, seemed to point suggestively to a particular branch of our subject as appropriate for an opening address. This consideration, and, to my thinking, the fitness of the occasion, led me to believe that the British Empire itself was a very proper subject for such reflections as could be compressed within the limits of an inaugural Presidential Address. Many of my predecessors have eloquently and wisely dealt with various topics of admitted geographical rectitude—with geography in its more strictly scientific study, with its nature and its purview, with its recent progress, and with the all-important question of how it could be best taught methodically and how most profitably it might be studied. In dealing with the important practical application of our science to the facts of National life—Political geography—I feel that perhaps a word of explanation is necessary. Pure geography, with its placid aloofness and its far-stretching outlook, combined sometimes with a too rigid devotion to the facts and conclusions of strict geographical research, is apt to incline many scientific minds to an admirable quiet-eyed cosmopolitanism—the cosmopolitanism of the cloistered college or the lecture theater. It perhaps also at times has a tendency to create in purely academic students a feeling of half disdain or of amicable irritability against those who love the science for its political and social suggestiveness and elucidations. Thus there is a possible danger that geographers of high intellectual caliber, with enthusiasms entirely scholarly, may come to underrate Nationality and to look upon the world and mankind as the units, and upon people and confederacies and amalgamations merely as specific instances of the general type. We know that geography is often looked upon as the science of foreign countries more especially. Such mental confusion is undoubtedly less common than it was, yet it still influences, unconsciously, the minds of many people. It is well not to

* Address of the president of the Geographical Section of the British Association for the Advancement of Science, Bradford, 1900.

forget this curious fact, and to point out, as if it required emphasizing, that there is nothing foreign to geographical thought in the association of geography and patriotism, and that the home country is worthy of careful study, particularly when, as with us, our home country is not Yorkshire, nor England, nor the United Kingdom, but the whole British Empire. That is my justification and my apology for taking Political Geography and the British Empire as my subject, if justification and apology seem to any one to be necessary. To the generous hearts of our distinguished foreign visitors who honor us quite as much as they delight us by their presence, I am sure of my appeal. Every true man loves his own country the best in the world. That beautifying love of country does not require him to be ignorant of or hate other countries. The community of the civilized nations, no longer to be described as Christendom even, for Japan has been received into it, is a mighty fact in geography no less than in politics. To love mankind one must begin by loving individuals; before attaining to true cosmopolitanism one must first be patriotic.

Now, besides dealing with the topography of the globe, geography considers also the collective distribution of all animal, vegetable and mineral productions which are found upon its surface. The aspect of the science which deals with man's environment, and with those influences which mold his national character and compel his social as well as his political organization, is profoundly interesting intrinsically and of enormous practical usefulness when rightly applied. Given the minute topography of a country, a complete description of its surface features, its rivers, mountains, plains and boundaries, a full account of its vegetable and mineral resources, a knowledge of its climatic variations, we have at once disclosed to us the scene where we may study with something like clearness man's procession through the ages. Many of the secrets of human action in the past are explained by the landforms of the globe, while existing social conditions and social organizations can often thereby be intelligently examined and understood. Persistent national characteristics are often easy to explain from such considerations. For instance, the doggedness of the Dutch river-population, caused very greatly by a perpetual struggle against the sea, or the commercial carrier-instinct of the Norwegians, those northern folk born in a country which is all sea-coast of countless indentations. Having few products to barter, the Norwegians hire themselves to transport the merchandise of other peoples. We British also were obviously predestined to isolation and insularity, when perhaps in the human period the Thames ceased to be a tributary of the Rhine. Our Irish fellow-countrymen were similarly fated for all time to lead a separate, special and national life apart from our own, when at a still earlier period, geologically, the Irish channel was formed.

Such large-scale facts are not to be overlooked; there are others, however, of varying degrees of prominence. Some merely require to be interpreted thoughtfully, while others, after diligent study, may still remain dubious and matter for speculation. Geography is the true basis of historical investigation and the elucidation of contemporary movements. At the present time great social and political changes are occurring throughout the world—in Europe, Asia, Africa, and America, and in the islands of the great seas. These changes are absolutely dependent upon the physical peculiarities of the different lands acting upon generations of men during a prolonged period of time. As a consequence of certain soils, geographical characteristics and climates, we notice how harsh surroundings have disciplined some races to hardiness and strenuous industry, accompanied by keen commercial activity, which is itself both a result of increasing population and the cause of still greater overcrowding. Then we see other people at first sight more happily circumstanced. With them the struggle to live is less ferocious, their food is found with little toil. But we perceive that the outcome of generations of Nature's favoritism has been to leave them less forceful and less ingenious in the never-ending warfare of existence. By comparison they grow feeble of defense against the hungrier nations, ravenous for provender. Man forever preys upon his own kind, and an easy life in bland surroundings induces a flabbiness which is powerless against the iron training of harsh latitudes, or against the fierce energy and the virile strength produced by hereditary wrestling with unkindly ground.

The discovery of America and Vasco da Gama's voyage round the Cape originated movements and brought into play those subtle influences of foreign lands upon alien sojourners, and through them upon their distant kindred, which alter the course of history and modify national manners and perhaps national characteristics also. The colonization of territories in the temperate zone by European Governments, separated by vast ocean-spaces from their offshoots, has given origin to new and distinct nations different from the parent stock in modes of thought and in ways of life, a result due mainly, no doubt, to local physical conditions, but in part also, if only in part, to detachment, to complete and actual severance from the mother country. This brings us to that most interesting and important topic, geographically speaking, of Distance, an aspect of our science which is of the utmost concern to traders and statesmen; indeed, an eminent German geographer defines geography as the Science of Distances. To this subject of Distance I wish in particular to direct your attention, and especially to its bearings upon the British Empire.

The British Empire is equal in size to four Europes, while its population approximates four hundred millions. Although that may seem a somewhat grandiloquent method of description, it is a fairly accurate statement of fact. Still more interesting to us is another truth —that outside of these islands we have some ten millions of white-skinned English-speaking fellow-subjects. These islands are scarcely more than one-hundredth part of the whole Empire, although we count as four-fifths of its white population; of the total number of the Queen's subjects we are, however, no more than a tenth.

British Empire is somewhat of a misnomer, just as the North American and Australian Colonies were never colonies at all in the classical sense of the word. For the colonies are not independent of the mother country. An empire again really means a number of subject peoples brought together, and at first held together, by force. India is an empire, for instance. Some new title or phrase would have to be invented to describe accurately all the possessions of the British Crown from the government of India through all possible grades of more or less direct control until we come to some colony with representative institutions, and thence to the great commonwealths with responsible legislators and responsible cabinets. Happily, however, there is no need now for any novel designation. The style British Empire has become in time of stress a rallying cry for all the Queen's subjects, and the term has become sanctified by the noble, eager devotion shown to her Majesty, both as a beloved and venerated constitutional sovereign, and as the common bond of unity between those great self-governing daughter-nations which we in the past were accustomed to speak of as 'our colonies.' Consequently British Empire has henceforward a clearly defined, a distinct, a national significance, just as Imperialism has a special and peculiar meaning to all of us. We understand by British Empire and by British Imperialism a confederacy of many lands under the rule of her Britannic Majesty. This confederacy is dominated by white peoples—Anglo-Saxons, Celts, French-Canadians and others—knit together in most instances by the ties of blood relationship, but with equal if not greater closeness by common interests, an identical civilization and a love of liberty, in addition to that dignified but enthusiastic acceptance, already referred to, of the constitutional sovereignty of the same Queen. We may hope that generous democratic expansiveness and social assimilation will also in time detain willingly within the limits of this British confederacy of white peoples those other Christians and distant kinsfolk of ours in South Africa who are at present so bitterly antagonistic.

Ruled and controlled under liberal ideals by the center of authority there are, in addition, the great subject territories whose non-Christian population are less advanced in moral and material progress. They exhibit indeed every degree of backwardness, from the barbarism of the savagest tribesman to the intellectual but archaic civilization of ancient Asiatic nationalities.

Concerning the British Empire, and comparing it with other empires, ancient, recent or now existing, its two most remarkable features are its prodigious and long-continued growth and the persistency of its power. It cannot to all seeming grow much larger, from lack of expansive possibility. But it is unprofitable to predict. Every step which has been taken in the way of extension, particularly of late years, has been against the wishes, and in almost passionate opposition to the views of large sections of the people. Yet the process of enlargement has gone on continually, being often in actual despite of a Government, whose members find themselves powerless to prevent absorptions and concretions which they would gladly avoid. Objections to this perpetual growth of empire in territory, and to the resulting responsibility which we not altogether willingly accept, are unanswerable theoretically. The too heavy and continually increasing strain upon our military resources every one can appreciate. The limit in power of the strongest navy in the world is at least as obvious as the vital necessity that our Navy be largely and ungrudgingly strengthened. Naturally the cry of cautious, patriotic men is the same now that it has always been—'Consolidate before you step farther.' In India, owing to conscientious and strenuous opposition to every suggestion of expansion, and to the almost violent form which that opposition often took, our progress has been on the whole slow and comparatively safe. We have (I, of course, avoid all allusion to very recent policy) as a rule consolidated, strengthened ourselves, and made our ground sure before another advance. But there is a general impression that in other parts of the world we have been hastily and unfortunately acquisitive, whether we could help it or not; that the new provinces, districts and protectorates are some of them weak to fluidity; that the great and unprecedented growth of the Empire has led to a stretching and thinning of its holding links which are overstrained by the weight of unwieldy extension and far beyond the help of a protecting hand. I hope to be able to show that in some important respects this suspicion is not altogether true; that science, human ingenuity and racial energy have given us some compensations, and that it is not paradoxical nor incorrect to say that our recent enormous growth of empire has been everywhere accompanied by a remarkable shrinkage of distances—by quicker and closer intercommunication of all its parts one with another and with the heart center. In short, the British Empire, in spite of its seemingly reckless outspread, its sometimes cloudy boundaries, its almost vague and apparently meaningless growth, is at the present day more braced together, more manageable, and more vigorous as a complete organization than it was sixty years ago. The difference between its actual extent in the last year of the century and its size at the date of the Queen's accession can be estimated by a glance at a remarkable series of maps published in the 'Statesman's Year-book for 1897,' while since 1897, and at this instant as we all know well, its mighty bulk is being still further increased.

The world as a whole has strangely contracted owing to a bewildering increase in lines of communication, to our more detailed geographical knowledge, to the formation of new harbors, the extension of railways, the increased speed and the increased number of steamships, and the greatly augmented carrying power of great sailing vessels built of steel. Then, hardly second in importance to these influences are the great land lines and the sea-cables, the postal improvements, the telephones, and perhaps we may soon add the proved commercial utility of wireless telegraphy. This universal time diminution in verbal and personal contact has brought the colonies, our dependencies, protectorates, and our dependencies of dependencies, closer to each other and all of them nearer still to us. Measured by time-distance, which is the controller of the merchant and the cabinet minister just as much as of the soldier, the world has indeed wonderfully contracted, and with this lessening the dominions of the Queen have been rapidly consolidating. Nor is this powerful influence by any means exhausted. In the near future we may anticipate equally remarkable improvements of a like kind, especially in railways, telegraph lines and deep-sea cables, and in other scientific discoveries for transmitting man's messages through water, in the air, or perhaps by the vibrations of the earth. For us particularly, railway schemes of expansion must be mainly relied upon to open up and connect distant parts of the Empire. Our true and only trustworthy road of intercommunication between the heart of the Empire and its limits must always be the sea. For general trade purposes, such as the convenience of business travelers, all continental lines and all the great projected railways will be helpful, whatever nation controls them; but our certain security is the sea, the sea which protects us, which has taught us to be an Imperial people. But if we ever forget that, there may be a calamitous awakening. We must not be persuaded to build—or at any rate to place reliance upon—land roads or railways through regions inhabited by tribes and peoples over whom we have not complete military as well as political control. Persian, Arabian, North African railway projects are happily rarely heard of now. As national enterprises they never were and never could be practicable, or otherwise than dangerous mistakes. We are a world-power solely because of our warships and because of our command of the sea. In the future also we shall remain a world-power only so long as we hold command of the sea in the fullest sense of the term, not merely by the force and efficiency of the fighting Navy, but by the excellence and the perfecting of our mercantile marine, by increasing its magnitude, carrying power and speed, and by anxiously attending to its recruitment by English sailors. We must not attempt to overtax our resources to guard railway lines through foreign semi-civilized or savage countries by exported or local armies. A heavy land responsibility lies upon us already. Under a little more we might be easily overweighted and crushed down. We must concentrate all our surplus energies upon our sea communications. Therefore the railway lines which I spoke of as helping to consolidate the Empire in the near future are those only which are projected or are being built in the various colonies and dependencies, lines to distribute and to collect, to connect provinces, and feed harbors. The mighty Canadian Pacific Railway is unique in the Empire. It not only complies with all these requirements, but in addition it provides to Australia and the Eastern dependencies an alternative road, convenient and safe. As I said before, all railways, wherever built, will probably help us directly or indirectly in the long run, provided we are never committed to the protection of any one of them outside of our own boundaries.

And what has been said about railways applies, with obvious modifications, to telegraph lines and to maritime cables. The more general the extension of these, and the more numerous they become, the greater benefit there will be to this country in its double capacity as the greatest trader and the greatest carrier of merchandise in the world; while the actual equivalent to a diminution of time-distance in traveling is to be found in the instantaneous verbal message which can be despatched to the most distant point of the Empire. But we ought certainly to join all the shores of the Queen's dominions by sea-cables completely controlled by British authority. To rely upon connection between our own cables through telegraph systems stretching across foreign countries, however friendly, or to permit the ends of these sentient nerves of the Empire to emerge upon shores which might possibly become an enemy's country, is dangerous to the point of recklessness, that parent of disaster. As a melancholy instance of my meaning it is only necessary for us to remember the Pekin catastrophe—how we suffered from those dreadful intervals of dead silence, when we could not even communicate directly with our own naval officers at Taku, or with anyone beyond Shanghai, although we have in our possession a place of arms at Wei-hai-Wei upon the Gulf of Pechili. It is obvious that we ought to have an all-British cable for pure strategic purposes as far as Wei-hai-Wei, our permanent military outpost on the mainland.

Now to give some suggestions of the increased facilities for carrying merchandise, for conveying passengers quickly about the world, and for the sending of messages to all parts of the earth, a few, a very few, salient facts may be quoted about ships—sailing ships and steam vessels—and about telegraphs and cables.

In 1870 there were no more than ten British sailing ships which exceeded or reached two thousand tons burden. In 1892 the yards on the Clyde alone launched forty-six steel sailing vessels which averaged two thousand tons each. In 1895 the number of large steel sailing ships being built in the United Kingdom was down to twenty-three, and, speaking generally, it is inevitable that sailing vessels must give way to ocean steamships for most kinds of cargo—cattle, coals, wool, grain, oil and everything else.

Now let us turn to the results in shortening journeys accomplished by the progress made in the construction and in the driving machinery of steamships within the last forty years, which has especially been fruitful in such improvements.

During this century the six months' voyage round the Cape to India became a forty and then a thirty days' journey by what was known as the overland route for mails and passengers through Egypt. By degrees it had become shorter still by the railway extensions on the Continent and by the unbroken steamship passage through the Suez Canal, until now the mails and hurrying travelers may reach London in twelve or fourteen days after leaving Bombay; and the great liners of the P. & O. Company can arrive in the Thames eight days later. This famous corporation, after her Majesty had been reigning nearly ten years, possessed only fourteen ships, with an aggregate of 14,600 tons. Now it owns a princely fleet of fifty-three ocean steamers, with a total capacity of 142,320 tons. Practically the voyage to India in her Majesty's reign has been diminished by one-half at least.

Also since the Queen's accession the passage between the British Isles and the Commonwealth of Australia has grown shorter, from the ninety days taken by the sailing clippers to the fifty-three days occupied by Brunel's 'Great Britain.' At the present time it lasts from thirty to thirty-five days by the Suez Canal route, while it has been finished in as little as twenty-eight days. Australia is consequently only half as far away, in time, as it was; while, if the Suez Canal were closed for any reason, we have at our disposal, in addition to the Cape route with its quick steamers, which is linked to us by the Pacific Ocean road, the splendid service of that Empire-consolidator, the Canadian Pacific Railway.

The important part played by the Suez Canal in this connection will be discussed a little later. Now I am merely indicating by a few well-known facts the diminution of distance by the improvements which have been made in the ships themselves and in their propelling machines.

Across the Atlantic the rapidity of traveling and the general average speed of all cargo steamers have increased remarkably. Very interesting statistics on this point were given to the British Association for the Advancement of Science last year, at Dover, by Sir William White, in the Presidential Address of Section G. We may say, without repeating details, that during the last half of the nineteenth century the breadth of the Atlantic has practically been diminished one-half.

In 1857 the Union Company contracted to carry mails in thirty-seven days to the Cape. Now the contract time is nineteen days. This again diminishes the distance by one-half. As an instance of the remarkable change which has been made in steamships within forty years, it may be mentioned that the first 'Norman' of the Union Company took forty-two days to reach the Cape, while the present 'Norman' has covered the journey in fourteen days twenty-one hours. I need not specify particularly the equivalent acceleration of speed upon other great steamship lines. All our sea distances have been shortened 50 to 60 per cent. in an identical way.

It is not too bold to predict that the Atlantic, from Queenstown to New York, will, before long, be steamed in less than four days. The question has now resolved itself simply into this—will it pay shipowners to burn so much coal as to ensure these rushing journeys before a cheaper substitute for coal is found? We know that a torpedo-destroyer has been driven through the water at the rate of forty-three miles an hour by the use of the turbo-motor instead of reciprocating engines. Consequently an enormous increase in the present speed of the great Atlantic liners is certain if the new system can be applied to large vessels. By such very swift steamers, and by the example they will set to all established and competing steamship companies, the journey to Canada and subsequently to all other parts of the Empire will be continually quickened, until predictions which would now sound extravagant will in a few years be simple every-day facts.

We must turn next to the subject of telegraphic communication especially as it relates to the British Empire.

The mazes of land-lines and of sea and ocean cables are too numerous and intricate to be described in detail. Also the general effect of this means of bringing distant people together, and its transcendent importance for political, strategic and trade purposes, need not be too much insisted upon in this place, so obvious must they be to everyone. Yet, great as has been its power and advantage in all of those directions in the past, it is certain that still greater development and still greater service to the world will follow in the future even from existing systems, not to speak of their certain and enormous possibilities of growth. In the celerity of the actual despatch of a message we need not ask for much improvement. Lightning speed will be probably sufficient for our go-ahead children of the twentieth century. But where we may expect and shall undoubtedly get increased success is in multiplied facilities for sending telegrams all over the earth, and in widening their usefulness and convenience to all ranks and sections of the community. To obtain these necessary advantages there are two requisites—first a great and general cheapening of tariffs and, as a certain consequence of such reduced charges, a duplication or even a quadrupling of many of the present cables to prevent blocking; and, secondly, an indefinite extension of both lines and cables everywhere. Progress in submarine telegraphy undoubtedly means a lessening in the price of service and a firmer control by the State, as an obvious corollary to the large help to the companies already given by the general taxpayer, quite as much as it means those scientific inventions and scientific discoveries which the coming years have in store for us. At the present time the charges are far too high, ridiculously so as regards India, and the use of the great cables is, therefore, very often beyond the power of the small capitalist and the trader of the middle sort. Yet certain and early news is of supreme importance to large numbers of both classes. Its absence hampers or stops business, while its price is too severe a tax upon average profits. This fact has led to the invention of ingenious and elaborate codes. They might possibly have been devised in any case; but there is no doubt that messages by code would be certainly expanded so as to prevent all possible ambiguity, if telegraphing to distant countries were not so costly. The spreading of land-lines and sea-cables about the earth has gone on rapidly since 1870; to the extent that those already completed would seem even to be in advance of their requirement, if that requirement were to be measured by their full employment. Nevertheless it is to be wished that new companies could be formed and new lines laid down to excite competition and thereby to cheapen rates; or else that our Government should step in and regulate charges over subsidized British lines. For the power of the great telegraph corporations, by reason of their monetary resources, enables them to overcome ordinary rivalry and to treat public opinion with indifference. A general cheapening of rates has constantly been followed by increased profits, earned by the resulting augmentation of traffic, but it needs an enterprising directorate to face the necessary initial expenditure, except under pressure. Boldness and foresight in finance are naturally less prominent features in the management of the great telegraph companies than contentment with a high rate of interest on invested capital. All their energy and watchfulness are employed to crush competition rather than to extend their activities indefinitely. Moreover, money-making is their business, not Imperial statesmanship. If it were a question of the added security or the close coupling-up of the Empire (which are probably synonymous) on the one hand and a loss of profit (however splendid the dividends might still remain) on the other, we know what would be the result of their deliberations.

Important as are the sea-cables for statesmen, for strategy and for commerce, they are or will be equally important socially to keep up intimacy and swift intercourse between families half in Britain and half in India for instance, or between friends and relations in these Islands and in the great colonies. They might be made to give the sensation almost of actual contact, of holding the hand of your friend, of speaking directly to his heart. It is this interchange of personal news and private wishes, quite as much as the profound political and commercial aspects of lightning communication with all parts of the Empire, which will bind the Empire in bonds stronger than steel, easy as affection, to hold it together with unassailable power. Consequently the health and strength of the Empire depend very greatly upon a cheapening of telegraph charges. Doubtless a time will come when all our main cables of the first importance will be in the hands of Government, when they will only touch upon British territory, and when they will be all adequately protected from an enemy. Those are truly Imperialistic and patriotic aspirations. But we must never forget the grand part in bringing together, within whispering distance, as it were, the different parts of the world, and consequently of our world-wide Empire, which has been taken in the past by such Napoleonic organizers as the late Sir John Pender. It is to him and to such men as he that we owe those splendid beginnings which by means of vital reflexes from the nerve-center of the Empire have helped to fire our white fellow-subjects all over the globe with a loftier patriotism and with new, brave and broader ideals of nationality.

It was coincident with the opening of the Suez Canal in 1869 that the liveliest interest began to be taken in sea-cables, and a master-mind perceived their commercial possibilities. Before that time the success of the constructing companies had not been great. Sir John Pender then founded the famous Eastern Telegraph Company by the amalgamation of four existing lines, which had together laid down 8,500 miles of sea-cables, besides erecting land-lines also. A year later, in 1873, from three other companies he formed the Eastern Extension Australasia and China Telegraph Company, which jointly possessed 5,200 miles of submarine lines. From that date the extension of electric communication to all parts of the earth, over wild as well as over civilized countries, and beneath the salt water, has only been equaled by their average remunerativeness. Now there are 175,000 miles of submerged cables alone, of which this country owns no less than 113,000 miles. The history of some of these cables is full of interest, and might attract the delighted attention of the lover of picturesque romance no less than the student of commercial geography. It also supplies suggestions and many facts, both to the physical geographer and to the student of seismic phenomena. Science has taught the companies to economize time, labor and material in cable-laying operations, as well as how to improve the working instruments. Human ingenuity, business perception and organizing power have shown once more their startling possibilities when directed and controlled by cool, clear-eyed intelligence combined with general mental capacity.

It is only necessary to reaffirm, for the reasons already given, the national, the imperial, the commonwealth requirement for cheap telegraphy, and the profound necessity there is both strategically and politically for complete government control by purchase, guarantee or other equitable means over main cables which connect Great Britain with her daughter states, her Indian empire, and her dependencies. Our communications with our own folk must be independent of private companies and completely independent of all foreign nations.

All the details which I have given are illustrative of man's successful energy and of his progressive ingenuity in enslaving the great forces of the earth to diminish distance, to shorten world-journeys, and to speed world-messages. Another human achievement, the piercing by Lesseps of the Suez Isthmus, has had remarkable consequences. It had been talked of in England centuries ago. Christopher Marlowe makes Tamerlane brag:

'And here, not far from Alexandria,
Whereas the Tyrrhene and the Red Sea meet,
Being distant less than full a hundred leagues,
I meant to cut a channel to them both
That men might quickly sail to India.'

The illustrious French engineer solved one great problem in 1869, only to originate others which are of profound importance to commercial geography—and to the British Empire most of all. The Suez Canal has brought India and the Australasian Commonwealth wonderfully near to our shores. It has greatly diminished many time-distances, but why has it not injured our Eastern trade? Also is there any danger or menace of danger to that trade? From the very beginnings of the great commerce, the Eastern trade has enriched every nation which obtained its chief share. It has been the seed of the bitterest animosities. It alienated Dutch and English, blood relations, co-religionists, co-reformers, into implacable resentment, and bitter has the retribution been. On the other hand it brought into temporary alliance such strange bedfellows as the Turks of the sixteenth century and the Venetians. At the present day what international jealousies and heartburnings has the same rivalry not fostered! For all the trading peoples know how vital is that traffic.

In the earliest days of commercial venturings the Eastern trade focused at Alexandria, afterwards at Constantinople and the Italian 'factory' stations of the Eastern Mediterranean. Barbarous upheavals in Central Asia interrupted the current at times, but only as temporary dams. Then came Vasco da Gama's voyage round the Cape and its sequels—the diversion of the rich merchandise of the Orient from the Italian ports and from the Eastern Mediterranean to the sea-coast cities of the Atlantic. Out of the relentless scramble of the Atlantic nations for this, the grandest of the trader's prizes, the English came out bloodily triumphant and the British have remained the dominant shippers ever since. But when the Suez Canal was trenched through, a geographical reversal followed: the merchant's chief path may be said to have left the Cape circuit and to have regained the old line, with immensely added facilities, to debouch upon the Eastern Mediterranean. Why has it not affected us more profoundly? Are not geographical canons outraged by the great steamers passing by the French and Italian ports to find distributing centers in these islands? I think that theoretically it is so, even admitting that the foreign harbors are more difficult than ours. Practically only a few industries have suffered; the volume of our trade has increased greatly and it still remains easily preeminent. One of the chief explanations I believe to be this: Geographical considerations were defeated, for the time at any rate, by the excellence of our banking system when the Suez Canal was opened. The wealth of the country, then as now, instead of being separated and divided into isolated patches, was accumulated in the hands of bankers and was readily and easily available for commercial enterprises. So the necessary steamers—huge, and of special line—were built at once by our companies and launched into the Eastern trade before their rivals could begin to stir. This country had the invaluable help of its monetary facilities. Wealthy shipping corporations, once fully organized and successful, have great power, by reason of their reserves and resources, to hustle and ride off the attacks of weaker less experienced competitors. Supposing this great change had but just occurred—our advantages, though still distinct, would have been less remarkable. And in the future international trade jealousy will be keener and the competition even more severe. We must not forget that our geographical position is no longer in our favor for steamships plying from the East, and, as in the immediate past, we must throw away no chances, but seek to make up for that admitted defect by foresight, by education, by maintaining and constantly adding to our experience, and by defending and supporting that admirable system—our national banking system—which has carried us over seemingly insurmountable obstructions to brave trade triumphs.

The general considerations which I have named might lead to the inference that actual geographical disadvantages, in trade competition for instance, may sometimes be conquered by man's resourcefulness and energy. Within obvious limitations that is certainly true. At places, as we know, the borderland between geography and many of the natural sciences is often vague and confusedly interlaced. So perhaps also with mechanical and economic science our boundaries at certain spots overlap. Quick steamers, far-reaching telegraph lines, and the piercing of isthmuses by ship-canals may at the first glance appear outside the purview of the geographer. Yet from that particular aspect of geography which I have already spoken of as the Science of Distances we perceive how relevant they are, how worthy of study. Truly ours is a very catholic science, and we have seen how even the comparative value of national banking systems may help to explain seeming geographic inconsistencies, to reconcile facts with possibly unexpected results, and to show how the human element modifies, perhaps, the strictly logical conclusions of the geographer intent upon physical conditions alone. It is for the statesman and the philosopher to speculate upon the character and the permanency of such influences. Our success as an Empire will probably depend for its continuance upon a high level of national sagacity, watchfulness and resource, to make up for certain disadvantages, as I think, of our geographical position since the cutting of the Suez Canal; and it will also depend upon the comprehensive and intelligent study of all branches of geography, not the least important of which to my view is the Science of Distances—the science of the merchant, the statesman and the strategist.

A STUDY OF BRITISH GENIUS.

BY HAVELOCK ELLIS.

II. NATIONALITY AND RACE.

IT is scarcely necessary to remark that nationality and race, when used as distinguishing marks of people who all belong to the British Islands, are not identical terms and are both vague. The races—however we may describe them*—constituting the people of Great Britain are to be found in all the main divisions of the two islands, and the fact that a man is English or Scotch or Irish tells us nothing positive as to his race. Some indication of race, however, is in many cases furnished if we know the particular district to which a man's ancestors belonged, and this indication is further strengthened if we can ascertain his physical type.

In endeavoring to ascertain the ancestral roots of these eminent men I have almost entirely discarded the evidence of birthplace; so far as possible I have sought to find where a man's four grandparents belonged; if they are known to belong to four different regions it is then necessary to insert him into four groups; when the evidence is less complete he plays a correspondingly smaller part in the classification. It very rarely happens that the four grandparents can all be positively located.

I find that 76.8 per cent. of eminent British men and women are English, 15 per cent. Scotch, 5.3 per cent. Irish and 2.9 per cent. Welsh. The proportion of English is very large, but if we take the present population as a basis of estimation it fairly corresponds to England's share; this is not so, however, as regards the other parts of the United Kingdom; Wales, and especially Ireland, have too few people of genius, while Scotland has produced decidedly more than her share.†

*For an admirable and lucid summary of the present position of this question see Ripley's 'Races of Europe', ch. xii.

† In a recent careful study ('Where We Get Our Best Men,' London, 1900,) Mr. A. H. H. Maclean has shown that of some 2,500 British persons of ability belonging to the nineteenth century 70 per cent. are English, 18 per cent. Scotch, 10 per cent. Irish, and 2 per cent. Welsh. We thus find that by taking a much lower standard of ability and confining ourselves to the most recent period, Scotland stands higher than ever, while Ireland benefits very greatly at the expense of both England and Wales. This is probably not altogether an unexpected result. It is on the whole confirmed by an analysis of British 'Men of the Time,' made by Dr. Conan Doyle ('Nineteenth Century,' Aug., 1888).

If we consider separately the eminent persons in whose ancestry two or more of the elements of British nationality (English, Welsh, Scotch and Irish) are mixed we find that the English proportion is only 51 per cent., the Scotch 16.8, while the Irish element has risen to equality with the Scotch, 16.8, and the Welsh is as high as 15.4. This would seem to indicate that the Irish and the Welsh are especially adapted for cross-breeding in the production of genius.

If we turn to the eminent persons of partly foreign blood (those of wholly foreign blood, like Disraeli, the elder Herschel and Romilly, being necessarily excluded from our study) we find that they constitute a very inconsiderable proportion of the whole. A strain of foreign blood (not going further back than the grandparents) occurs, so far as the 'Dictionary' enables us to ascertain it, only forty-six times. In twenty-four of these cases the element is French (at least half of them being Huguenot), in six German, in six Dutch. The most noteworthy fact about these elements of foreign blood is the peculiarly beneficial effect a French strain has in producing intellectual ability.

It is somewhat remarkable that the geographical distribution of eminent women by no means follows that of eminent men. Here, after England, Ireland leads, and Scotland is but little ahead of Wales. The intellectual brilliancy of Irish women is, indeed, remarkable, and has been displayed in literature as well as on the stage.

These facts serve to indicate that on the whole British ability has not been very unfairly distributed over Great Britain. We are still entitled to ask whether it is also fairly distributed among the populations of different physical type inhabiting the British Islands.

In investigating this point I have supplemented the somewhat scanty information contained in the 'Dictionary' by examination of such portraits of these eminent persons as I have been able to find in the London National Portrait Gallery, and I have confined myself almost exclusively to the color of the hair and eyes. For various reasons the data thus obtained are not altogether satisfactory; the imperfect and often vague statements of the biographers, the frequently faded tones of the pictures, sometimes badly hung, have furnished indications which are often doubtful and not seldom conflicting. An artist is a reliable observer in such matters, but he is liable to disregard the facts in order to obtain his effect, as we may see in Millais's portrait of Gladstone in the National Gallery, where the eyes are represented of quite different colors, one blue, the other brown. The evidence in some cases has been so conflicting that I have had to disregard it altogether, and in many cases the results obtained are probably only an approximation to the truth. With these allowances, however, we may still obtain results which have some value and are not without interest.

From the point of view of hair-color and eye-color I have divided

British persons of genius into four classes: Fair (with blue or predominantly blue eyes, and light or brown hair), Mixed (with greenish, blue-yellow or blue-orange eyes,* and brown hair), Dark (hazel or brown eyes and brown or black hair), and a class of individuals belonging to the so-called 'Celtic type' (blue or gray eyes and more or less black hair). The Fair type includes 22 per cent. cases, the Mixed type 29 per cent., the Dark type 41 per cent., and the Celtic type 8 per cent. This result probably indicates that all the races occupying Great Britain—however we may define or classify those races—have furnished their contribution to British genius. The interesting and somewhat unexpected fact which emerges is the undue predominance of the Dark class, a predominance by no means exclusively due to Irish and Welsh influences, since very dark men of genius have been furnished by the Scotch Lowlands and the English eastern counties, where the populations are, on the whole, decidedly fair. This tendency is the more striking when we recall that the aristocratic class shows a tendency to fairness, and that our men of genius have been largely drawn from that class. It would be out of place, however, to discuss further the question of pigmentation.

While British genius is thus spread in a fairly impartial manner over the British Islands, and while all the chief physical types appear to have contributed men of genius, there are yet certain districts which have been peculiarly prolific in intellectual ability. In England there are two such centers, the most important being in Norfolk and Suffolk, and to some extent the adjoining counties; Norfolk stands easily at the head of British counties in the production of genius.† The other English center is in Devonshire and Somerset. In Scotland a belt running from Aberdeen through Forfar, Fife, the country round Edinburgh, Lanark (including Glasgow), Ayr and Dumfries is especially rich in genius. In Ireland the chief center (if we leave Dublin out of consideration) is in the southeastern group of counties: Kilkenny, Tipperary, Waterford and Cork; there is a less important north-eastern center in Antrim and Down.

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*It may be necessary to point out that eyes vary in color from unpigmented (blue) to fully pigmented (brown); between these two extremes we have various mixtures of blue with yellow or brown. The so-called 'black' eye is really brown.

† It may be noted that the founders of New England, both on the political and the religious sides, were mainly produced by this East Anglian center of genius. The people of this region are racially connected with the Dutch, and have always combined a genius for statesmanship and an aptitude for compromise with an inflexible love of independence. I may add that I have dealt more fully with some of the points touched on in this section in an article on the geographical distribution of British ability, shortly to appear in the *Monthly Review*.

III. SOCIAL CLASS.

In considering to what social classes the 902 eminent British men and women on our list belong, we naturally seek to ascertain the position of the fathers. In 262 cases it has not been easy to pronounce definitely on this point, and I have, therefore, classed these cases as doubtful. The remaining 640 may be classed with a fair degree of certainty. I find that they fall into the following groups: Upper Classes (or 'good family') 110 (12.2 per cent.), Yeomen and Farmers 39 (4.3 per cent.), Church 113 (12.5 per cent.), Law 49 (5.4 per cent.), Army 26 (2.9 per cent.), Medicine 26 (2.9 per cent.), Miscellaneous Professions 80 (8.9 per cent.), Trade 113 (12.5 per cent.), Crafts 63 (7 per cent.), Unskilled Workers 21 (2.3 per cent.), while the remaining 262 of doubtful origin constitute 29 per cent. of the whole. In a very few cases (not more than half a dozen) the status of the father is entered under two heads, but, as a rule, it has seemed sufficient to state what may be presumed to be the father's chief occupation at the time when his eminent child was born.

In the order in which I have placed the groups they may be said to constitute a kind of hierarchy. I place the Yeomen and Farmers immediately after the Upper Class group. Until recent years, the man who lived on the land which had belonged to his family for many centuries occupied a position not essentially different from that of the more noble families with somewhat larger estates around him. Even at the present day, in remote parts of the country it is not difficult to meet men who live on the land on farms which have belonged to their ancestors through several centuries. Such aristocrats of the soil, thus belonging to 'old families,' frequently have all the characteristics of fine country gentlemen, and in former days the line of demarcation between them and the 'upper class' must often have been difficult to draw. I have formed my 'upper class' group in a somewhat exclusive spirit; I have not included in it the very large body of eminent men who are said to belong to 'old families'; these I have mostly allowed to fall into the 'doubtful' group, but there is good reason to believe that a considerable proportion really belong to the class of small country gentlemen on the borderland between the aristocracy in the narrow sense and the yeoman and farmer class. To this class, therefore, must be attributed a very important part in the production of the men who have furnished the characteristics of British civilization.

The same must be said of the clergy (including dissenting ministers of all denominations), whom I place next because they are largely drawn from the same ranks and have on the whole led very similar lives. The religious movements of the past century have altogether transformed the lives of the clergy, but until recent years the parson was usually simply a country gentleman somewhat better educated, more in touch with intellectual tastes and pursuits, than the other country gentlemen among whom he lived. The proportion of distinguished men and women contributed from among the families of the clergy can only be described as enormous. In mere number the clergy can seldom have equaled the butchers or bakers in their parishes, yet only two butchers and three bakers are definitely ascertained to have produced eminent children, as against 113 parsons. Even if we compare the Church with the other professions with which it is most usually classed, we find that the eminent children of the clergy considerably outnumber those of lawyers, doctors and army officers put together. This preponderance is the more remarkable when we remember that (although I have certainly included eminent illegitimate children of priests) it is only within the last three and a half centuries that the clergy have been free to compete in this field. Law, Medicine and the Army furnish contingents which, though very much smaller than that of the Church, are sufficiently important to be grouped separately, but all the remaining professions I have thrown into a single group. These are: Officials (Government officials, noblemen's stewards, clerks, etc.) 19, Artists (painters, sculptors, engravers, architects) 15, Actors, etc., 14, Musicians, Composers, etc., 8, Naval, etc., 8, Men of Letters 5, Schoolmasters 4, Engineers, Surveyors and Accountants 4, Men of Science 3. Although so few of the fathers of eminent men can be described professionally as men of letters or men of science, it must be added that in a considerable number of cases literary or scientific aptitudes were present.

We now reach a group of altogether different character, Trade. It is a group of great magnitude, but its size is due to the inevitable inclusion of a very large number of avocations under a single heading. These avocations range from banking to inn-keeping. The bankers evidently form the aristocracy of the trading class, and a remarkable number, considering the smallness of the class (not less than 8), have been the fathers of eminent sons. Under the rather vague heading of 'Merchants' we find 16, and there are 6 manufacturers. Wine merchants, brewers, vintners, publicans and others connected with the sale or production of alcoholic liquors have yielded as many as 13 distinguished sons, who have often attained a high degree of eminence, from Chaucer to Joule. Tea and coffee are only responsible for one each. There are 8 drapers, mercers and hosiers, and 6 tailors and hatters; grocers and a great number of other shop-keeping trades count at most 3 eminent men each. It is, perhaps, noteworthy that at least 4 Lord Mayors of London have been the fathers of distinguished sons; only one of them (Gresham) attained fame in business, the others becoming men of letters and scholars. It must be added in regard to this group that in a certain number of cases the particular 'trade' or 'business' of the father is not specified.

The group which I have denominated 'Crafts' is closely related to that of 'Trade,' and in many cases it is difficult or impossible to decide whether an occupation should be entered under one or the other head. But, speaking generally, there is a very clear distinction between the two groups. The trade avocations are essentially commercial, and for success they involve, above all, financial ability; the crafts are essentially manual, and success here involves more of the qualities of the artist than of the tradesman. Just as the banker is the typical representative of commercial transactions, so the carpenter stands at the head of the crafts. There seems to be something peculiar in the life or aptitudes of the carpenter especially favorable to the production of intellectual children, for this association has occurred as many as 13 times, while there are 4 builders. No other craft approaches the carpenter in this respect; there are 5 shoemakers, 5 cloth-workers, 5 weavers (all belonging to the early phase of industrial development before factories), 5 goldsmiths and jewelers, 4 blacksmiths, while many other handicrafts are mentioned once or twice.

Finally, we reach the group of parents engaged in some unskilled work, and, therefore, belonging to the very lowest social class. It is the smallest of all the groups, and, though including some notable persons, it can scarcely be said to be a preeminently distinguished group. As many as 8 of the parents were common soldiers, the rest mostly agricultural laborers.

It may be interesting to inquire whether our eminent men, when grouped according to the station and avocation of their fathers, show any marked group-characters; whether, in other words, the occupation of the father exercises an influence on the nature and direction of the intellectual aptitudes of the son. To some extent it does exercise such an influence. It is true that there are eminent men of very various kinds in all of these groups. But there is yet a clearly visible tendency for certain kinds of ability to fall into certain groups. It is not surprising that there should be a tendency for the son to follow the profession of the father. Nor is it surprising that a great number of statesmen should be found in the upper class group. Men of letters are yielded by every class, perhaps especially by the clergy, but Shakespeare and, it is probable, Milton belonged to families of yeomen. The sons of lawyers, one notes, even to a greater extent than the eminent men of 'upper class' birth, eventually find themselves in the House of Lords, and not always as lawyers. The two groups of Army and Medicine are numerically identical, but in other respects very unlike. The sons of army men form a very brilliant and versatile group, and include a large proportion of great soldiers; the sons of doctors do not show a single eminent doctor, and if it were not for the presence of two men of the very first rank—Darwin and Landor—they would constitute a somewhat mediocre group. It is an interesting, and I think a significant, fact that the fathers of as many as 25 artists exercised either a craft or some trade very closely allied to a craft. Great actors and actresses, more than any other group of eminent persons, tend to be of low, obscure or dubious birth; 4, at least, can be definitely set down as the children of unskilled laborers.

When we survey the field of investigation I have here very briefly summarized, the most striking fact we encounter is the extraordinary extent to which British men and women of genius have been produced by the highest and smallest social classes, and the minute part which has been played by the 'teeming masses' in building up British civilization. This is not altogether an unexpected result, though it has not before been shown to hold good for the entire field of the intellectual ability of a country.* To realize the enormous preponderance of the aristocracy in the production of these eminent men, and the oligarchic basis of British civilization, it must be remembered not only, as I have already pointed out, that a very considerable proportion of the 'Doubtful' group belong to 'old families,' which are certainly often 'good families,' but also that I have excluded altogether the children of peers, notwithstanding that they form a group which has played a very important part indeed in the national life. As we descend the social pyramid, although we are dealing with an ever-vaster mass of human material, the appearance of any individual of eminent ability becomes an ever rarer phenomenon, while the eminent persons belonging to the lowest and most numerous class of all are, numerically at all events, an almost negligible quantity.

One is tempted to ask how far the industrial progress of the nineteenth century, the growth of factories, the development of urban life, will alter the conditions affecting the production of eminent men. It seems clear that, taking English history as a whole, the conditions of rural life have been most favorable to the production of genius. The minor aristocracy and the clergy—the 'gentlemen' of England—living on the soil in the open air, in a life of independence at once laborious and leisurely, have been able to give their children good opportunities

*In Maclean's statistical study of the origins of British men of ability during the nineteenth century it is shown that 26 per cent. of those of known origin were sons of 'aristocrats, officials, etc.'; the result was almost identical when the 100 men of preëminent ability were considered separately. Mr. C. H. Cooley ('Annals of the American Academy,' May, 1897) investigated the point in regard to a group of distinguished European poets, philosophers and men of letters, and found that 45 belonged to the upper and upper middle classes, 24 to the lower middle class, and only 2 to the lower class.

for development, while at the same time they have not been able to dispense them from the necessity of work. Thus, at all events, it has been in the past. How it will be in the future is a question which the data before us in no way help to answer. So far as can be seen, the changing conditions of life have as yet made no change in the conditions required for producing genius. Life in the old towns formerly fertile in intellectual ability—towns like Edinburgh, Norwich, Bury St. Edmunds and Plymouth—was altogether unlike life in our modern urban centers, and there is yet no sign that the latter will equal the former in genius-producing power. Nor is there any sign that the education of the proletariat will lead to a new development of eminent men; the lowest class in Great Britain, so far as the data before us show, has not exhibited any recent tendency to a higher yield of genius, and what production it is accountable for remains rural rather than urban.

DISCUSSION AND CORRESPONDENCE.

RANDOM REMARKS OF A LADY SCIENTIST.

To the Editor: I am a lady scientist, and I suppose you will think it very rude in me to intrude what I think into the grand affairs of a great scientific magazine. But I really must say to you that it is very shameful of you to encourage Mr. Starr Jordan to indulge his fiendish delight in depreciating feminine science—Karyokinesis. I feel his attack bitterly, for after passing an examination—equal to that described by Monsieur Arago in his Autobiography, during which a bright young man of more than usual assurance even for a Frenchman was so put upon by old Mr. Monge, the mathematician, that he fainted and had to be carried out past Mr. Arago and the other gentlemen in the antechamber on a shutter—in astronomy, geology, chemistry, physics, meteorology both in the past perfect and future indicative, mathematics and sociology, I obtained my present position as copyist at $480 per annum in the Direction of Science, Division of Karyokinesis.

I do not believe at all in this ex-post-facto theory of abolishing time and space, which is unconstitutional, anyhow, because it is forbidden by the Declaration of Independence and is imperialism. Now, I am going to take Mr. Starr Jordan up, word for word, and show that he is simply ridiculous.

Telepathy is a pure science. It is pure because it was a woman who invented it. No man could ever have had the sense to get up such a science. A man's intellect is fatally defective. You positively can not make it comprehend that if everybody stops doing drudgery because the world is an oyster, things will go on just the same, if not better. I know there are exceptions, but such exceptional men are really, speaking psychologically, women, and may for convenience of reference be called Untermenschen; and probably Mr. Alexander Dumas, fils, was describing one of these gifted minds in his charming moral story where Count Petit Lavellère de Château-Bourbon capers about the sleeping-apartment of Madame Revocation de la Tour de Nesle on all fours like a spaniel, with her real point-lace handkerchief in his mouth.

Compare the delicate suggestiveness of this beautiful picture with the coarse vulgarity of a vile Scot's lord at a card party when his partner, the Viscountess Smith, played the wrong card. "You old bitch," roared the *noble (!)* lord, "what did you play that card for?" And then, recalled to his environment by the look of astonishment on her ladyship's face, he blurted out: "Your pardon's begged, mum. I thought I was speaking to me wife," just as though that poor woman was his 'chum.'

Of course, at this stage of scientific expansion it is impossible to rear every man as an *Untermensch*, as we should be able to rear him were we in possession of the universities, and like he is reared in the seraglio by the eunuchs and the ladies of the harem so quaintly pictured by Lord Byron, a man of strong Turkish characteristics, in his sweet tale of Don Juan. When, however, advancing civilization has discredited the vague and unsatisfactory principle of evolution or the survival of the fittest or force science for the immediate and visible principle of Karyokinesis, or egg science, which depends on hatching and not on principle, however, then the strange notion that the meaning of childhood is to give time to live through the history of the race will be discarded, and it will be openly taught that a child goes through this time-killing process in its own mother's bosom, and that telepathy is, therefore, particularly a feminine science, as it is only a woman who can write history based on original facts at the rate of 40,000,000 years in nine months. When the world has been brought to respect the true literary function of woman, then she will recognize her duty to rescue history by properly editing her historical productions on the part consecrated by immemorial usage to that purpose, and not till then.

Now, I must say that I think all this fault-finding about instrumentation is just too silly for anything; but I don't think Mr. Starr Jordan is as bad as some other people I know. It always seemed to me that some of these men, perhaps even the married ones who live in a far, far away State, are just put out because so many pretty girls, and as many ugly ones as could ring in, *crowd* around the telepathic *savant* and *never* go near *them*. But I am not speaking of the vanity of men, which is simply immense; for, as in the Dark Ages, devoted women fled from the brutality of the world and vowed their maidenhood to Heaven in a nunnery, so I have vowed myself to science in the Division of Karyokinesis.

Men have their principia as a starting point in their 'science of brains,' as I suppose they would call it, and it winds up in the 'conservation of energy'; and now they are trying to find out the meaning of a star's childhood which it passes in the Milky Way, just as though that wasn't the proper place for an orphan to be born in. Women have their Karyokinesis for a starting point and wind up in telepathy. Where is the difference? Our science is older than theirs as a philosophy. What is the meaning of chivalry but adoration of Karyokinesis? What is the cell theory but chivalry materialized? Well might the genus beautifully symbolized as the slave of the lamp in Aladdin's Wonderful Lamp kick up such a row when Aladdin wanted an egg put under the skylight of his palace.

The feminine in science acknowledges no master save caprice—whim and an Uebermensch. Yet, while on the surface it is Uebermensch enthroned, beneath all is an unstable equilibrium caused by would-be Uebermenschen who are exploiting the wide interval between the reigning Uebermensch's promises and his performances. This is the basis of Karyokinetic sociology. Pious wishes, not natural laws, is its normal motto, and each for himself and the devil take the hindmost is its only possible principle of action. The 'psychology of the mob' thus is lifted from a subordinate to a primary social fact, and comes to mean the same as though it read 'the psychology of fashions,' which are supposed to be made in Paris. It is very absurd to hear the man intellect vaporing about the great social axioms which a self-perpetuating society *must* obey, and the rule of action which a *manly* and only possibly true non-imperialistic people *must* try to follow out if it wishes to stamp out imperialism, and the so-called 'laws' which your stick-in-the-mud scientists are formulating at a snail's pace—laws which 'prove' the accuracy of these 'majestic' generalizations of Moses and of Jesus. No, the feminine in science demands immediate, up-to-date facts, or, if it will afford Mr. Starr Jordan any satisfaction, hysterical theories for its inductions, and these are furnished by telepathy, which, like every dramatic science, requires scenery and stage furniture, so as to be able to tell the past by the actual *me*, the cogito ergo sum automaton, not by the interrogation of invaluable sequence and stuff.

Seated upon his stage, surrounded by a painted vale of Italian softness and bathed in an atmosphere of amorous music and perfumes, with soft couches that invite the drowsy indolence that crawls upon the intellect, the telepathic physiological psychologist or Uebermensch can not, it is true, get ahead of the future; but he can get behind the past; he can annihilate time, he can annihilate space, for by the magic power of his resistless will he can make the cells of the nervous system retrokaryokinetate to the period when they opened and shut a bivalve or sojourned upon the planet Mars. This, then, is the difference between a telepath and a charlatan: the charlatan is a broker who deals in futures; the telepath is a commission merchant who deals in eggs.

Rebecca Sharpe.

P. S.—As I go over this to put in missing commas and words, it seems to me that it is made up crazy quilt patchwork fashion, so I suppose it is hardly a virtue to say that, though I first mixed it all up and then wrote it out of my own head, I got the woman facts from old Mrs. Blackleg, who keeps the boarding-house where I lodge, and the sociological facts from a poor fellow who is madly in love with me and has proposed ever so many times, though I have never given him the slightest encouragement, no, never; but he will, and he will, and he will. Not that I am no scientist and don't know original facts. That is not true, for when I was studying up for examination I noticed how the jellyfish Medusa could easily heal its wounded nervous system, and the starfish, too, and so needed no protection, as every part could go off on its own hook; and then how Nature, in making a more centralized nervous system, made a limestone coat for the poor thing, and so on, until I, trying to work out the puzzle of mental fatigue, found that the dear old lady made a clean jump to a double nervous system for backbone animals, one set for vascular work and the other for fighting purposes, and brains made ribs of the entrenchment of the clam and the cuirass of the turtle. And without bothering you any more, I only want to say that when man and woman were somatically one, and when, for purposes best known to a wise and unscrupulous Providence, they somatically became two, that woman remained mankind and nearer to nature, and man must be regarded as a mere *freak*, which accounts for his ridiculousness and his 'laws,' which are the dread enemies of the worship of Karyokinesis. But I forget all this when riding home in the cool evening air, and the electric car goes bobbing up and down as it tears down the hill, and I hug up close to that broad-shouldered social wretch who is fighting Mrs. Blackleg and her telepaths for my happiness.

CHRISTIAN SCIENCE.

To the Editor: It certainly has been sufficiently obvious, by the communication of Mr. Smith in your February issue, that the means of thought-communication between 'material scientists' and 'Christian Scientists' are by no means easy or adequate. Not being able to rise above 'human logic,' I am placed along with many other worthies, in whose company I take pride, amongst the 'materialists,' and am accordingly and very properly reminded that my opinion on matters pertaining to religion and to Christianity are of little consequence. Let it be also noted *en passant* that I am not regarded as having attacking 'Christian Science,' but only credited with the belief that I thought I had. Consistently with their own doctrines this really should amount to the same thing. So it will be well to disclaim any intention of attacking, in the personal sense which your correspondent gives to the discussion, the upholders of this or any other faith. It is always important to keep in mind the admonition of Huxley that in controversy one should not wander from the really essential question of what is right and what is wrong to the entirely unimportant matter of who is right and who is wrong.

But my main purpose in sending this note is to protest against the assumption of my critic that the representatives of Christianity are arrayed with him and against me in the advocacy of certain doctrines which I insist are not characteristically religious ones, and which, if they are distorted into a religious guise, can not by that shift escape the candid comment of commonsense science. It is an injustice to the representatives of Christian faiths to put them, by implication or assertion, in the position of giving support to tendencies which they have an equal interest with the expounders of science in opposing. I shall content myself with one quotation from an authoritative source—Bishop Fallows, of Chicago—which places this dubious attempt to mingle religion with unscientific medical dogmas in the only light in which right-minded persons of whatever training can complacently look upon it.

"If my good friends," says the Bishop, "are going to start, or believe in a professed religious system because they have been healed through the influence of a mental law as universal as gravitation, the people who have been cured by patent nostrums have just as much reason to establish a religious cult of Christian liver pillists, Christian Sarsaparillists, Christian Celery Compoundists, or Christian Cholera Mixturists, as had Mother Eddy to found a church of Christian Scientists. 'By their fruits ye shall know them.' I do know some of the best Christians living who believe with unshaken faith that they were cured by these patent nostrums. But they have had the good sense to remain in the church and not claim a special dispensation for the discoveries of their favorite patent medicines."

Joseph Jastrow.

University of Wisconsin.

THE INVENTOR OF THE SEWING MACHINE.

To the Editor: In the November Popular Science Monthly the munificent gift of Miss Helen Gould for a Hall of Fame is noticed, and thirty names are designated as the choice of certain prominent men (not named) for place therein as the most eminent Americans.

In the list given the name of Elias Howe appears, which must produce astonishment in the minds of every one who has a knowledge of him or of the history of the sewing machine, upon which alone his claim to notoriety rests. To all who are acquainted with the advent of that machine, Howe occupies a very minor place. Patents were granted for such machines long before Howe entered the field, and he never succeeded in producing a practical machine, until more than one device invented by others was added to it.

Several inventors were striving to make a practical sewing machine, which was finally accomplished on different lines by some of them. The fact that Howe received royalties from these men, who procured the extension of his patent, was a matter of policy that we pass as irrelevant to the question of the introduction of this great public acquisition, in which he took no active part.

Howe was not a first-class mechanic, and the devices he patented were all elaborated before him by others, and not until other important devices were added did the sewing machine come into use. To place his name on the roll of fame above a host of his superiors on the records of the Patent Office would be doing American genius a grave injustice that would render the Hall of Fame absurd. I trust no such radical mistake will be perpetrated.

Vindicator.

SCIENTIFIC LITERATURE.

THE FOUNDATIONS OF KNOWLEDGE.

Little doubt can exist longer that the coolness which marked the relationship between Science and Philosophy from about 1840 until within the last decade is passing away rapidly. Thanks partly to the development of experimental psychology, partly to the broader training given at our colleges, where science has won a recognized place in the undergraduate course, the younger men who specialize in philosophy possess some acquaintance with the scientific attitude and temper. To them, and to the professed votary of science, the new work, entitled 'Foundations of Knowledge,' by Professor Ormond, of Princeton (Macmillan), can not fail to present some attractive and some curious considerations. In witness of his sympathy with the modern outlook, and to a certain extent under pressure of its demands, the 'McCosh Professor,' of all people, has striven hard to adopt an experiential basis. He sees quite clearly that neither the hide-bound empiricism of the traditional English school, nor the vaulting *a priori* dialectic of Hegel and his English-speaking derivants, suffice to philosophical salvation at present. Accordingly, he has provided a sober, straightforward analysis of the implications hidden under such terms as Experience, Knowledge, Reality. This forms the First Part of his essay. Having thus expelled traditional subjects of contention, he proceeds to consider the various characteristic ways in which knowledge grows from a less to a more complex synthesis of things. In this connection, he deals with the same material upon which metaphysicians have racked their brains time out of mind—Space, Time, Quantity, Quality, Cause, Substance, taking the stage successively. And it must be said that, although Professor Ormond's style is a trifle heavy, he contrives to set forth some sensible, fresh and, moreover, plain conclusions. But, as has been hinted, these matters are ancient history with all philosophers, as with some scientific workers. And so, this Second Part of the work does not stop here. As many are aware, the ideas just mentioned may be called static; and the modern tendency—very strong in science, equally strong with the younger philosophical men—makes its presence felt in Professor Ormond's discussion of dynamic aspects of experience. The conception of a social mind, leading to the ideas of relationship, interdependence and unitary mental life expressing itself in individuals, has attracted his close attention. It can hardly be said that he has embraced all the conclusions to which such conceptions lead necessarily. He makes reservations, or rather, the habit of his mind and the influences of his education induce him to stop short midway in his progress. Consequently, it turns out, in the Third Part of the book, that human experience possesses a 'transcendent or superordinary element.' Here, it seems, philosophy finds its peculiar work, while science deals with the ordinary or relative. Even a superficial acquaintance with the history of thought reminds us that this is a very old idea; one, too, which, like other old ideas, has been petarded often. But Professor Ormond presents it in a fresh way, and in as reasonable fashion as it is capable of assuming. Not that he justifies it, for it cannot be justified, except by Deity. At the same time, through its instrumentality he calls attention to one aspect of knowledge that has been subject to neglect of late. From this brief outline, the reader will gather, *first*, that the book possesses a certain originality of its own, it stands for solid work by its author and affords one the pleasure that such work gives. *Second*, it is attractive, because it marks a stage of transition. Ten years hence, these clean-cut distinctions within experience will have become impossible. The work is, therefore, to be commended as a faithful and forthright representation of that type of thinking which, though well aware of the futilities of eighteenth century dualism, has not yet awakened to the demands of twentieth century system. Being thus a type, it is well worth taking into consideration.

STATIONARY RADIANTS TO SHOWERS OF SHOOTING STARS.

The radiant of a shower of shooting stars is the point or area from which all the stars appear to move when perspectively projected on the celestial vault. If the tracks of a shower of meteors are laid down on a star map, and if these tracks are prolonged, all of them will intersect in a point, or, at least, within a small area—the radiant. The meteors are really moving in parallel straight lines in space. Their paths are perspectively projected into great circles of the celestial sphere, and have a common vanishing point. The case is easily understood by that of the 'sun drawing water,' which is often seen about sunset. The rays of the sun are really parallel, but they seem to radiate in all directions from the sun's disc in great circles that have a common vanishing point.

This perspective theory demands that the radiant point of a shower of meteors should rise, culminate and set by the earth's diurnal motion, precisely as the sun, or a star, rises, culminates and sets. The meteors on any night do, in fact, radiate from spots which remain fixed among the stars, and which rise, culminate and set as do the stars themselves. If the shower continues for many nights (like the Perseid shower, for instance) the place of the radiant usually shifts among the stars, as it ought to do, since its position is due to a geometric configuration which changes as the earth moves. The perspective appearances change as the place of the spectator is altered by the earth's motion in its orbit. Mr. W. F. Denning, of Bristol, England, an experienced and assiduous observer of meteors, reports that he has found cases where the appearances differ from these normal conditions. For certain showers of meteors, the radiant does not change its place among the stars as the earth moves in its orbit, but, on the contrary, the radiant remains stationary for weeks. A typical case of the sort is the shower of the Orionids. This shower persists for about two weeks (October 10-24), and the radiant remains stationary near the star υ Orionis, instead of shifting with the earth's motion as the laws of celestial perspective demand.

No satisfactory explanation of such stationary radiants has been forthcoming; and many astronomers have doubted the correctness of Mr. Denning's observations on that account. Granting that the observations are correct, an explanation of the phenomenon has been given by Professor von Niessl, of Brünn, and this explanation was briefly reported by Prof. Alexander Herschel at a recent meeting of the Astronomical Society of France. From a rather meager account of the report it appears that M. von Niessl has sought for a path of a meteor stream so situated in space and so curved that the observed phenomena would necessarily follow. Given the phenomena and the fact that they are produced by the perspective projection of the actual paths of meteors in space, he has inquired what the paths must be to satisfy all the conditions. If we assume swarms of meteors, moving with small velocities in space, in hyperbolic orbits nearly parallel, the orbits being asymptotic to the sun, meteors proceeding from such swarms would seem to have a stationary radiant. Moreover, such meteors must originate in certain fixed emissive centers in the stellar regions (beyond the solar system). The phenomena for certain aerolites whose fall has been observed are accounted for by reasonable assumptions as to the existence of the cosmical centers of emission, primitive velocity and direction.

Without seeing M. von Niessl's original paper it is impossible to give more than the foregoing brief report. It is obvious that if we assume a set of centers of emission exterior to the solar system, and suppose that they send out swarms of meteors which, in time, reach the solar system, it is possible to make reasonable assumptions as to velocity, etc., that will account for all the observed phenomena. A geometrical explanation of stationary radiants can be had in this way. It is not yet possible to say whether there is sufficient physical evidence to make the existence of such extra-solar emissive centers probable. All that can now be done is to report this essay towards a physical explanation of a very puzzling phenomenon.

THE UTILIZATION OF FOOD AND ALCOHOL IN THE HUMAN BODY.

Widespread interest has been taken in the results reported by Prof. W. O. Atwater on the food value of alcohol. These alcohol experiments constitute a part of a series of experiments on the utilization of food in the human body which have been in progress for a number of years. A technical description of a number of them forms a part of a bulletin by Professor Atwater *et al.* on 'The Metabolism of Matter and Energy in the Human Body,' just issued by the United States Department of Agriculture. The bulletin describes in detail fourteen experiments carried on with human subjects in the Atwater-Rosa respiration calorimeter. It presents additional data bearing upon the metabolism of matter and energy in the human body under conditions of rest and work, the conservation of energy under these conditions, the action of the ordinary food nutrients in the body, and the effect of muscular work upon nitrogen metabolism.

The aim in these experiments was to furnish the subject with approximately the quantity of nitrogen, carbon and energy in the basal ration that would be required to keep him in nitrogen and carbon equilibrium. This was practically attained. Upon the addition to the basal ration of an amount of alcohol or sugar furnishing approximately 500 calories of energy per day, it was found that the body appeared to store an amount of fat having practically an isodynamic value with the alcohol or sugar eaten. It is doubtful whether all the energy in the sugar was actually available to the body, some loss being sustained in transferring the sugar from the alimentary canal into the circulation. Assuming 98 per cent. of the energy of the sugar to be actually available to the body, it is calculated that this would give 505 calories of available energy furnished by the sugar, and 477 calories of extra fat stored by the body, as compared with the preceding experiments upon the basal ration.

The close agreement between the quantities of heat actually determined and the theoretical amounts furnished by the materials actually oxidized in the body is one of the interesting features of the experiments, and indicates the degree of accuracy which has been attained with the apparatus and the methods employed.

An important scientific result of these investigations thus far has been to demonstrate, in a manner which has never been done before, the application of the law of the conservation of matter and of energy in the human body.

The report is largely one of progress. The authors propose in future experiments to study further the metabolism of different classes of nutrients and the relative replacing power of the energy as furnished by different materials.

THE PROGRESS OF SCIENCE.

In the numerous reviews of the nineteenth century published in the magazines and in the daily press, science occupies the most prominent place. The news of the world for a day, as we read it in the newspaper, or for a month, as given in certain journals, may contain no reference to science, yet the contemporary events which at the time excite such general interest are forgotten, while the quiet progress of science gradually emerges in its true proportions. The century witnessed other great achievements—music in Germany, poetry in England, the novel in France, Russia and England—but these are like royal palaces, beautiful and complete, more likely now to decay than to grow. Science, on the other hand, has laid the foundations on which the future rests. The applications of science to the arts and to commerce, permitting one man to do what formerly required ten, and giving more nearly than ever before to each the return of his labor, have made modern democracy possible. The methods of science, slowly spreading and exerting their control, have made democracy comparatively safe. The results of science will help to make democracy worth the while. Thus, to take an example, there is now sufficient wealth to permit the education of each child; scientific methods will ultimately determine how he shall be educated, and science offers the material to be used in the training. It may be that we shall some day arrive at a scientific scholasticism, for atrophy and degeneration are no less real than growth and progress, but it seems probable that the history of the twentieth century will be chiefly a history of science.

The death of Queen Victoria closes an era in the history of a great nation; but, like the century, it is a somewhat artificial period. The monarchy in Great Britain is primarily a social institution, and it does not appear that the Queen exerted any influence on the development of science, except in so far as her sane and kindly character tended to maintain the peace and morality that are favorable to science. The death of the Prince Consort, forty years ago, was a distinct loss to science, for he was interested in scientific and educational problems, and showed in the case of the Exhibition of 1851 that he could exert powerful influence on their behalf. Queen Victoria was a German woman of domestic and religious type, and she was doubtless ignorant of the contributions to the physical sciences made by her subjects, while she regarded with aversion the advances in the natural sciences due to Darwin. Still, in the social heirarchy, of which the Queen was the head, science was recognized to a greater extent than ever before. Lords Kelvin, Lister, Playfair and Avebury were elevated to the peerage wholly or in part for scientific work, and minor titles have been conferred in many cases. Scientific men occupy a higher social and political position in Great Britain than in the United States, and this has been an outcome of the Victorian Age. It is not, however, due to the favor of a court, but to the great men of science of the period, and to the fact that many of these belong to the higher social classes. King Edward VII. will preside with dignity at scientific functions, but it is not likely that he will attempt to exert an active influence on behalf of science. Still, he was educated under the direction of a scientific man, Lord Playfair, and he is said to be well informed in the sciences. It is possible that he will not only give the social recognition which is not without value, but will, like the late Prince Consort, favor the direct encouragement of science by the Government.

A PROPHET is not needed to tell us that the relations between the Government and science will be closer in the twentieth century than ever before. Hundreds of millions of dollars are now annually spent by the leading nations in preparing for wars which may not occur, while only a small provision is made for the industrial wars continually in progress. In spite of recent events, it is likely that wars with ships and armies will gradually cease, and, while they continue, the results will depend increasingly on industrial and scientific factors. It is not so important for us to own warships as to know how to build and man them. It is not so essential to alter the rifle each time an improvement is made as to be able to invent and make the best rifle when needed. But supremacy among the nations no longer depends chiefly on performance in time of war. The rivalry in trade and manufactures, the struggle for material success and intellectual preeminence has become increasingly severe. As one species has supplanted another, not so much by directly opposing it, as by fitting itself better to the environment, so that nation will now survive and supplant others which is best able to adjust itself to existing conditions. First in importance are certain moral qualities which at present the State can not greatly forward; but next after these are the training and efficient use of intellectual traits, and here much can be accomplished by proper organization and the offering of opportunity. In the United States the establishment of unrivaled scientific and educational institutions would have an important function in unifying the nation and giving expression to its spirit. The patriotism and loyalty which in Great Britain find their emblem in the monarch must here seek other expression. They could take no better form than pride in the scientific and educational institutions of the nation.

As a matter of fact, the United States Government does make larger provision for scientific work than any other nation. The bills now before Congress will assign to this purpose perhaps $9,000,000. This is by no means a small sum, yet it is only 12 cents from each of us, and there is every reason to advocate its increase as rapidly as men can be found to whom the money may be safely entrusted. The Department of Agriculture and the Geological Survey have earned the confidence of the country, and their appropriations will be increased. Thus the House has approved an item allotting an additional $100,000 to the Division of Forestry. It is probable that the arts and manufactures would profit more by the establishment of a department corresponding to the Department of Agriculture than by the continuation of a protective tariff. A step in this direction will doubtless be made by this or the next Congress in the authorization of a National Standardizing Bureau. The bill has been approved by committees of the Senate and of the House, and only pressure of other business is likely to interfere with its immediate adoption. As we have already explained, the United States is in this direction far behind nations with smaller resources, and it is satisfactory to know that this state of affairs will not long continue.

THERE are two directions in which the appropriations of the Government for scientific work should be increased, and there are special reasons why these should be urged by men of science not engaged in the Government service. We refer to proper salaries for certain of the scientific men at Washington and the adequate support of the United States National Museum. It is unwise for scientific men employed by the Government to ask for an increase of salary, as they thereby lose influence and are regarded as self-seeking. A strong presentation of the unfairness of the present state of things should be made by those unconnected with the Government service. Every business man knows—and Congress is largely composed of able business men—that it is unwise to pay inadequate salaries to those who fill responsible offices. Thus the present agricultural appropriation bill, as approved by the House, allots $187,520 to the Division of Forestry, of which $2,500 is for the salary of the chief. Now the efficiency with which this large sum is expended depends on the chief, and it is clearly economical to secure the services of the best man in America. Such men are found, attracted by the great opportunities for advancing science offered by the Government service, but they are often called away to other work of equal importance with larger salary. Thus an officer of the Department of Agriculture receiving $1,800 has this year accepted a position under the Japanese Government with a salary of $7,000. Men from the Government bureaus will be found in all our universities, while it is but seldom that a man will go from a university position to Washington. The present agricultural appropriation bill contained a modest increase of salary for some of the scientific officers, but the provisions were regarded as out of order on the ground that they were new legislation. It is to be hoped that a bill will be introduced at once containing these provisions for the reorganization of the Department of Agriculture.

The needs of the United States National Museum should be urged by men of science throughout the country, because its organization is such that it has no really responsible head, whose duty it is to present its claims to Congress. The museum has developed under the Smithsonian Institution, but, as Joseph Henry pointed out, the functions of the two institutions are entirely different. It may possibly be best for the museum to remain under the Smithsonian Institution, owing to administrative reasons; but it should at least have the autonomy possessed by the Bureau of American Ethnology with an independent director. The sheds in which the great, though somewhat unsymmetrical, collections are housed at Washington are a reproach both to science and to the Government. New York City has spent millions of dollars on the building for its museum, while the National Government has done practically nothing. Every member of Congress takes pride in the National Library, and no one regrets the millions of dollars that it cost. It is but right to give material expression in the best form possible to the intellectual life of the nation. But why should not the museum have a building equally representative, and funds for the increase of its collections by well-organized scientific expeditions? It will doubtless have them if we wait long enough, but there are more efficient ways to obtain things than by waiting.

Senator Morgan has introduced a bill establishing a National Observatory of the United States on almost exactly the lines recommended in the last issue of this journal. There is now a real opportunity to secure a reform, advocated for years by our leading astronomers, and all interested in science should unite in urging the passage of the present measure. The text of Senator Morgan's bill is as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the United States Naval Observatory shall hereafter be known as the National Observatory of the United States and shall be governed by a director thereof, who shall report directly to and be under the supervision of the Secretary of the Navy.

Section 2.—That the Director of the National Observatory shall be an eminent astronomer, appointed by the President, by and with the advice and consent of the Senate, at a salary of five thousand dollars per annum, and shall be selected from the astronomers of the National Academy of Sciences unless, in the judgment of the President, an American astronomer of higher scientific and executive qualifications shall be found.

Section 3.—That the Secretary of the Navy may detail for duty as astronomers at the National Observatory such professors of mathematics and other officers of the Navy as he shall deem necessary in the interests of the public service; but on and after the passage of this act no appointments shall be made of such professors unless required for service at the Naval Academy.

Section 4.—That there shall be a Board of Visitors of the National Observatory, to consist of one Senator, one member of the House of Representatives, and three astronomers of eminence, to be selected by the Secretary of the Navy. The Board of Visitors shall make an annual visitation, or more frequent visitations, of the Observatory, advise with the director thereof as to the scientific work to be prosecuted, and report to the Secretary of the Navy on the work and needs of the observatory on or before the first day of November in each year. The members of the said board may receive an allowance not exceeding ten dollars per day each during their actual presence in the city of Washington while engaged on the duty of the board, and their necessary traveling expenses; but no officer of the Government appointed on the board shall receive any additional compensation for such duty above his actual expenses.

The probability that a National Standardizing Bureau will be authorized by the present Congress adds interest to the plans of the National Physical Laboratory recently established in Great Britain. Experimental work, somewhat limited in character, has for a long while been carried on at Kew Observatory, and it was hoped that the new laboratories might be erected near by. Plans were drawn up for a physical building to cost $30,000, and an engineering building to cost $20,000. There was, however, opposition to the erection of these buildings in the Old Deer Park, and in October the Government decided to assign to the laboratory Bushey House and the surrounding grounds, 25 acres in extent. The building as it now stands will be turned into a laboratory for the more delicate measurements, and a new laboratory for engineering will be erected. The work that it is proposed to carry out, as soon as the buildings can be occupied, includes the connection between the magnetic quality and the physical, chemical and electrical properties of iron and of its alloys, the testing of steam gauges and various kinds of springs, standard screws and electrical measuring instruments, and optic and thermometric determinations. These subjects have an evident connection with trade and industry, and there is every reason to suppose that the cost of the laboratory will be saved many fold every year by economies in the arts and manufactures, while at the same time physical measurements can be carried out in an institution of this character which no university would be likely to undertake. It should be noted that the National Physical Laboratory is under the direct control of the Royal Society, which insures the highest attainable degree of efficiency.

A valuable contribution to the study of the inert gases of the atmosphere is made by Professors Liveing and Dewar in a paper read before the Royal Society on December 13. The gases were obtained by liquefying air by contact with the walls of a vessel at atmospheric pressure cooled below 200° C. Some 200 ccm. of liquid air were thus condensed, and the more volatile portion was then distilled over into a receiver cooled with liquid hydrogen. This portion, consisting of about 10 ccm. was then passed into spectrum tubes, first, however, traversing a U-tube immersed also in liquid hydrogen. In this manner the gas was completely freed from every trace of nitrogen, argon and compounds of carbon. The tubes showed the spectra of hydrogen, helium and neon with great brilliancy, but also a large number of lines which could not be referred to any known origin. This shows conclusively that a sensible proportion of hydrogen exists in the earth's atmosphere, a point which has been much disputed in the past. If it be true, as has been shown mathematically, that owing to the velocity of the hydrogen molecule, the earth cannot retain this gas in its atmosphere, then there must be a continued accession of hydrogen to the atmosphere from interplanetary space. If this is the case, it is probable that there must be a similar transfer of other gases, and therefore the authors of the paper sought in the spectra evidence of the presence of the characteristic lines of the spectra of nebuæ, of the corona, and of the aurora. Nebular lines were found in the tubes as above prepared; but in one, the gas of which had not been passed through the U-tube, and which contained traces of nitrogen and argon, a line was found very close to the principal green nebular ray, which did not appear in the other tubes, and which may indicate that the substance that is luminous in the nebulæ is really present in the earth's atmosphere. Several lines were found which may possibly be referred to coronal rays, but further study is necessary before this can be established. Still, more doubt attaches to the auroral rays, one of which seems to be identical with a strong ray of argon. The ingenious method devised for the collection of the gases, the demonstration of the presence of hydrogen in the atmosphere, and the possibilities opened up by this manner of attack render this research notable.

The progress which has been made in recent years in determining the useful and injurious dairy bacteria, and the means of controlling their growth, has greatly promoted the intelligent production and handling of milk for household consumption and in butter-making. In this work a number of the agricultural experiment stations have taken an important part. The Storrs Experiment Station in Connecticut is among this number, and its twelfth annual report, just issued, gives an interesting résumé of the something over two hundred types of bacteria which Professor Conn has found in dairy products during the ten years he has been engaged in this work. On the basis of his studies he proposes a classification of dairy bacteria. Although the total number of species found in dairy products is large, only a comparatively few occur with very great regularity. Professor Conn concludes that those of the region represented by his investigations consist chiefly of three groups of closely related bacteria. Of these the most abundant are *Bacterium acidi lactici* I. (Esten) and *B. acidi lactici* II. (new species), which constitute the first group. The former occurs almost universally in milk and cream, is nearly always present in sour milk, and has been found by far the most abundant in all samples of ripened cream examined. The second form, while very abundant in sour milk and cream, occurs in less numbers. Several of the pure commercial cultures for ripening cream in butter-making consist of bacteria of this type. The next most important group is represented by a species regarded as identical with *B. lactis aerogenes*, and includes a number of types of great similiarity, but with different physiological characters. It has been found almost universally in milk, but never in very great numbers. Some of the pure cultures used in Europe for cream ripening appear to belong to this group. Typical sour milk, with its tendency to fragmentation and its sour odor, Professor Conn thinks, is never developed without the aid of some of the organisms of this group. The third type is the *Micrococcus lactis varians* of the author. It is common in fresh milk, and is thought to exist in the milk ducts, which is not the case with the preceding types, the source of contamination with which is believed to be entirely external. It is commonly overgrown by the lactic organisms and is less common in old milk. While the classification of dairy bacteria is regarded as necessarily a tentative one, it is offered as a basis for bringing together the work of American dairy bacteriologists.

Another paper in this report bearing on the subject of dairying relates to the use of milk of tuberculous cows—a matter of more than usual interest in view of the attention which is being given to the general subject of tuberculosis and its transmission. Experiments in using the milk of tuberculous cows for feeding calves at the Storrs Station have been in progress for several years. During the first two years, when the cows had the disease only in its earliest stages, the young cattle which received their milk and ran with them constantly, exhibited no signs of the disease as far as could be detected by the tuberculin test or physical examination. But the result for the next year and a half was quite different. Five calves were fed the milk of these same cows, and all five responded to the tuberculin test and proved to be diseased. The physical condition of three of the cows indicated that during the last year the disease had progressed decidedly in them. While the results indicate that the danger from the spread of tuberculosis to other animals through the milk is not always as great as has been supposed, they suggest the exercise of greater precaution in excluding from use for supplying family milk all cows in which the disease is sufficiently advanced to be detected. Experiments at a number of places have shown that the milk of tuberculous cows may be pasteurized and safely used for raising calves, but precautions should be taken to insure confining its use to this purpose.

Professor E. C. Pickering, director of the Harvard College Observatory, has been awarded the gold medal of the Royal Astronomical Society.—The Helmholtz medal of the Prussian Academy of Sciences has been conferred on Sir George Gabriel Stokes, of Cambridge University, this medal having been previously conferred only on Professor Virchow and Lord Kelvin.—Sir Archibald Geikie has retired from the directorship of the Geological Survey of Great Britain and Ireland.—We note with regret the death of Elisha Gray, the American inventor; of M. Ch. Hermite, the French mathematician; of Professor Max von Pettenkofer, the bacteriologist; of Frederic W. H. Myers, secretary of the Society for Psychical Research; and of Miles Rock, the American geodesist.—The International Zoological Congress will hold its fifth session in Berlin, beginning on August 12.—The Astronomical and Astrophysical Society of America will hold its next meeting in December.—William H. Crocker, of San Francisco, has offered to defray the expenses of a solar eclipse expedition to be sent by the University of California from the Lick Observatory to Sumatra to observe the total eclipse of the sun on May 17.—A bill has been introduced in the House of Representatives directing the general Government, through the Secretary of the Interior, to secure title to the cliff dwellers' region of New Mexico for park and scientific purposes, and one in the Senate appropriating $5,000,000 for the purchase of land in the Appalachian Mountains for a national forest reserve.—Mr. Joseph White Sprague has left his estate, valued at $200,000, so that it will ultimately revert to the Smithsonian Institution.—Johns Hopkins University has received a conditional gift of land for a new site valued at $700,000.—The French and German generals have removed from the wall of Pekin the superb astronomical instruments erected two centuries ago by the Jesuit fathers, and propose to send them partly to Berlin and partly to Paris. The American general has protested against this as an act of vandalism.—Dr. Adams Paulsen, director of the Meteorological Institute of Copenhagen, has gone to North Finland to study the aurora. He undertook a similar expedition last winter to North Iceland.—Prof. Baldwin Spencer and Mr. Gillen have arranged for another expedition in continuation of their investigations into the habits and folk-lore of the natives of Central Australia and the Northern Territory.

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MALPIGHI, SWAMMERDAM AND LEEUWENHOEK.

BY PROFESSOR WILLIAM A. LOCY,
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AS Cuvier justly remarks, the seventeenth century was a fruitful one for science. It was then that the method of investigating nature by direct observation and experiment was reestablished. After the long period of intellectual decline, the mental life of mankind was to be lifted again to the level it had attained in the age of the highest development of Greek philosophy. The complete arrest of inquiry into the domain of nature and the adherence to tradition had lasted so long that the faculty of testing and experimeting seemed to be almost extinct. The unfriendliness of the ecclesiastics and other intellectual authorities to investigation, and the dire consequences to the individual of a movement towards intellectual freedom, served to repress the natural desire of the human intellect for a knowledge of itself and the universe. Any one who broke over the restraints went against every appeal to self-interest, and deserved much credit for independence and courage.

Nevertheless, in this untoward atmosphere the spirit of unbiased inquiry was awakened through the efforts of a few independent minds; among these select few, who, as pioneers in the revival of exact science, have an enduring interest for all educated people, we must remember Malpighi, Swammerdam and Leeuwenhoek. Although their work marks an epoch, they were not the only pioneers, nor the first ones; Vesalius, Galileo, Harvey and Descartes had started the reform movement in which our triumvirate so worthily labored.

One of these men—Malpighi—was an Italian, and the other two were Netherlands Dutchmen. Their great service "consisted chiefly in this, that they broke away from the thraldom of book-learning, and, relying alone upon their own eyes and their own judgment, won for man that which had been quite lost, the blessing of independent and unbiased observation." The importance of this step for its broad-reaching effects even upon the intellectual life of our own time is not easily overestimated. Much of the work of the present is built upon the foundations they laid.

There is a singularly unappreciative attitude towards scientific work, of the biological kind, done before 1850, and a widespread disposition to look upon the advances of the present time as peculiarly our own, based wholly upon 'modern' work and 'modern' methods. This sometimes takes the extreme form, in the rising generation of practical workers, of looking upon the scientific investigations of the past ten years as of necessarily better quality than those of any preceding period, because they are the most recent. But this is to do injustice to our predecessors, and it is wholesome to take a look into the past, to see some of the fine observational work done long ago, and to be compelled to recognize the continuity of biological development, both as regards work and ideas.

If it were Johannes Müller with whom we were to deal, a marvel could be shown, but the work of Malpighi, Swammerdam and Leeuwenhoek belongs to a period a century and a half before his time. For these men it is just to claim, in addition to the service indicated above, the possession of the true scientific spirit, the introduction of the microscope and of more exact methods into scientific investigation, and, through their work, the beginning of that better comprehension of the natural universe that we call modern science.

It is natural that working when they did, and independently as they did, their work overlapped in many ways. Malpighi is noteworthy for many discoveries in anatomical science, for his monograph on the anatomy of the silkworm, for observations on the minute structure of plants and on the development of the chick in the hen's egg. Together with Grew, he is regarded as the founder of plant histology. Swammerdam did excellent and accurate work on the anatomy and metamorphosis of insects and the internal structure of mollusks, frogs and other animals. Leeuwenhoek is distinguished for much general microscopic work; he discovered various microscopic animalcula; he established by direct observation a connection between arteries and veins, and examined microscopically minerals, plants and animals. To him more than to the others the general title of 'microscopist' might be applied.

Let us, by taking them individually, look a little more closely at the lives and labors of these men.

MARCELLUS MALPIGHI. 1628-1694.

There are several portraits of Malpighi extant. These, together with the account of his personal appearance given by Atti,* enable us to tell what manner of man he was. The portrait given here is the

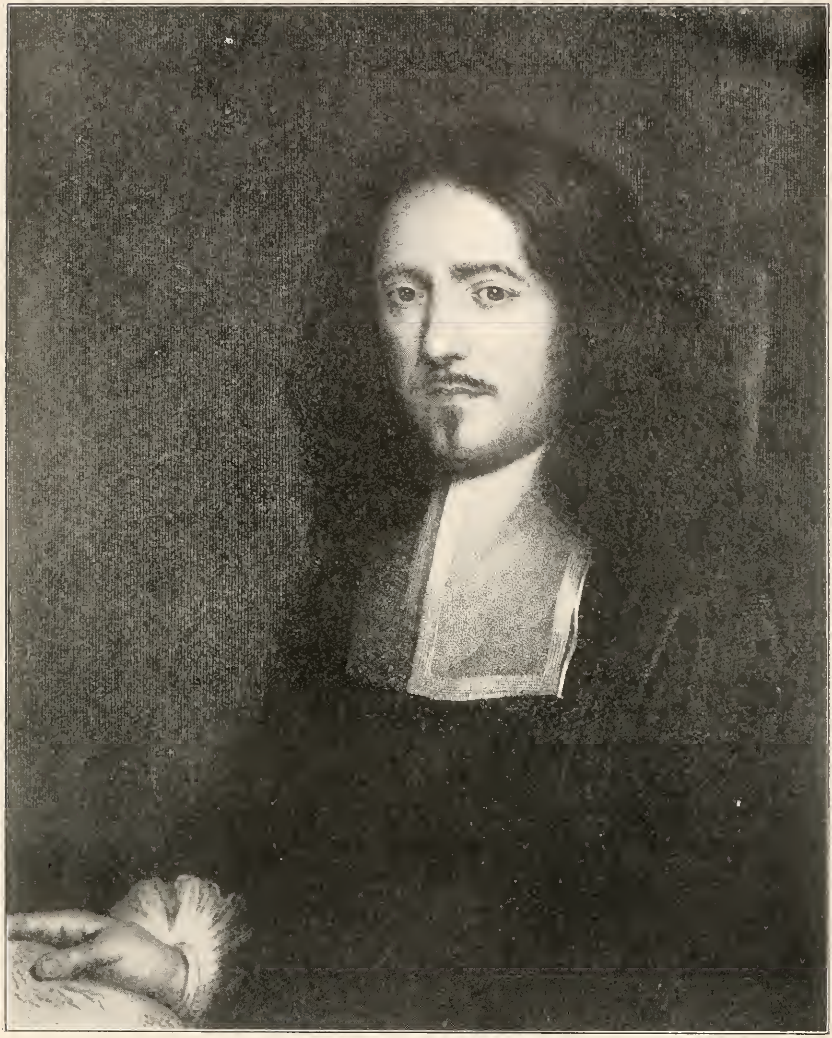

FIG. 1. MARCELLUS MALPIGHI.

one painted by Tabor, and presented by Malpighi to the Royal Society of London. As Pettigrew says, 'it shows a countenance highly intellectual, and as a work of art is of no mean importance.' Some of the other

* Atti. 'Notizie Edite ed Inedite Della Vita e Delle Opére Di Marcelli Malpighi De Lorenzo Bellini.' Bologna, 1847: 4°: 525 pp.

portraits are less attractive, and give evidence of imperfect health in the lines and wrinkles of his face. According to Atti, he was of medium stature, with a brown skin, delicate complexion, a serious countenance and melancholy look.

Accounts of his life show that he was modest, quiet and of a pacific disposition, notwithstanding the fact that he lived in an atmosphere of acrimonious criticism, of jealousy and controversy. Under all this he suffered acutely, and his removal from Bologna to Messina was partly to escape the harshness of his critics. Some of his best qualities showed under these persecutions; he was dignified under attack and moderate in reply. In his posthumous works his replies to his critics are free from bitterness and written in a spirit of great moderation. This picture from Ray's correspondence shows the same control of his spirit. Under the date of April, 1684, Dr. Tancred Robinson writes: "Just as I left Bononia I had a lamentable spectacle of Malpighi's house all in flames, occasioned by the negligence of his old wife. All his pictures, furniture, books and manuscripts were burnt. I saw him in the very heat of the calamity, and methought I never beheld so much Christian patience and philosophy in any man before; for he comforted his wife and condoled nothing but the loss of his papers."

Malpighi was born at Crevalcuore, near Bologna, in 1694. His parents were farmers, or landed peasants; enjoying a certain independence in financial matters, they designed to give Marcellus, their eldest child, the advantages of masters and the schools. He began a life of study, and showed a taste for belles-lettres and for philosophy, which he studied under Natali.

Through the death of both parents, in 1649, Malpighi found himself, at the age of twenty-one, an orphan, and, as the eldest of eight children, domestic affairs devolved upon him. He had as yet made no choice of profession, but, through the advice of Natali, he resolved, in 1651, to study medicine, and, in 1653, at the age of twenty-five, he received from the University of Bologna the degree of M. D.

In the course of a few years he married the sister of Massari, one of his teachers in anatomy, and became a candidate for a position in the University of Bologna. This he did not immediately receive, but about 1656 he was appointed to a post in the University, and began his career as teacher and investigator. He must have shown aptitude for this work, for soon he was called to the University of Pisa, where, fortunately for his development, he became associated with Borelli, who was older and assisted him in many ways. They united in some work, and together they discovered the spiral character of the heart muscles. But the climate of Pisa did not agree with him, and after three years he returned, in 1659, to teach in the University of Bologna, and applied himself assiduously to anatomy.

Here his fame was in the ascendant, notwithstanding the machinations of his enemies and detractors, led by Sbaraglia. He was soon (1662) called to Messina to follow the famous Castelli. After a residence there of four years he again returned to Bologna. He retired to a villa near the city, and devoted himself to anatomical studies.

Malpighi's talents were appreciated even at home. The University of Bologna honored him in 1686 with a Latin eulogium, the city erected a monument to his memory, and after his death, in the city of Rome, his body was brought to Bologna and interred with great pomp and ceremony. He also received recognition from abroad, but that is less remarkable. In 1668 he was elected an honorary member of the Royal Society of London. He was very sensible of this honor; he kept in communication with the society; he presented them with his portrait, and deposited in their archives the original drawings illustrating the development of the chick.

In 1691 he was taken to Rome by the newly elected Pope, Innocent XII, as his personal physician, but under these new conditions he was not destined to live many years. He died there, in 1694, of apoplexy. His wife, of whom it appears that he was very fond, had died a short time previously. Among his posthumous works is a sort of personal psychology written down to the year 1691, in which he shows the growth of his mind and the way in which he came to take up the different subjects of investigation.

In reference to his discoveries and the position he occupies in the history of natural science, it should be observed that he deserves the title of an 'original as well as a very profound observer.' While the ideas of anatomy were still vague 'he applied himself with ardor and sagacity to the study of the fine structure of the different parts of the body'; he extended his studies to the structure of plants and different animals, and also to development. Entering as he did, a new and unexplored territory, he, of course, made many discoveries, but no man of mean talents could have done his work. He used every method at his command for investigating the structure of tissues and animal forms—macerating, boiling, injections of ink and colored fluids, and also applied the microscope to the discovery of tissues.

During forty years of his life he was always busy with research. Many of his discoveries had practical bearing on the advance of anatomy and physiology as related to medicine. In 1661 he demonstrated the structure of the lungs. Previously these organs had been regarded as a sort of homogeneous parenchyma. He showed the presence of air-cells, and had a tolerably correct idea of how the air and blood are brought together in the lungs, the two never actually in contact, but always separated by a membrane. These discoveries were first made on the frog, and applied by analogy to the interpretation of the lungs of the human body. He was the first to insist on analogies of structure between organs throughout the animal kingdom, and to make extensive practical use of the idea, that discoveries on simpler animals can be utilized in interpreting the similar structures in the higher ones.

It is very interesting to note that in connection with this work, he actually observed the passage of blood through the capillaries of the transparent lungs of the frog, and also in the mesentery. Although this antedates the similar observations of Leeuwenhoek, nevertheless the work of Leeuwenhoek was much more complete, and he is usually recognized in physiology as the discoverer of the capillary connection between arteries and veins. At this same period Malpighi also observed the blood corpuscles.

Soon after he demonstrated the mucous layer, or pigmentary layer of the skin, intermediate between the true and the scarf skin. He had separated this layer by boiling and maceration, and described it as a reticulated membrane. Even its existence was for a long time controverted, but it remains in modern anatomy under the title of the malpighian layer.

His observations on glands were extensive, and while it must be confessed that many of his conclusions in reference to glandular structure were erroneous, he left his name connected with the malpighian corpuscles of the kidney and the spleen. He was also the first to indicate the presence of papillæ on the tongue. This is a respectable list of discoveries, but much more stands to his credit. Those which follow have a bearing on comparative anatomy, zoology and botany.

Monograph on the Structure and Metamorphosis of the Silkworm. Malpighi's work on the structure of the silkworm takes rank among the most famous monographs on the anatomy of a single animal. Much skill was required to give to the world this picture of minute structure. The marvels of organic architecture were being made known in the human body and the higher animals, but 'no insect—hardly, indeed, any animal—had then been carefully described, and all the methods of work had to be discovered.' The delicacy, beauty and intricacy of the organic systems in this group of animals were well calculated to arouse wonder and admiration. He worked with such enthusiasm in this new territory as to throw himself into a fever and to set up an inflammation in the eyes. "Nevertheless," says Malpighi, "in performing these researches so many marvels of nature were spread before my eyes that I experienced an internal pleasure that my pen could not describe." In the words of Miall:

"We must recall the complete ignorance of insect-anatomy which then prevailed, and remember that now for the first time the dorsal vessel, the tracheal system, the tubular appendages of the stomach, the reproductive organs, and the structural changes which accompany transformation were observed, to give any adequate credit to the writer of this masterly study. Treading a new path, he walks steadily forward, trusting to his own sure eyes and cautious judgment. The descriptions are brief and simple, the figures clear, but not rich in detail. There would now be much to add to Malpighi's account, but hardly anything to correct. The only positive mistakes which meet the eye relate to the number of spiracles and nervous ganglia—mistakes promptly corrected by Swammerdam."

He showed that the method of breathing was neither by lungs nor gills, but through a system of air-tubes, communicating with the exterior through button-hole shaped openings, and, internally, by an infini-

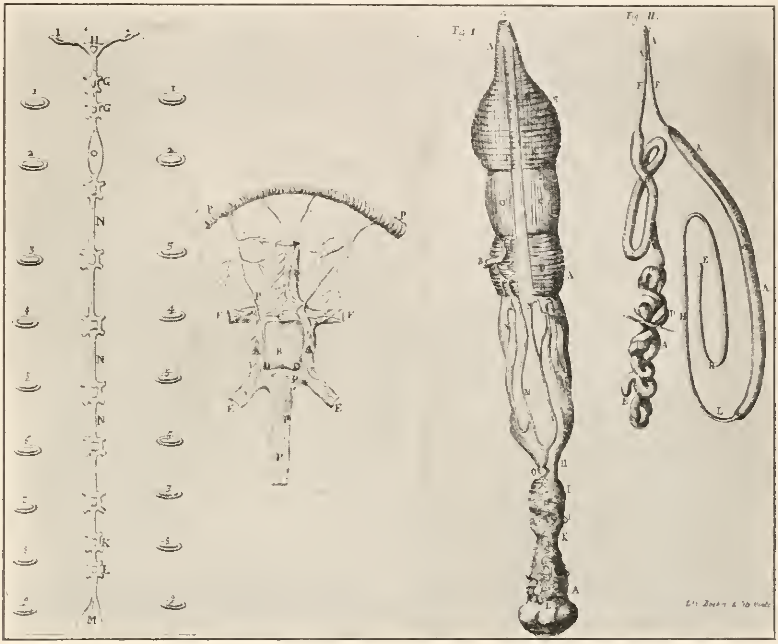

FIG. 2. FROM MALPIGHI'S ANATOMY OF THE SILKWORM.

tude of branches reaching to the minutest parts of the body. Malpighi showed an instinct for comparison; instead of confining his researches to the species in hand, he extended his observations to other insects, and he gives sketches of the breathing tubes, held open by their spiral thread, taken from several species.

The nervous system he found to be a central white cord with swellings in each ring of the body, from which nerves are given off to all organs and tissue. The cord which is, of course, the central nervous system, he found located mainly on the ventral surface of the body, but extending by a sort of collar of nervous matter around the œsophagus and, on the dorsal surface, appearing as a more complex mass, or brain, from which nerves are given off to the eyes and other sense organs of the head. As illustrations from the monograph we have, in Fig. 2, reduced sketches of the drawings of the nervous system and the food canal in the adult silkworm. The sketch at the left hand illustrates the central nerve cord, and the small one near the center shows one ganglion enlarged, and part of the breathing tubes connected with it. The original drawing is on a much larger scale, and reducing it takes away some of its coarseness. All of his drawings lack the finish and detail of Swammerdam's work.

He showed also the food canal and the tubules connected with the intestine, which retain his name in the insect anatomy of to-day, under the designation of malpighian tubules. The silk-forming apparatus was also figured and described. These structures are represented, as Malpighi drew them, on the right of Fig. 2.

This monograph, which was originally published in Latin in 1669, has been several times republished. The best edition is that in French, dating from Montpellier, in 1878, and which is preceded by an account of the life and labors of Malpighi.

Anatomy of Plants. Malpighi's anatomy of plants constitutes one of his best as well as one of his most extensive works. In the folio edition of his works, 1675-79, the 'Anatome Plantarum' occupies not less than 152 pages and is illustrated by ninety-three plates of figures. It comprises the structure of bark, stem, roots, seeds, process of germination, treatise on galls, etc., etc.

The microscopic structure of plants is amply illustrated, and he anticipated to a certain degree the ideas on the cellular structure of plants. Burnett says of this work: "His observations appear to have been very accurate, and not only did he maintain the cellular structure of plants, but also declared that it was composed of separate cells, which he designated 'utricles.'" Thus did he foreshadow the cell-theory of plants, as developed by Schleiden in the nineteenth century. When it came to interpretations of his observations, he made several errors. Applying his often-asserted principle of analogies, he concluded that the vessels of plants are organs of respiration and of circulation from a certain resemblance that they bear to the breathing tubes of insects. But his observational work on structure is good, and if he had accomplished nothing more than this work on plants he would have a place in the history of botany.

Work in Embryology. Difficult as was his work in insect anatomy and plant histology, a more difficult one remains to be mentioned, viz., his observations on the development of animals. He had pushed his researches into the finer structure of organisms, and now he attempted to answer this question: How does one of these organisms begin its life, and by what series of steps is its body built up? He turned to the chick, as the most available form in which to get an insight into this process, but he could not extend his observations successfully into periods earlier than about the twenty-four hour stage of development. Two memoirs were written on this subject, both in 1672. Of all Malpighi's work, this has received the least attention from reviewers, but it is, for the time, a very remarkable piece of work. No one can

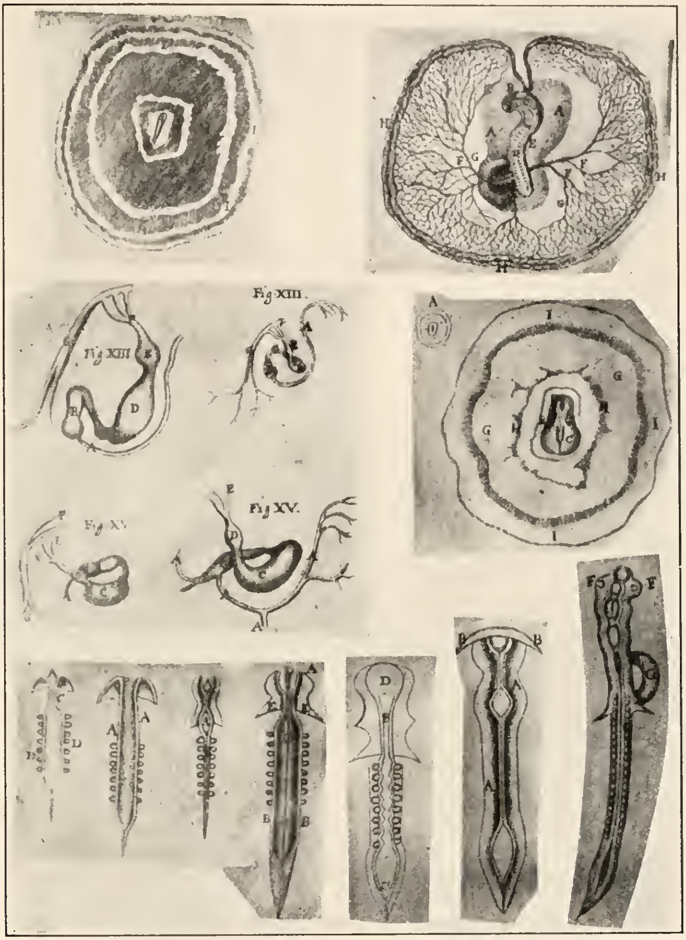

FIG. 3. MALPIGHI'S SKETCHES SHOWING THE EMBRYOLOGICAL DEVELOPMENT OF THE CHICK.

look over the ten folio plates without being impressed with the extent and accuracy of his observations. His earliest sketches show an open neural groove with an enlargement for the head end, and from this stage onward he carries the development of the chick by sketches to the period of hatching. These sketches are of interest not only to students of embryology, but also to educated people, to see how far observations upon the development of animals had progressed in 1672. His are, doubtless, the earliest figures ever made showing the comparatively early stages of development. Harvey's observations on development, published in 1631, were not accompanied by illustrations, and the sketches of Fabricius, *ab aqua pendente*, published in 1604, were far surpassed by Malpighi's, the youngest stages represented being much older than his.

Fig. 3 shows a group of selected sketches from different plates, but they fail to give an adequate idea of the extent of the work, taken as a whole. It is very interesting to note the figures showing the formation of the heart and aortic arches. The execution of the figures in this work is less coarse than those on the silkworm.

The embryological thought of his time was dominated by the theory of preformation or predelineation. Just as when we examine a seed, we find within an embryo plantlet, so it was supposed that the minute embryos of all animal life existed in miniature within the egg. Harvey had expressed himself against it, and the doctrine was overthrown by Wolff in the following century. Malpighi's position, however, was based on actual observation; he was not able to find by examination any stage in which there was no evidence of organization. Dareste says that he examined eggs in a very hot August, in which there is reason to believe that developmental changes had gone forward to a considerable degree. Be this as it may, the imperfection of his instruments and methods would have made it very difficult to have seen anything definitely in stages below twenty-four hours. As a result of his experience, he says:

"When we undertake to discover the principle of life of animals in the egg we are astonished to find the animal already formed there; thus our labor is vain, for as soon as we encounter the first movement of life we are obliged to recognize parts that are visible to our eyes. * * * On this account, it may be necessary to declare that the first beginnings preexist in the egg," etc. In his posthumous works he "is less circumspect, and goes even to the point of describing the mechanism of evolution of these primitive elements."

Malpighi was a naturalist, but of a new type; he began to look below the surface, and essayed a deeper level of analysis, in observing and describing the internal and minute structure of animals and plants, and when he took the further step of investigating their development he was anticipating the work of the nineteenth century.

JOHN SWAMMERDAM. 1637-1680.

Swammerdam was a different type of man—nervous, incisive, very intense, stubborn and self-willed. Much of his character shows in the portrait by Rembrandt. Although its authenticity has been questioned, it is the only portrait* known of Swammerdam.

He was born in 1637, nine years after Malpighi. His father, an apothecary of Amsterdam, had a taste for collecting, which was shared

FIG. 1. JAN SWAMMERDAM.

by many of his fellow-townsmen. "The vast commerce and extended colonial empire of the Holland of that day fostered the formation of private museums." The elder Swammerdam had the finest and most

* I am indebted to Professor Dr. Hoffman, of Leyden, for this copy.

celebrated collection in all Amsterdam. This was stored, not only with treasures, showing the civilization of remote countries, but, also, with specimens of natural history, for which he had a decided liking. Thus "from the earliest dawn of his understanding the young Swammerdam was surrounded by zoological specimens, and from the joint influence, doubtless, of hereditary taste and early association, he became passionately devoted to the study of natural history."

His father intended him for the church, but he had no taste for divinity, though he became a fanatic in religious matters towards the close of his life; at this period he could brook no restraint in word or action. He consented to study medicine, but for some reason he was twenty-six years old before entering the University of Leyden. This delay was very likely due to his precarious health, but, in the meantime, he had not been idle; he had devoted himself to observation and study with great ardor, and had already become an expert in minute dissection. When he went to the University, therefore, he at once took high rank in anatomy. Anything demanding fine manipulation and skill was directly in his line.

At Leyden he studied anatomy under the renowned Sylvius and surgery under Van Horne. He also continued his studies in Paris, and about 1667 took his M. D. degree.

During this period of medical study he made some rather important observations in human anatomy, and introduced the method of injection that was afterwards claimed by Ruysch. In 1664 he discovered the values of lymphatic vessels by the use of slender glass tubes and, three years later, first used a waxy material for injecting blood vessels.

It should be noted, in passing, that Swammerdam was the first to observe and describe the blood corpuscles. As early as 1658 he described them in the blood of the frog, but his observations were not published till fifty-seven years after his death by Boerhaave, and, therefore, he does not get the credit of this discovery. Publication alone establishes priority, not first observation, but there is conclusive evidence that he observed the blood corpuscles before either Malpighi or Leeuwenhoek had published their observations.

After graduating in medicine he did not practise, but followed his strong inclination to devote himself to minute anatomy. This led to differences with his father, who insisted on his going into practise, but the self-willed stubbornness and firmness of his nature showed themselves. It was from no love of ease that Swammerdam thus held out against his father, but to be able to follow an irresistible leading towards minute anatomy. At last his father was planning to stop supplies, in order to force him into the desired channel, but Swammerdam made efforts, without success, to sell his own personal collection and preserve his independence. His father died, leaving him sufficient property to live on, and brought the controversy to a close soon after the son had consented to yield to his wishes.

Boerhaave, his fellow-countryman, gathered his complete writings after his death and published them in 1737 under the title 'Biblia Naturæ.' This is preceded by a life of Swammerdam, in which a graphic account is given of his phenomenal industry, his intense application, his methods and instruments. Most of the following passages are selected from that work.

He was a very intemperate worker, and in finishing his treatise on bees (1673) he broke himself down.

"It was an undertaking too great for the strongest constitution to be continually employed by day in making observations and almost as constantly engaged by night in recording them by drawings and suitable explanations. This being summer work, his daily labors began at 6 in the morning, when the sun afforded him light enough to enable him to survey such minute objects; and from that time till 12 he continued without interruption, all the while exposed in the open air to the scorching heat of the sun, bareheaded, for fear of interrupting the light, and his head in a manner dissolving into sweat under the irresistible ardors of that powerful luminary. And if he desisted at noon it was only because the strength of his eyes was too much weakened by the extraordinary efflux of light and the use of microscopes to continue any longer upon such small objects.

"This fatigue our author submitted to for a whole month together, without any interruption, merely to examine, describe and represent the intestines of bees, besides many months more bestowed upon the other parts; during which time he spent whole days in making observations, as long as there was sufficient light to make any, and whole nights in registering his observations, till at last he brought his treatise on bees to the wished-for perfection.

"For dissecting very minute objects, he had a brass table made on purpose by that ingenious artist, Samuel Musschenbroek. To this table were fastened two brass arms, movable at pleasure to any part of it, and the upper portion of these arms was likewise so contrived as to be susceptible of a very slow vertical motion, by which means the operator could readily alter their height as he saw most convenient to his purpose. The office of one of these arms was to hold the little corpuscles, and that of the other to apply the microscope. His microscopes were of various sizes and curvatures, his microscopical glasses being of various diameters and focuses, and from the least to the greatest, the best that could be procured, in regard to the exactness of the workmanship and the transparency of the substance.

"But the constructing of very fine scissors, and giving them an extreme sharpness, seems to have been his chief secret. These he made use of to cut very minute objects, because they dissected them equably, whereas knives and lancets, let them be ever so fine and sharp, are apt to disorder delicate substances. His knives, lancets and styles were so fine that he could not see to sharpen them without the assistance of the microscope; but with them he could dissect the intestines of bees with the same accuracy and distinctness that others do those of large animals.

"He was particularly dexterous in the management of small tubes of glass no thicker than a bristle, drawn to a very fine point at one end, but thicker at the other."

These were used for inflating hollow structures and also for making fine injections. He dissolved the fat of insects in turpentine and carried on dissections under water.

An unbiased examination of his work will show that it is of a higher quality than Malpighi's in regard to critical observation and richness in detail. He also worked with minuter objects and displayed a greater skill. As one writer says:

"He had in the highest degree all the attributes which mark the eminent observer. In delicate and subtle manipulation, in contriving new methods to meet every case, in acute and accurate perception, he has never been surpassed and rarely equaled."

United with these exceptional talents as an observer was a mystical quality of mind that made his interpretations less happy, and often led him to strange ideas. It is an interesting psychological combination. His observations are accurate, but his interpretations fanciful. For instance, in observing the transformations of insects, he came to a stage in which he could see the parts of the adult insect encased, as it were, in the pupa. This led him to see, in fancy, an evidence of encasement of one generation within another in all animals and to adhere to that curious idea of *emboitement*, which had so many believers in his time. He even saw in this the proof, to his mind, that the germs of all forthcoming generations of mankind were originally located in the common mother Eve, all closely encased one within the other, like the boxes of a Japanese juggler. The end of the world was by him conceived of as a necessity when the last germ of this wonderful series had become unfolded.

The last part of his life was dimmed by fanaticism. He read the works of Antoinette Bourignon and fell under her influence; he began to subdue his warm and stubborn temper, and to give himself up to religious contemplation. She taught him to regard scientific research as worldly, and, following her advice, he gave up his passionate fondness for studying the works of the Creator, to devote himself to loving and adoring that same Being. Always extreme and intense in everything he undertook, he likewise overdid this, and yielded himself to a sort of fanatical worship until the end of his life, in 1680. Had he possessed a more vigorous constitution, he would have been greater as a man. He lived, in all, but forty-three years; the last six or seven years were unproductive from his mental distractions, and before that much of his time had been lost by sickness.

It is time to ask, with all his talents and prodigious application, what did he leave to science? This is best answered by an examination of the 'Biblia Naturæ,' into which all his work was collected. His treatise on 'Bees and Mayflies' and a few other articles were published during his lifetime, but a large part of his observations remained entirely unknown until they were published in this book fifty-seven years after his death. In the folio edition it embraces 410 pages of text and fifty-three plates, replete with figures of original observations. It "contains about a dozen life-histories of insects worked out in more or less detail. Of these, the Mayfly is the most famous; that on the honeybee the most

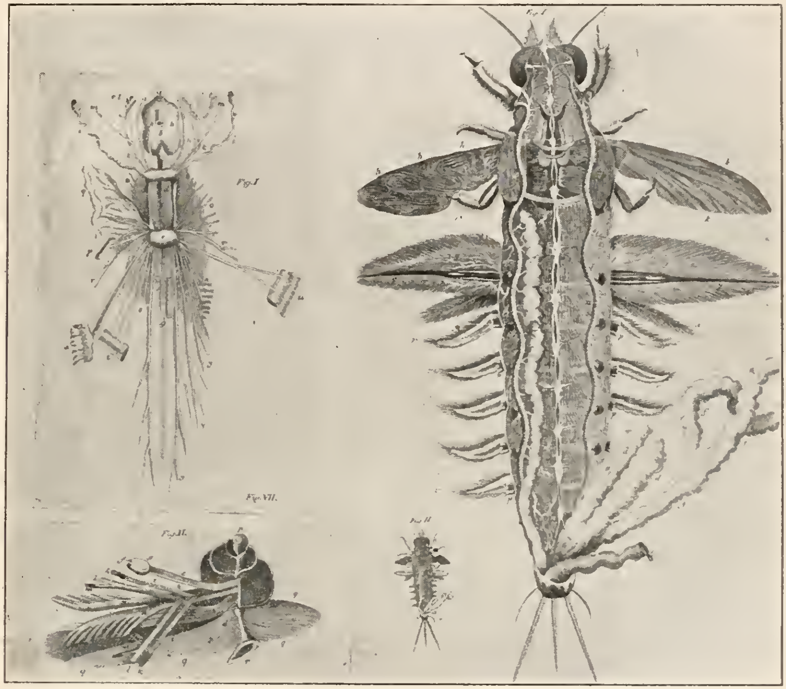

FIG. 5. FROM SWAMMERDAM'S 'BIBLIA NATURÆ.'

elaborate." The greater amount of his work was in structural entomology. It is known that he had a collection of about 3,000 different species of insects, which for that period was a very large one. There is, however, a considerable amount of work on other animals: the fine anatomy of the snail, structure of the clam, the squid; observations on the structure and development of the frog; observations on the contraction of muscles, etc., etc.

It is to be remembered that Swammerdam was extremely exact in all that he did. His descriptions are models of accuracy and completeness.

Fig. 5 shows reduced sketches of his illustrations of the structure of the snail, and also of the larva of an insect. The upper sketch on the left-hand side shows the central nervous system and the nerve trunks connected therewith, and the lower figure on the same side shows the shell and the principal muscles. This is an exceptionally good piece of anatomical work for the time, and is a fair sample of the fidelity with which he worked out details in the structure of small animals. Besides showing this, these figures also serve the purpose of pointing out that Swammerdam's fine anatomical work was by no means confined to insects. His work on the structure of the young frog was equally noteworthy.

But we should have at least one illustration of his handling of insect anatomy to compare more directly with that of Malpighi, already given (p. 567). The right-hand side of Fig. 5 is a reduced sketch of the anatomy of the larva of an ephemerus, compared with the work of Malpighi; we see there a more masterly hand at the work, and a more critical spirit back of the hand. The nervous system is very well done, and the greater detail in other features shows a disposition to go into the work deeper than Malpighi.

Besides work on structure and life histories, Swammerdam showed, experimentally, the irritability of nerves and the response of muscles after their removal from the body. He not only illustrates this quite fully, but seems to have had a pretty good appreciation of the nature of the problem of the physiologist. He says:

"It is evident from the foregoing observations that a great number of things concur in the contraction of the muscles, and that one should be thoroughly acquainted with that wonderful machine, our body, and the elements with which we are surrounded, to describe exactly one single muscle and explain its action. On this occasion it would be necessary for us to consider the atmosphere, the nature of our food, the blood, the brain marrow and nerves, that most subtle matter which instantaneously flows to the fibers, and many other things, before we could expect to attain a sight of the perfect and certain truth."

In reference to the formation of animals within the egg, Swammerdam was, as Malpighi, a believer in the preformation theory. The basis for his position on this question has already been stated.

There was another question in his time upon which philosophers and scientific men were divided, that was in reference to the origin of living organisms: Does lifeless matter, sometimes, when submitted to heat and moisture, spring into life? Did the rats of Egypt come, as the ancients believed, from the mud of the Nile, and do frogs and toads have a similar origin? Do insects spring from the dew on plants? etc., etc. The famous Redi had performed his noteworthy experiments the year after Swammerdam's birth, but opinion was divided upon the question as to the possible spontaneous origin of life, especially among the smaller animals. Upon this question, Swammerdam took a positive stand; he ranged himself on the side of the more scientific naturalists against the spontaneous origin of life. In reference to this matter he says:

"In attentively examining the development of insects, of animals with blood, and vegetables, one recognizes that all these beings grow and develop according to one law, and one feels how false is the opinion that attributes to fortuitous causes such regular and constant effects."

FIG. 6. ANTONIUS A. LEEUWENHOEK.

ANTONY VAN LEEUWENHOEK. 1632-1723.

In Leeuwenhoek we find a composed and better balanced man. Blessed with a vigorous constitution, he lived ninety-one years, and worked to the end of his life. He was born in 1632, four years after Malpighi and five before Swammerdam; they were, therefore, strictly speaking, contemporaries. He stands in contrast with the other men in being self-taught; he did not have the advantage of a university training, and apparently never had a master in scientific studies. This lack of systematic training shows in the desultory character of his extensive observations. Impelled by the same gift of genius that drove his confrères to study nature with such unexampled activity, he, too, followed the path of an independent and enthusiastic investigator.

The portrait which forms a frontispiece to his 'Arcana Naturæ' represents him at the age of sixty-three, and shows the pleasing countenance of a firm man in vigorous health. Richardson says: "In the face peering through the big wig there is the quiet force of Cromwell and the delicate disdain of Spinoza." "It is a mixed racial type, Semitic and Teutonic, a Jewish-Saxon; obstinate and yet imaginative; its very obstinacy a virtue, saving it from flying too far wild by its imagination."

There was a singular scarcity of facts in reference to Leeuwenhoek's life until 1885, when Dr. Richardson published in 'The Asclepiad'* the results of researches made by Mr. A. Wynter Blyth in Leeuwenhoek's native town of Delft. I am indebted to that article for much that follows.

His 'Arcana Naturæ' and other scientific letters contained a complete record of his scientific activity, but 'about his parentage, his education and his manner of making a living there was nothing but conjecture to go upon.' The few scraps of personal history were contained in the 'Encyclopædia' articles by Carpenter and others, and these were wrong in sustaining the hypothesis that Leeuwenhoek was an optician or manufacturer of lenses for the market. Although he ground lenses for his own use, there was no need on his part of increasing his financial resources by their sale. He held under the court a minor office designated 'Chamberlain of the Sheriff.' The duties of the office were those of a beadle, and were set forth in his commission, a document still extant. The requirements were light, as was also the salary, amounting to about £26 a year. He held this post for thirty-nine years, and the stipend was thereafter continued to him to the end of his life.

Van Leeuwenhoek was derived from a good Delft family. His grandfather and great-grandfather were Delft brewers, and his grandmother a brewer's daughter. The family doubtless were wealthy. His schooling seems to have been brought to a close at the age of sixteen, when he was 'removed to a clothing business in Amsterdam, where he filled the office of bookkeeper and cashier.' After a few years he returned to Delft, and at the age of twenty-two he married and gave himself up largely to studies in natural history. Six years after his marriage he obtained the appointment designated above. He was twice married, but left only one child, a daughter by his first wife.

He led an easy, prosperous, but withal a busy life. The microscope had recently been invented, and for observation with that new instrument Leeuwenhoek showed an avidity amounting to a passion.

* 'Leeuwenhoek and the Rise of Histology.' Asclepiad, Vol. II.; 1885.

"That he was in comfortable if not affluent circumstances is clear from the character of his writings; that he was not troubled by any very anxious and responsible duties is certain from the continuity of his scientific work; that he could secure the services of persons of influence is discernible from the circumstances that, in 1673, De Graaf sent his first paper to the Royal Society of London; that in 1680 the same society admitted him as fellow; that the directors of the East India Company sent him specimens of natural history, and that, in 1698, Peter the Great paid him a call to inspect his microscopes and their revelations."

Leeuwenhoek seems to have been fascinated by the marvels of the microscopic world, but the extent and quality of his work lifted him above the level of the dilettante. He was not, like Malpighi and Swammerdam, a skilled dissector, but turned his microscope in all directions; in the mineral, as well as the vegetable and animal kingdoms. Just when he began to use the microscope is not known; his first publication in reference to microscopic objects did not appear till 1673, when he was forty-one years old. He gave good descriptions and drawings of his instruments, and those still in existence have been described by Carpenter and others, and, therefore, we have a very good idea of his working equipment. During his lifetime he sent as a present to the Royal Society of London twenty-six microscopes, each provided with an object to examine. Unfortunately, these were removed from the rooms of the society and lost during the eighteenth century. His lenses were of fine quality and were ground by himself. They were nearly all simple lenses of small size, but considerable curvature, and needed to be brought close to the object examined. He had different microscopes for different purposes, giving a range of magnifying powers from 40 to 270 diameters and possibly higher. The number of his lenses is surprising; he possessed not less than 247 complete microscopes, two of which were provided with double lenses and one with a triplet. In addition to the above he had 172 lenses set between plates of metal, which gives a total of 419 lenses used by him in his observations. Three were of quartz, or rock crystal, the rest were of glass. More than one-half the lenses were mounted in silver, three were in gold.

It is to be understood that all his microscopes were of simple construction; no tubes, no mirror; simply pieces of metal to hold the magnifying-glass and the objects to be examined, with screws to adjust the position and the focus. We shall perhaps get the best idea of how they were used and brought into focus by reference to Fig. 7, which is copied from Richardson's article in 'The Asclepiad.' This shows the way the instrument was arranged to examine the circulation of blood in the transparent tail of a small fish. The fish was placed in water in a slender glass tube, and the latter was held in a metallic frame, to which a plate (marked D) was joined, carrying the magnifying glass. The latter is indicated in the circle above the letter D, near the tail-fin of the fish. The eye was applied close to this circular magnifying-glass, which was brought into position and adjusted by means of screws. The two small sketches show a front and a back view of another one of his microscopes. The small circle shows the position of the lens inserted in a metallic plate. On the opposite side was a sort of object holder, whose position was controlled by screws. In some instances, he had a concave reflector with a hole in the center, in which his magni-

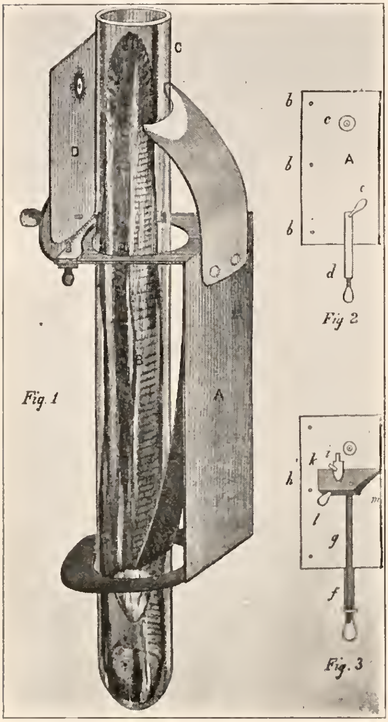

Fig. 7. Leeuwenhoek's Microscope.

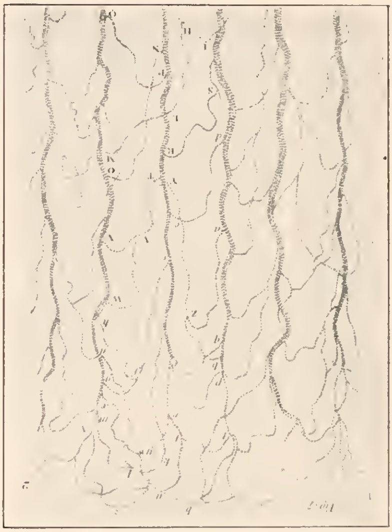

Fig. 8. Capillary Circulation, after Leeuwenhoek.

fying-glass was inserted, and, in this form of the instrument, the objects were illuminated by reflected and not by transmitted light.

His microscopic observations were described and sent to learned societies in the form of letters. "All or nearly all that he did in a literary way was after the manner of an epistle," and these were so numerous as to justify the cognomen, 'The man of many letters.' "The French Academy of Sciences, of which he was elected a corresponding member in 1697, got twenty-seven; but the lion's share fell to the young Royal Society of London, which in fifty years—1673-1723—received 375 letters and papers." "The works themselves, except that they lie in the domain of natural history, are disconnected and appear in no order of systematized study. The philosopher was led by what transpired at any moment to lead him."

In 1686 he observed the minute circulation and demonstrated the capillary connection between arteries and veins. This was perhaps his most important observation for its bearing on physiology. It must be remembered that Harvey had not actually seen the circulation of the blood, which he announced in 1628. He assumed on entirely sufficient grounds the existence of a complete circulation, but there was wanting in his scheme the direct ocular proof of the passage of blood from arteries to veins. This was supplied by Leeuwenhoek. Fig. 8 shows one of his sketches of the capillary circulation. In his efforts to see the circulation he tried various animals; the comb of the young cock, the ears of white rabbits, the membraneous wing of the bat were progressively examined. The next advance came when he directed his microscope to the tail of the tadpole. Upon examining this he exclaims:

"A sight presented itself more delightful than any mine eyes had ever beheld; for here I discovered more than fifty circulations of the blood, in different places, while the animal lay quiet in the water, and I could bring it before my microscope to my wish. For I saw not only that in many places the blood was conveyed through exceedingly minute vessels, from the middle of the tail towards the edges, but that each of the vessels had a curve or turning, and carried the blood back towards the middle of the tail, in order to be again conveyed to the heart. Hereby it plainly appeared to me that the blood-vessels which I now saw in the animal, and which bear the names of arteries and veins, are, in fact, one and the same; that is to say, that they are properly termed arteries so long as they convey the blood to the furtherest extremities of its vessels, and veins when they bring it back to the heart. And thus it appears that an artery and a vein are one and the same vessel prolonged or extended."

This description shows that he fully appreciated the course of the minute vascular circulation and the nature of the communication between arteries and veins. He afterwards extended his observations to the web of the frog's foot, the tail of young fishes and eels.

In this connection it should be remembered that Malpighi, in 1661, observed the flow of blood in the lungs and mesentery of the frog, but he made little of it. Leeuwenhoek did much more with his discovery, and gave the first clear idea of the capillary circulation. Leeuwenhoek was also anticipated by Malpighi in reference to the microscopic structure of the blood. (See also under Swammerdam.) To Malpighi the corpuscles appeared to be globules of fat, while Leeuwenhoek noted that the blood discs of birds, frogs and fishes were oval in outline and those of mammals circular. He reserved the name of 'globule' for those of the human body, erroneously believing them to be spheroidal.

Among his other discoveries bearing on physiology and medicine may be mentioned: The branched character of heart muscles, the stripe in voluntary muscles, the structure of the crystalline lens, the description of spermatozoa after they had been pointed out to him in 1674 by Hamen, a medical student in Leyden, etc. Richardson dignifies him with the title, 'The Founder of Histology,' but this, in view of the work of his great contemporary, Malpighi, seems to me an overestimate.

Turning his microscope in all directions, he examined water and found it peopled with minute animalcules, those simple forms of animal life, propelled through the water by innumerable hair-like cilia, extending from the body like banks of oars from a galley, except that in many cases they extend from all surfaces. He saw not only the animalcules, but also the cilia that move their bodies.

His descriptions of the various forms of these animalcules are interesting, and in strangely archaic language. Here is one of them, changed from Dutch into English:

"In the year 1675 I discovered living creatures in rain-water which had stood but four days in a new earthern pot, glazed blew within. This invited me to view this water with great attention, especially those little animals appearing to me ten thousand times less than those represented by Mons. Swammerdam, and by him called waterflies or waterlice, which may be perceived in the water with the naked eye. The first sort by me discovered in the said water, I divers times observed to consist of five, six, seven or eight clear globules, without being able to discover any film that held them together or contained them. When these *animalcula*, or living atoms, did move they put forth two little horns, continually moving themselves; the place between these two horns was flat, though the rest of the body was roundish, sharpening a little towards the end, where they had a tayle, near four times the length of the whole body, of the thickness (by my microscope) of a spider's web; at the end of which appeared a globule, of the bigness of one of those which made up the body; which tayle I could not perceive even in very clear water to be mov'd by them. These little creatures, if they chanced to light upon the least filament or string, or other such particle, of which there are many in the water, especially after it has stood some days, they stook entangled therein, extending their body in a long round, and striving to dis-entangle their tayle; whereby it came to pass, that their whole body lept back towards the globule of the tayle, which then rolled together serpent-like, and after the manner of copper or iron wire, that having been wound around a stick, and unwound again, retains those windings and turnings,"* etc.

"Any one who has examined under the microscope the well-known bull animalcule will recognize in this first description of it the stalk

* 'Kent's Manual of the Infusoria.' Vol. 1, p. 3. Taken from the 'Philosophical Transactions' for the year 1677.

and its form after contraction in the 'tayle which retains those windings and turnings.'

He discovered also the Rotifers, those favorites of the amateur microscopists, made so familiar to the general public in works like Gross's 'Evenings at the Microscope.' He showed their remarkable powers of resuscitation after complete drying. He observed that when water containing these animalcules evaporated they were reduced to fine dust, but became alive again after great lapses of time by the introduction of water.

He made many observations on the microscopic structure of plants. Fig. 9 gives a fair sample of the extent to which he observed the cellular construction of vegetables and anticipated the cell-theory.

Fig. 9. From Leeuwenhoek's 'Arcana Naturæ.'

While Malpighi's work in that field was more extensive, these sketches from Leeuwenhoek represent very well the character of the work of the period on minute structure of plants.

It remains to say that on the two biological questions of the day he took a decided stand. He was a believer in preformation or predelineation of the embryo in an extreme degree, seeing in fancy the complete outline of both maternal and paternal individuals in the spermatozoa, and going so far as to make sketches of the same. But upon the question of the spontaneous origin of life he took the side that has been so triumphantly demonstrated in this century against the occurrence of spontaneous generation.

We see in these three gifted contemporaries different personal characteristics. Leeuwenhoek, the composed and strong, attaining an age of ninety-one; Malpighi, always in feeble health, but directing his efforts with rare capacity, reaching the age of sixty-seven; while the great intensity of Swammerdam stopped his scientific career at thirty-six and burned out his life at the age of forty-three.

They were all original and accurate observers, but there is variation in the kind and quality of their intellectual product. The two university-trained men showed capacity for coherent observations; they were both better able to direct their efforts towards some definite end; Leeuwenhoek, with the advantages of vigorous health and long working period, lacked the systematic training of the schools, and all his life worked in discursive fashion; he left no coherent piece of work of any extent like Malpighi's 'Anatome Plantarum' or Swammerdam's 'Anatomy and Metamorphosis of Insects.'

Swammerdam was the most critical observer of the three, if we may judge by his work in the same field as Malpighi's on the silk-worm. His descriptions are models of accuracy and completeness, and his anatomical work shows a higher grade of finish and completeness than Malpighi's. Malpighi, it seems to me, did more in the sum total than either of the others to advance the sciences of anatomy and physiology and through them the interests of mankind. Leeuwenhoek had larger opportunity; he devoted himself to microscopic observations, but he wandered over the whole field. While his observations lose all monographic character, nevertheless they were important in opening new fields and advancing the sciences of anatomy, physiology, botany and zoology.

The combined force of their labors marks an epoch in the establishment of the scientific method and in the ushering in of a new grade of intellectual life.

TWO CONTEMPORARY PROBLEMS IN EDUCATION.

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TWO of the important problems that the contemporary interest in education has brought prominently before the public are I. What shall we do about the elective system of studies which is daily extending its sway over schools and colleges throughout the country? and II. How shall we bridge the gap between the high school and the lower grades; *i. e.*, how shall we minimize the waste in the pupil's school education, and make his entire school career serve continuously and progressively—as it should—his gradually expanding interests, needs, powers, and duties?

I.

It is well known that even those secondary schools and colleges which do not recognize electives, as such, and cling to 'courses of study,' permit not merely a choice between different 'courses,' but they also, usually, permit substitutions of studies in one 'course' for studies in another; so that, really, if not nominally, a considerable range of choice, or election of studies, is permitted in most secondary schools and colleges nearly everywhere throughout the country.

Both experience and observation seem to justify this widespread adoption of the elective system, in some form, in secondary schools and colleges. During the years of secondary school and college education the pupil passes through the important stage of adolescence and youth. He emerges from childhood to manhood. During these years he may be, and should be, led to self-revelation, and he should be aided to organize his mental life in accordance with his dominant interests and capacities, both for vocational and extra-vocational activities. After an individual's interests have emerged distinctly, all voluntary effort is reserved for his preferences; and that achievement is most productive when it is based on interests and capacity, need not be argued. Daily experience proves that an individual's dominant interests ultimately determine the extent of his private and public usefulness and the sources of his pleasures—that, in short, they determine the richness or the poverty of his life, in the broadest sense of those words.

If this be admitted, the importance of discovering and cultivating a youth's dominant interests is apparent. He should, therefore, choose his own curriculum as soon as possible. He can learn to choose wisely only by choosing repeatedly, under guidance, as wisely as possible. Hence, although a child twelve or thirteen years old should not freely choose his own courses of study, he is, nevertheless, entitled to have his preferences considered in the choices which his parents and teachers permit him to make. As he grows older, his ability to choose wisely should be deliberately cultivated, so that usually, by the time he has completed his secondary-school education—rarely before that time—he may be prepared to choose his further studies without restrictions. A youth of eighteen or nineteen, who has been learning to choose, who has had training in foresight for five or six years, is not likely to abuse his privileges, nor is he likely to be ignorant of the importance of wise counsel, nor to wish to dispense with it.

But it may be said that if a youth is allowed to choose his own studies, he is not trained to 'work against the grain.' I am not sure that I understand the meaning attached to this phrase by those who use it. But, in my opinion, the only sense in which any sane person, in adult life, works 'against the grain,' is when he applies himself to a disagreeable or even repulsive task for the sake of some ultimate end that is intrinsically agreeable to him, or recognized as good by him. There is no other working against the grain worth cultivating. No one, not even an ascetic, habitually does disagreeable things for their own sake.

When an adult works faithfully at a disagreeable task, he does it primarily because it is clear to him that his personal interests are at stake—that his daily bread, or honor, or social elevation, depends on the performance of his work or his duty, however disagreeable it may be. In other words, there are strong extraneous motives, *the force of which he can appreciate,* that cause him to apply himself to the uninviting or repelling task before him. True, many a man does live his life under just such disadvantageous conditions. But it is a life of mere drudgery, from which he might have been saved if he had learned in youth to choose that calling which is in harmony with his dominant interests and capacities. His work might then have been hardly less a pleasure than his leisure, and he would, of course, have been a more useful member of society, and would have earned more leisure, because of the increased efficiency of his work.

But can any one with any knowledge of boy nature assert that faithful application to the positively and permanently uninteresting can be cultivated by extraneous motives, even if it were desirable? The motives which appeal to the adult are meaningless to the boy. Moreover, he feels instinctively that consciousness was added to the equipment of mankind, in the process of human evolution, for guidance, and he insists as long as he can on using it for that purpose. The remote reasons which apparently weigh heavily against the pupil's strong disinclination in the minds of his governors do not and cannot appeal to him as intrinsically valid. One can, of course, compel the performance of disagreeable tasks, and by repetition of compulsion one can convince a refractory youth that *some* achievement is always possible and necessary, in spite of his strong aversion to a particular kind of work. But what one usually cultivates, under such circumstances, is not a growing strength to master difficulties, but chiefly the habit of skilful, even of subtle evasion—the habit of calculating not how much one can do, but how little one must do.

Again, the effect of compelling a youth to pursue a subject permanently uninteresting is pernicious in another way. It cultivates the abominable habit of being satisfied with partial or inadequate achievement. Permanent lack of interest in a given field of work is an indication of corresponding incapacity; for growing interest and capacity always go together. Under such circumstances a youth never feels the glow of conscious mastery of the subject for its own sake; half achievement is the result of forced, half-hearted endeavor, and both become the rule.

The result may be even worse. To be constantly baffled undermines one's confidence in one's own powers, and ultimately imperils self-respect. To force a youth to work against the grain for its own sake is, therefore, futile, and worse than futile; for it not only fails to accomplish its purpose, but actually cultivates the evasion of school work, the aversion to school work, and, in extreme cases, it may even destroy the capacity for work of any sort. Morever, it must not be forgotten that evasion of work, aversion to work, and *ennui* are the fertile soil in which all the vices flourish.

Again, all such efforts to make a youth work 'against the grain,' for its own sake, by the pursuit of uninteresting studies are artificial, and wholly unnecessary. What we want a youth to acquire is the power of overcoming difficulties, and the corresponding habit of adequate achievement. This power and the corresponding habit are cultivated *by overcoming difficulties*, not by forced and *unsuccessful attempts* at overcoming them. Every subject affords abundant opportunity for overcoming difficulties, and when it is in harmony with the pupil's interests and powers, those difficulties *will be overcome*; first, because they lie in the way of further progress in a subject which he wishes to master; and second, because he possesses the requisite natural capacity for conquest, because he daily feels the *sense of achievement*—the strongest of all incentives to exertion. Hence, conquest may become the rule. Through conquest alone comes the habit of *working in spite of difficulties*, which is the kind of working against the grain worth trying for.

Finally, as was pointed out above, a man's life is more significant and richer in every way, the more his dominant interests and powers determine both his serious pursuits and his refined pleasures. The natural preferences of pupils during the stage of secondary education should, therefore, be *heeded*, not thwarted. There is no other effective way to cultivate the habit of 'working against the grain' in the only sense in which such work is wise. It is no argument to say that generations of men have been trained to work against the grain under rigidly prescribed programs of study. The sufficient reply to such an argument is already contained in what has been said about the relative effect of extraneous motives in youth and in adult life. It may be added, therefore, that this capacity where it exists has been developed in spite of, not because of, the rigid prescription of studies.

Of course, nothing that has been said applies to shirking. The shirk deserves no concessions, and should have no mercy. What the pupil has chosen to do, both the home and the school must insist that he *shall* do.

The question about elective studies is, accordingly, not 'shall we recognize electives?' That question has been answered in the affirmative. The question is, 'What is the wisest administration of electives in secondary education?' While each school is seeking the answer to this question in its own way, there is substantial agreement on one point: namely, that there should be restriction on the pupil's freedom to choose his own curriculum of studies. But opinions vary widely as to what these restrictions shall be, and how they shall be administered. I hold that these restrictions should be as few as are consistent with his permanent welfare. To prevent the harm which might result from the pupil's ignorance and immaturity—to guard against the possibility of the pupil's cutting himself off from an illuminating acquaintance with nature and her ways on the one hand, and the historical culture of the race, as embodied in books, social institutions and art, on the other, some of the secondary school pupil's work must be prescribed. To insure that training in choice that was emphasized a moment ago, and the best possible preparation for complete living in the fullest sense of the term, a considerable part of the instruction should be offered without other restrictions than those of sequence and amount. The fundamental questions are, of course, what studies shall we prescribe for all pupils, and when shall we permit a pupil to discontinue a study once undertaken?

The experience of teachers who have worked under both prescribed and elective systems seems to point conclusively to the fact that no study, however highly esteemed by parents or teachers, will be a real influence in the pupil's development, and so contribute to his future usefulness and happiness in any important way, unless it is, in some degree at least, intrinsically interesting to him. Hence, no pupil should be required to pursue a study after it is clear that it does not appeal to him. Under most circumstances one year is enough—and it is not too much—to ascertain whether a study does, or does not, really challenge a youth's interest and capacity. Hence, to answer the second of the two questions just proposed, first, I should say that, in general, after a pupil has made his choice of a study, he should be required to pursue it for a year. As to the first question, namely, What studies shall be prescribed for all? it seems to me clear that no youth should be allowed, through ignorance or caprice, to cut himself off from any one of the great sources of human inspiration and guidance. If we could rely on having a varied and substantial program of studies during the pre-high-school years, some of the prescriptions I am about to suggest might well be omitted: notably the mathematics. But as long as the pre-high-school grades, even those immediately preceding the high-school grades, cannot yet be seriously regarded as the beginning of high-school education in most school systems—among them some of the best in the country—in order to guard against the blindness of ignorance when pupils come up to the high school, it is necessary to insist on a considerable amount of prescription.

I would, therefore, prescribe for every non-collegiate pupil, during his secondary school career, at least one year of the study of his mother tongue, giving most of the time to literature with its inspiring and guiding influences; at least one year of science, so taught as to show the pupil how man is coming to master nature by understanding her, and at the same time, also, how completely one who knows nothing of natural science is cut off from participation in some of the most interesting, profound and far-reaching problems of contemporary thought; one year of a modern foreign language, through which he may learn to appreciate fully his mother tongue, and through which at the same time he may widen his mental horizon so as to include ultimately the literature, the institutional life, the ideals in a word, the intellectual resources of another modern nation besides his own; one year of history—English or American—so taught as to show the meaning of democratic institutions and the means of safeguarding and improving them. If American history is prescribed, I would have it so taught as to fill the pupil's mind with the most important truths about what his country is, and what it really stands for; not glossing over its past and present defects and unduly exalting its merits, but bringing into strong relief our worthiest political ideals, and laying special emphasis on the lesson that the approximate realization of worthy political ideals has always been and still is possible only through the intelligent participation of citizens in public affairs, not primarily as office holders, but still more as alert and active private citizens; to do this, not so much by didactic instruction or exhortation, as by the inevitable logic of events skilfully portrayed; I would prescribe, further, one year of the history of industry and commerce, together with the elements of civics treated historically, that the pupil may see the interdependence of material prosperity and social stability, and learn to look upon contemporary social and economic problems in the light of their historical evolution; one year of elementary algebra and geometry that may open his mind to one of the most useful, the most profound, and to some minds most fascinating systems of thought which man has developed—a result which can never be expected to follow from what the pupil has learned in the narrow field covered by arithmetic; one year of drawing and manual training that will introduce the pupil, on the one hand, to the elements of the fine arts, the decorative arts and the mechanic arts, and on the other, lead him to a just appreciation of the importance of all three in ministering to the æsthetic and the material interests of men, and help him to adjust his own relation to them in thought and deed.*

That is to say, under existing conditions, I mean with the existing unsatisfactory pre-high-school education, still unsatisfactory in spite of the well-nigh universal and decidedly creditable recent attempts to improve it, it seems to me wise to prescribe for every high school pupil at least one year of the language and literature of his mother tongue; one year of American or English history (chiefly political); one year of English and American economic history and civics; or, when possible, one year of elementary political economy, one year of a modern foreign language; one year of science (physical geography, or botany and zoology); one year of algebra and geometry (together); one year of drawing and manual training; each of these subjects with a time allotment of from three to four periods a week.† This prescribed work includes subject matter comprising about one-third of all the work a pupil of ordinary capacity should be required to do during four years of the ordinary high-school program, chosen from each of the great divisions of human culture. It thus affords a reasonably satisfactory basis for the guidance of pupils, teachers and parents, in the choices which they make or advise in harmony with the pupil's real tastes and capacities. It seems to me, therefore, a safe basis for the administration of the elective system in our secondary schools.

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* Of course, I do not mean to imply that these results can be fully realized in a single year's instruction in the subjects named in this paragraph. I mean that these results are to be aimed at, whatever the duration of the instruction may be.

† I suggest the following time schedule for these studies: English, 3; English History, or American History, 3; Economic History and Civics, or Political Economy, 3; Modern Language, 4; Physical Geography, or Botany and Zoology, 4; Algebra *and* Geometry, or Algebra or Geometry, 4; Manual Training and Drawing, 4. (The numbers mean so many exercises per week.)

II.

The other problem which I wish to discuss is closely connected with the problem of electives. It is, in effect, how shall we overcome the persistence of the artificial separation of the high school from the rest of the school system—a separation that sometimes almost amounts to isolation? Reference was made above to the unsatisfactory condition of our pre-high-school education in spite of the widespread endeavor to improve it. The grammar school is still emphasizing, too much, a very large remnant of the old formal curriculum. Arithmetic, English grammar and political geography are still looked upon as the solid studies of the later years of the grammar school, as they were before the days of enriched programs. The work in foreign languages, algebra, geometry, history, elementary science, manual training, where any or all of these studies are recognized at all, is still looked upon in most school systems as a new and more or less ornamental addition to the real work of the grammar school.*

In other words, we have not yet taken the newer studies in the grammar school program *seriously*. Hence, as I have already mentioned, most high schools do not regard the work done in these studies in the lower grades as really *done*; and so, in spite of the congested grammar school programme, due to the insertion of the new studies without elimination of the old ones, *root and branch*, from the last years of the grammar school, the high school still assumes—and probably in most cases justly—that everything below the high school is still chiefly a drill in the school arts, just as it used to be; and that such beginnings of a real education as have been attempted in the lower grades are not really beginnings—they are only trifling with high school subjects; and that, consequently, all those subjects must be begun over again. The result is that the separation of the high school from the

* The reluctance of some communities and some teachers to abandon the old-time grammar school studies in the later years of the grammar school program, and to substitute for them the studies that constitute a real education, is largely due to the mistaken belief that the really unpractical and purely technical details of arithmetic and English grammar, and the statistical geography, that still consume so large a share of the pupil's time and attention in the last two or three grammar grades possess more practical utility, and have more educational value than good courses in history, literature, foreign language, elementary algebra and geometry, manual training, sewing and cooking. It should be said, also, that many principals and superintendents doubtless hesitate to adopt the improved program because they have not in their corps a sufficient number of properly equipped teachers—teachers who can be assigned to teach both in a given high school and in the upper grades of one or more grammar schools in its vicinity. But such teachers are not hard to find. Our colleges are sending them forth by the score every year.

lower grades—the 'gap,' as it is often called, between 'the grades' and the high school—still exists, very much as it always has.

This curious break, in what is intended to be a thoroughly unified educational scheme, is such a contradictory phenomenon, in spite of its serious reality, that it would be incomprehensible if it had not followed naturally from the different origins of our elementary and our secondary schools. Our secondary schools originated as (Latin) grammar schools, *i. e.*, as college preparatory schools, designed for a particular social class, and hence possessing no essential articulation with the public elementary schools. The academies, although not class schools to the same extent as the older 'grammar schools,' still concerned themselves little, if at all, with the elementary education of their pupils. When the high schools were founded on the combined model of the 'grammar school' and the academy, these traditions of secondary education were perpetuated—below the high school not a real education, only a preparation for education; education itself was deferred to the high school. Hence, the gap between the high school and the lower grades—the artificial isolation of the high school from the lower grades, which still persists in spite of our recent and contemporary endeavor to bring them together.

Nevertheless, the remedy is really not difficult to apply. We have already made so much progress that the final steps ought not to be difficult to take. We shall take them when we discontinue elementary English grammar as a distinct study, at the end of the sixth grade, and begin there a modern foreign language; when we cut out all the arithmetic in and after the seventh grade, and substitute elementary geometry and algebra; when we similarly cut out most of the political geography in and after the seventh grade, and gradually transform all our nature study during the same time into elementary natural science. When we make these and some other equally important changes *seriously*, and add them to the other improvements already substantially accomplished in our contemporary pre-high-school grades, we shall bridge the gap between elementary and secondary education; and the artificial isolation of the high school in a system of which it is really intended to be an integral part will be outgrown.

I should like to discuss the effect of these suggested changes more at length, but I must content myself here with touching only one of them. It will be noticed that I have spoken of a modern language, not of Latin, as a suitable foreign language for pre-high-school pupils. The reasons for this suggestion are not far to seek. Latin is a difficult language, and when begun at an early age, and without any previous study of a foreign language, is not economically acquired. By economically, I mean the minimum expenditure of time and energy required to make substantial progress in the language. This is becoming apparent in the very stronghold of classicism itself—in Germany. It may not be generally known that during the past few years a very interesting experiment has been in progress in Germany; namely, the experiment of cutting off the first three years of the nine years devoted to Latin in the gymnasium and real-gymnasium, and substituting instead three years of French. Three years ago there were in Germany twenty-six gymnasiums and real-gymnasiums, in which this experiment was in progress. Now, I am told, there are no less than forty. The head-masters of these schools were unwilling, in some cases that came under my observation, to express any opinion on the probable results of this experiment until more time had elapsed. The experiments were begun not long after the celebrated conference on secondary education, called by the Emperor in 1890. But others were emphatic in their belief that the experiment would be a success in the interests of Latin itself; and it was really chiefly on this alleged ground that the experiment had been permitted at all. I have no doubt that the results will justify the expectations entertained by its promoters. In this country one of our best known classical schools* has substituted for some years past, for the first year of a six-year course in Latin, a year of French; and there is no disposition whatever to return to the former régime.

A further argument for deferring Latin until after a modern language has been studied could be derived from the analogy of the very successful courses in elementary Greek now established in several American colleges—courses in which at least two years, sometimes three years, of 'preparatory' Greek are done in a single year; and the work is done much better than it can be done in the preparatory school, on account of the greater maturity of the pupils, and their previous linguistic training. All this points to the wisdom of deferring Latin to the later secondary school years *in the interests of the Latin.*

But there is another even stronger reason why a modern language, instead of Latin, should be begun in the grammar school. Of course, I have in mind a *serious* study of the modern language—as serious as if the language were Latin, and with a similar expectation of building on it a superior language training later on. These reasons are, first, that in two or three years a serious study of a modern language will yield a result in general culture infinitely superior to what can be derived from Latin at the same age—*i. e.*, it will give the pupil the power to enjoy and to use another literature besides his own; and especially a literature that he *can* use and enjoy, whether he ever goes to school another day or not; and this cannot be asserted of Latin. I need not remind you that most pupils do not enter the high school; and hence,

* The Roxbury Latin School.

unless they have an opportunity to study a foreign language in the grammar school, they do not get it at all.

Other arguments for such sequence of our language courses as I am pleading for are near at hand; *e. g.*, a pupil's knowledge of, and command over, his mother tongue gains enormously through the study of a foreign language—a modern language is as good for this purpose, for young pupils, as Latin, or even better than Latin; and a modern language in itself may have a commercial value which Latin never has, except, at present, for teachers.

Now, if we had two or three pre-high-school years of a modern language, followed by at least one year—the first high school year—of another modern language *in* the high school, and this followed by three years of Latin and two of Greek for those who care for the ancient languages, who can doubt that our present somewhat meager achievements in the classics in the high school would be greatly increased in quantity and that they would be vastly better in quality? This is the sensible language course of the future for those who study the classics in the high school, as I conceive it, when the high school is completely articulated to the grammar school. When that time comes I think, also, that we shall have precisely inverted the relative emphasis we now place on the classics and on the modern languages in pre-collegiate education for collegiate pupils. We shall follow the pre-high-school modern language courses by substantial high school courses in the languages, and so continue the real education of the pupil begun in the grammar school, instead of deferring it as we now do for the classical student until he reaches the college. For, at present, classical education in the secondary school, like the formal education that used to precede it in the elementary school, is, for most pupils, only an alleged preparation for education, not education itself.

When we articulate our pre-high-school courses in history, science, mathematics, manual training, and the rest, with the corresponding high school course, in some such way as has just been suggested for foreign language courses, we shall then make the pupil's school career a *real* and not a deferred education at every stage of his progress; and the historical disparity between the *kind* of studies pursued below the high school and those pursued in the high school will disappear. There will be no artificial separation of the high school from the rest of the school system. We shall have adjusted our educational endeavor to the real process of the pupil's unfolding development, and shall really make our schools minister equally to all classes of pupils, whether they have the good fortune to be born of wealthy and socially superior parents, or whether merely equipped with ability and earnestness, they are obliged to make the most of the brief educational career their circumstances will permit.

A STUDY OF BRITISH GENIUS.

BY HAVELOCK ELLIS.

IV. HEREDITY AND PARENTAGE.

THE heredity of intellectual genius has been very fully discussed, with special reference to eminent persons of British birth, by Mr. Francis Galton.* With, perhaps, even an excess of zeal—for persons of somewhat minor degrees of ability have sometimes been taken into account—Mr. Galton has shown that intellectual ability has frequently tended to run in families. If this hereditary tendency is by no means omnipresent, the present data prove conclusively that it is a very real factor. Notwithstanding that the effects of hereditary position have been so far as possible excluded, and that our lists only include persons of preeminent ability, distributed over fifteen centuries, it is yet found that among these 902 persons there are 31 groups, of two or three individuals in each group, who are closely related. These groups include 65 persons in all. The recognized relationships are father and son, brother and brother, brother and sister, sister and sister, uncle and nephew, aunt and nephew, uncle and niece, grandfather and grandson. Cousinship and more remote relationships also occur, but have not been included.† In nineteen of these groups the ability shown may be said to be of a similar kind; in twelve it may be said to be of different kinds. There are only three cases in which the group consists of three persons: the Bacons, the Kembles, the Wordsworths. It is scarcely necessary to remark that in a very large number of cases the preeminent persons in our list were nearly related to other eminent persons who have not reached the degree of distinction entitling them to appear in the list. Of these no note has been taken.

I have, however, noted every case in which it is stated or implied that one or other, or both, of the parents possessed an unusual amount of intellectual ability, by no means necessarily involving any degree whatever of 'eminence.' These cases are very numerous, and as such ability may often have been displayed in very unobtrusive ways, it must frequently have escaped the attention of the national biographers. In

*See especially his 'Hereditary Genius.'

† It is quite possible, however, that such remote relationships are not without significance. One cannot but be struck by such a fact as the relationship of Shelley through his mother with the lyric poet Southwell, with whom he has so real an emotional affinity.

123 cases the father showed such ability; in 65 cases the mother is noted as of unusual ability, or else as being closely related to some person of eminent ability; in 20 of the 65 cases the mother was closely related to some person of very eminent ability, and may, therefore, be fairly presumed to have transmitted an intellectual aptitude whether or not she showed marked signs of such aptitude herself. In 14 cases both the father and the mother probably transmitted intellectual aptitudes. Making allowances for this, it may be said that at least 181 men and women of distinguished ability, or about 20 per cent. of our 902 eminent persons, have inherited intellectual aptitudes. Bearing in mind that in many cases the aptitudes of the parents are unknown or have passed unnoticed, and that in other cases the national biographers have failed to record known facts, it is not improbable that the proportion of cases in which one or other of the parents of our 902 eminent persons displayed more than average intellectual ability may be at least doubled.

If we consider the eminent women separately we find that, while 8 have had fathers of unusual intellectual ability, only 2 have had mothers from whom it can be said that they probably inherited. In one further case (Fanny Burney) both parents possessed ability, the father, however, in a more eminent degree than the mother. Moreover, the two cases in which the mother may probably be said to have transmitted the ability (Mrs. Siddons and Joanna Baillie) are more dubious than those in which it was transmitted by the father. So far as the present very limited data go, it seems probable, therefore, that women have a still more marked tendency than men to inherit intellectual aptitudes from their fathers.

It would be interesting to inquire into the moral and emotional qualities, the 'character,' of the parents. This, however, is extremely difficult and I have not attempted it. If we could do so we might find that the mothers of eminent men have had greater influence on their sons than the facts, so far as it has been possible to ascertain them, regarding the transmission of purely intellectual aptitudes would lead us to believe. In a great many cases the mother was a woman of marked piety, and we are frequently led to infer an unusual degree of character on the part of the mother, if not of the father. Moral qualities are quite as essential to most kinds of genius as intellectual qualities, and they are, perhaps, even more highly transmissible. They form the basis on which intellectual development may take place, and they may be transmitted by a parent in whom such development has never occurred. The very frequent cases in which men of eminent intellectual ability have declared that they owed everything to their mothers* have some-

*A remark of Huxley's in a letter to the present writer—"Mentally and physically I am a piece of my mother"—may be taken as typical of such declarations.

times been put aside as the expressions of an amiable weakness. It requires some credulity, however, to believe that men of preeminent, or even less than preeminent, intellectual acuteness are unable to estimate the character of their own parents. The frequent sense of indebtedness to their mothers expressed by eminent men may be taken as largely due to the feeling that the inheritance of moral or temperamental qualities is an even more massive and important inheritance than definite intellectual aptitudes. Such inheritance coming to intellectual men from their mothers may often be observed where no definite intellectual aptitudes have been transmitted. It is not, however, of a kind which can well be recorded in biographical dictionaries, and I have not, therefore, attempted to estimate its frequency in the group of preeminent persons under consideration.

I have, however, attempted to estimate the frequency of one other form of anomaly in the parents besides intellectual ability. The parents of persons of eminent intellectual power may not themselves have been characterized by unusual intellect; but they may have shown mental anomaly by a lack of aptitude for the ordinary social life in which they were placed. In at least 31 cases (or over 3 per cent.) we find that the father was idle, drunken, brutal, extravagant, unsuccessful in business, shiftless, or otherwise a ne'er-do-weel. In such cases, we may conclude, the father has transmitted to his eminent child an inaptness to follow the beaten tracks of life, but he has not transmitted any accompanying aptitude to make new individual tracks. This list could easily be enlarged if we included milder degrees of ineffectiveness, such as marked the father of Dickens (supposed to be represented in Micawber). A certain degree of inoffensive eccentricity, recalling Parson Adams, seems to be not very uncommon among the fathers of men of eminent ability, and perhaps furnishes a transmissible temperament on which genius may develop. It may be noted that 5 of the ne'er-do-weel fathers (a very large proportion) belonged to eminent women. Whether this confirms the conclusion already suggested as to the special frequency of paternal transmission in the case of women of eminent ability I cannot undertake to say. It may be added, however, that a ne'er-do-weel father, by forcing the daughter to leave home or to provide for the family, furnishes a special stimulus to her latent ability.

In 276 cases I have been able to ascertain with a fair degree of certainty the size of the families to which these persons of eminent ability belong. A more than fair degree of certainty has not been attainable, owing to the loose and inexact way in which the national biographers frequently state the matter. Sometimes we are only told that the subject of the article is 'the child' or 'the son'; this may mean the *only* child, but it is impossible to accept such a statement as evidence regarding the size of the family, and the number of families with only children may possibly thus have been unduly diminished. Again, the biographers in a very large number of cases ignore the daughters, and from this cause again their statements become valueless. In estimating the natality of the families producing children of ability I have never knowingly reckoned the offspring of previous or subsequent marriages; so far as possible, we are only concerned with the fecundity of the two parents of the eminent persons. So far as possible, also, I have reckoned the gross fecundity, *i. e.*, the number of children born, not the number of children surviving; in the case of a large number of eminent men this gross fertility is known from the inspection of parish registers; in a certain proportion of cases it is probable, however, that we are only dealing with the surviving children. On the whole, the ascertainable size of the family may almost certainly be said to be under the mark. It is, therefore, the more remarkable that the average size of genius-producing families is found to be larger than that of normal families. The average of the normal English family is at the very most 6;* the average size of our genius-producing families is 7 (more exactly, 6.96). In order to effect an exact comparison I have looked about for some fairly comparable series of figures, and am satisfied that I have found it in the results of an inquiry by Mr. F. Howard Collins concerning 4,390 families.† These families furnish an excellent normal standard for comparison; they deal mainly with 'Anglo-Saxon' people (in England and America) of the middle and upper classes; they represent, with probably but very slight errors of record, gross fertility; they are apparently not too recent, and they betray little evidence of the artificial limitation of families. The mean size of Collins's group of fertile families is found by Pearson to be 4.52 children. Comparing in more detail the composition of our genius-producing families with the normal average, we obtain the following results:

Size of family	1	2	3	4	5	6	7	8
Normal families	12.2	14.7	15.3	14.1	11.1	8.6	7.8	6.3
Genius-producing families	6.2	6.2	11.0	8.4	10.6	10.2	11.7	6.9

Size of family	9	10	11	12	13	14	over 14
Normal families	3.9	2.7	1.4	1.0	.5	.2	.1
Genius-producing families	5.5	4.4	5.8	4.0	2.9	1.8	4.0

Unless, as is scarcely probable, the mental eccentricities of biographers lead to very frequent selection on definite lines, it will be seen that there is a very marked tendency for genius-producing families to

* This was the average fertility of 1,700 marriages, as ascertained by Ansell, Duncan, 'Sterility in Women,' p. 4. Galton found the mean of 204 marriages 4.65, and Pearson the mean of 378 fertile marriages 4.70.

†As quoted by Karl Pearson, 'The Chances of Death,' Vol. I., p. 70. In passing through Mr. Pearson's mathematical hands the 4,390 emerge as 4,444, and it is on this number that my percentages for normal families are based.

be abnormally large.* In genius-producing families there is an invariable deficiency of families below the average normal size, and an invariable excess of families above that size. In the largest size group (over 14) the excess becomes extravagantly large; this, however, may be partly accounted for; we may be sure that the biographers have seldom failed to record families of this size, so this group has really been recruited from the families of all our 902 eminent persons. Even on this basis, however, it remains extremely large; in Denmark, for instance, it is stated, a family of 22 children only occurs once in 34,000 marriages.†

If, as seems probable, it may be asserted that genius-producing families are characterized by a tendency to an abnormally high birth-rate, this is not a fact to cause surprise. It might, indeed, have been anticipated. The mentally abnormal classes generally belong to families with a high birth-rate. This has been shown by Ball and Régis (confirmed by Marandon de Montyel) to be markedly the case as regards the insane. Magri has found it to be the case as regards criminals, as well as regards the epileptic, hysterical and neurasthenic.

An interesting point, and one which can scarcely be affected at all by any twist in the biographical mind, is the fact that our men of ability (the women are here excluded) are the offspring of predominantly boy-producing parents. Taking the 64 families in which the number of boys and girls in the family is clearly stated, and excluding 12 of these as consisting only of boys, we find that there are about 6 boys to 5 girls, or more exactly, 111 boys to 100 girls. The normal proportion of the sexes at birth at the present time in England is about 104 boys to 100 girls. It is in accordance with the predominantly boy-producing tendency of families yielding men of genius that the families yielding women of genius should show a predominantly girl-producing tendency. Here, indeed, our cases are far too few to prove much, but the results are definite enough so far as they go. Putting aside the families consisting only of girls, the sexual ratio is rather more than 3 boys to 4 girls, or more exactly, in the ratio of 85 boys to 100 girls. Putting the matter in another way, we may say that, while in every ten families from which men of genius spring, the boys pre-

*This tendency has already been noted by Galton when investigating English men of science, and by Yoder in studying a small miscellaneous group of eminent men.

†In our genius-producing group there are 4 families of more than 19 children. Doddridge was the youngest of 20 children; Popham was the youngest of his mother's 21 children; Colet was the eldest and only surviving child of 22; Dempster was, or stated himself to be, the 24th, of 29 children. There was a strong tinge of romance about Dempster, and I fear that we cannot accept this statement with such complete confidence as would be desirable.

dominate in six families, in ten families from which women of genius spring the boys predominate only in three.

I have made a tentative effort to ascertain what position in the family the child of genius is most likely to occupy. In a large number of cases we are only told his position as a son, not as a child; these are, of course, excluded. In order to investigate this point I considered the families of at least 8 children (and subsequently those of at least 7 children) and noted where the genius child came. This showed a very abnormally large proportion of eminent first children, and also abnormally few second and third children. Suspecting that certain peculiarities of the biographical mind (needless to enter into here, since we are not investigating the psychology of biographers) may have somewhat affected this result, I have confined myself to a simple inquiry less likely to be affected by any mental tendencies of the biographers. In families of different sizes, what relation do eldest genius children and youngest genius children bear to genius children of intermediate position? The results are very decisive. If, for instance, we take families of 7 children, it is found that they yield 8 eldest children of ability and 3 youngest, but only 10 for all the intermediate positions. If we take 8-children families, there are 3 eldest children of ability and 3 youngest, but only 10 intermediate. Again, 9-children families show as many as 4 eldest children of ability and 4 youngest, but only 1 intermediate child. So with 10-children families, there are 3 eldest children of ability and 3 youngest, but only 3 for all intermediate positions. It is so with families of 11 children and of 13 children. The only exception I have detected is in the case of 12-children families, in which group youngest children are wanting. So marked is the preponderance of eldest and youngest children of ability that only in two of these seven groups (7-children families to 13-children families) do the intermediate children of ability exceed in number the eldest and youngest children combined. It is evident that there is a special liability for eldest and youngest children to be born with intellectual aptitudes, the liability being greater in the case of the former than of the latter, for there are in the seven groups 24 eldest children to 18 youngest children, the intermediate children numbering 40.

Here again the results, however remarkable they may appear, are strictly such as we might have been led to expect. In the other mentally abnormal classes we find exactly similar phenomena. Thus, among 433 idiots Mitchell found that 138 were first-born children and 89 last-born children; so that here not only were the eldest and youngest children in an absolute majority over all those of intermediate position, but the eldest had to the youngest almost the same ratio (4 to 3) as we have found in the genius group. Shuttleworth has lately stated that among the so-called 'Mongolian' variety of imbeciles quite 40 per cent.

are the youngest members of large families. Bohannon found that youngest children tend to be exceptional and abnormal, precocity being a specially prominent trait among them. Among the socially degenerate classes Dugdale found first-born and last-born prominent, the former tending to be criminals, the latter paupers.

Whenever it has been possible I have noted the age of the father at the birth of his eminent child. It has been possible to ascertain this in 204 cases, and the data thus obtained may be considered as fairly free from fallacy, so far as the biographical mind is concerned. The range of age is considerable, from 15, the age of Napier of Merchiston's father at his birth, to 79, the age of Charles Leslie's father, the period of potency in the case of the fathers of persons of eminent ability thus ranging over 64 years. The 204 cases may be grouped in five-year age-periods as follows:

Under 20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60 and over
1	7	22	54	41	33	24	9	7	6

These figures run in a fairly smooth and regular way, and I believe that they are very noteworthy and significant. It will be seen that 30-34 is the most frequent age of fatherhood, and that while there are very few cases of fatherhood during the ten preceding years, when sexual vigor is at its height, the majority of eminent persons have been begotten by fathers who had already passed this age of most frequent fatherhood. This result is the more significant when we remember that we are chiefly dealing with the upper social classes (for it is in their cases that these facts are most easily ascertained), and that we must exclude the quite modern tendency to retardation of the age of marriage. I have no figures of the age of fatherhood among normal subjects quite fairly comparable with those here presented. The significance of the age of fatherhood has been chiefly studied, so far as I am aware, by Marro in North Italy, and we cannot assume that the conditions are there quite the same. Marro divided the fathers of his normal subjects into three classes: (1) Below 25 years of age, a stage of immaturity; (2) from 26 to 40 years of age, a stage of maturity; (3) over 40 years of age, a stage of decadence. He found that 8.8 per cent. fathers of normal subjects belonged to the first group, 66.1 to the second class and 24 to the third. The corresponding figures for the fathers of the persons of eminent ability concerned in the present inquiry are 3.9, 57.3 and 38.7. Whatever the value of this comparison, there can be little doubt that an abnormally high age prevails among the fathers of our eminent persons. I have only been able to ascertain the age of the mother in 40 instances. In these cases it is distributed as follows:

Age of mother.........	21-24	25-29	30-34	35-39	40-44	45-49	50
Number of cases.......	8	13	8	5	4	1	1

Except for the one very unusual instance at 50 (Dibdin's mother), this distribution seems to indicate that the mothers of persons of intellectual ability are predominantly at the period of greatest vigor and complete sexual maturity when they produce their distinguished children. Notwithstanding the tendency of first-born children to show intellectual ability, none of the mothers are under 21.

It may be noted that in at least 36 of the 276 cases in which we have details of the family history (or in about 13 per cent.) the mother was a second or third wife. In at least 6 cases the father was a second husband.

It would have been instructive to compare the ages of the parents and to ascertain the degree of disparity. I have only been able to do this in 34 cases. There is a marked tendency to disparity which ranges up to 49 years.* Whatever may be the normal amount of disparity between the ages of parents, it certainly tends to range chiefly below 4 years, but in this group only 8 cases (*i. e.*, in the proportion of about 23 per cent.) show less disparity than 4 years; the majority range between 4 and 8 years, and as many as 8 (*i. e.*, in the proportion of over 22 per cent.) show a greater disparity than 10 years.† In 6 out of the 34 cases the mother was older than the father. In a considerable proportion of cases both parents were elderly.

On the whole it would appear, so far as the evidence goes, that the fathers of our eminent persons have been predominantly middle-aged and to a marked extent elderly at the time of the distinguished child's birth; while the mothers have been predominantly at the period of greatest vigor and maturity, and to a somewhat unusual extent elderly. There has certainly been a notable deficiency of young fathers, and, still more notably, of young mothers.

Our data at this point are too few to be very decisive, but, so far as they indicate anything, they enable us once again to bring men of 'genius' into line with the other mentally abnormal classes. The late Dr. Langdon Down (who at my suggestion investigated the point some twelve years ago) found that in the case of the parents of idiots there was a disparity of more than ten years in 23 per cent. cases, almost the same proportion as we have found in the parents of persons of intellectual ability. Among criminals also inequality of age in the parents, as well as elderly age of both parents, has been found by Marro to be more common than among the normal population. Marro (in his 'Carat-

*This very exceptional case was that of the father (an eminent bishop) of Charles Leslie, the nonjuring divine. In this case the father was 79, the mother 30.

†In Hungary, as a table given by Körösi shows, if we take men at ages between 26 and 30, covering the most frequent normal age of marriage, in only 3 per cent. cases is the discrepancy of age as much as ten years. The disparity, of course, tends to increase with the man's higher age at marriage.

teri dei Delinquenti' and 'La Pubertà') has investigated the whole question of the influence of the age of the parent on the character of the child. He has found that when both parents are in the same period of age development elderly parents produce the highest proportion of 'very intelligent' children (though not the highest proportion of 'intelligent' children). Marro has also found that, taking the fathers alone, although 'intelligent' children are mostly the offspring of young fathers, 'very intelligent' children are mostly the offspring of middle-aged and elderly fathers. He finds much the same result as regards mothers. He found that the insane show an excess of elderly fathers, while murderers show a deficiency of young fathers and a very great excess of elderly fathers. The highest proportion of defectively intelligent children (this harmonizing with Langdon Down's results) Marro also found among the offspring of elderly fathers. Elderly fathers and very young mothers were found by Marro to produce the largest proportion of 'good conduct' children, but not of intelligent children.

SUICIDE AND THE WEATHER.

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MUCH has been written and rewritten on the subject of suicide. It has long been a favorite topic with the student of social statistics, and has been scientifically treated from the standpoint of race, of nationality, of social condition, of occupation and of climate. Whole volumes have been devoted to the problem and magazine articles almost without number. It is not, however, my intention in this paper even to summarize the conclusions arrived at in all this mass of literature, but to discuss a phase of the subject which can not have escaped the reader of the daily paper, and has long proved an enigma to the special student of the problem of self-destruction—that is, the daily fluctuation in the occurrence of suicide. Why is it that upon picking up our daily paper one morning we see the heading 'Epidemic of Suicide', and find the details of six or eight or even a dozen successful or unsuccessful attempts recorded for the previous day—a number greater than for the whole week preceding? Yet such is often the case—so often, in fact, as not infrequently to have been the subject of editorial comment, with vague queries as to the cause of such a wave of emotional depression and consequent self-destruction.

The answers to this query have been many and varied, among the most frequent of which has been chance. Mimicry and suggestion have been proposed, and without doubt have their place in the solution of the problem of the periodical fluctuation of the suicide curve, but still can not account for all its peculiarities. The weather has also been suggested as the cause of the fluctuation referred to, and it is to the following out of this promising clew that this paper is confined.

From *a priori* grounds it would seem to be a good one, for of all the environmental conditions, those of the weather are the only ones which vary for all the individuals in a given locality simultaneously. A and B and C all have troubles peculiarly their own, the climax of which could not be expected to occur upon the same day; but when the east wind blows and the sky is leaden A, B and C all feel the influence, whatever it may be, and an empirical study of large numbers of A's and B's and C's, noting their behavior under such conditions, would seem to be the surest method of discovering just what the influence is.

That weather states have a mental effect has long been recognized. Literature is full of allusions to the fact, and not a few of the world's great thinkers have left on record their own emotional flights and depressions under different meteorological conditions. But most of us need to take no other word for the fact than our own. In all the vigor of perfect health such influence may hardly be recognized, but when the vital powers are depleted by the exhausting effects of a long nervous or physical strain, then this phase of the cosmical environment is sure to make itself felt. Then come the days when everything goes wrong. The groundwork of forgotten quarrels is remembered, uneasy questions arise with regard to the future; one gets tired of life. And how much of all this can be attributed to an east wind or a leaden sky—in other words, to weather effects? In order to answer this question we must define our use of the term 'weather effects.' From the standpoint of our present study we should include within the category of weather effects any marked inequality in the occurrence of suicide which may be found to bear a fixed relation to the fluctuations of what we call weather. We conclude that a fixed relation between a given weather state and an unusual prevalence of suicide is causal and not accidental. This is based upon an inductive study of large numbers of data, and is as valid as such studies can well be.

The problem, then, consists in discovering these fixed relations. In order to do this with exactness, the meteorologist's analysis of weather must be taken. To him a given weather state is a complex and not a simple phenomenon. He reads its temperature, its barometer, its humidity, its wind velocity, its sunshine or shade, and its precipitation, and it is only to the synthesis of these conditions that he applies the term weather. For the purpose of our present study it is not enough to say that the weather is fine, or disagreeable, or muggy, for those terms mean one thing to one person and something very different to another, so it has been necessary to make use of a definite meteorological nomenclature which is recognized the world over. The study is in no sense an attempt to account for suicide, but for the irregularity of its occurrence. Man always has sought and perhaps always will seek self-destruction as the relief for sorrow, fancied or real, and the basal reason for this is not to be found in the weather. We would not argue that the weather drives people to suicide save in very exceptional cases, but, on the strength of what follows, that under some weather states other things are peculiarly liable to drive people to the act. In other words, that some meteorological conditions so affect the mental state, so influence the emotional balance, that ordinarily endurable things become unendurable, and life seems no longer worth the living.

This problem, which seems to show a causal nexus between the weather and the mental state of the suicide, is a comparison of the occurrence of suicide under different meteorological conditions, with the normal prevalence of those conditions, noting the excess or deficiency.

The data were collected for New York City and the city of Denver, Col., and although the climatic conditions of the two cities are very different, it is in no sense a comparative study for them. In fact, so few data (two hundred and sixty suicides) were procurable for the western town that but little weight is given to conclusions based upon them, compared with the much greater number for New York City, and the study of the former is only incidentally mentioned.

The method of procedure was as follows: In order to procure the proper data of suicide for the city of New York the records of the coroner for five years were carefully gone over (some 28,000 separate death certificates), disclosing the particulars of 1,962 suicides, and the exact number (varying from 0 to 9) tabulated for each of the 1,826 days of those years. Next the police records for the same five years were studied, and the number of unsuccessful attempts for each day noted. This record is quite complete, since in the eyes of the law one attempting suicide is a criminal, and must be so branded on the books. From these two sources were obtained the exact number of persons who for each day of the period covered were of suicidal intent, unless some unsuccessful attempt escaped the surveillance of the police. In the present article neither age, sex, nationality, nor occupation is considered; simply the fact that some one wished to die by his own hand—for the five years, 2,946 in all for the city of New York.

When the data of suicide had thus been tabulated, the meteorological basis for the study was obtained from the records of the United States Weather Bureau. At the New York station (Denver for the Denver study) were copied the mean temperature, barometer and humidity, the total movement of the wind, the character of the day and the precipitation for each of the 1,826 days of the period considered, and placed opposite the already tabulated number of suicides. Then, by a somewhat laborious process of tabulation, the exact percentage of days which were recorded at the Weather Bureau under each of the seventy-seven definite meteorological conditions represented by the accompanying figures was computed. That is, the exact percentage characterized as 'clear,' as 'partly cloudy,' or 'cloudy,' as having some or no precipitation (without considering the amount), as having had a mean temperature between zero and five degrees F., between five and ten degrees, and so on for each one of the designated groups for temperature, barometer, humidity and wind. Now, it may be readily seen that these percentages represent the normal or expected occurrence of suicide for each meteorological group *if the weather had no effect*. For instance, if thirty per cent. of the days are found to be characterized as 'clear,' we should expect that same percentage of suicides for 'clear' days plus or minus the percentage due to probable error from accidental causes (which with the number of data used would be very small) *if the character of the day had no influence on* *their occurrence.* If forty per cent. did actually occur under such conditions, we should be forced to conclude that fair days were prolific of suicide, as indeed they seem to be. This principle was applied to each of the meteorological groups, and the figures show graphically the results.

For each, the general meteorological condition is indicated at the top; the definite group readings are given in small figures upon the heavy vertical lines which represent the occurrence of suicide for the group. Expectancy for each group is represented by the vertical distance A—B and excess or deficiency graphically shown in percentages of this, which may be read by means of the scale at the left.

The method of tabulation, by means of which the actual occurrence of suicide for each meteorological group, was determined was similar to that for expectancy, and needs no further explanation.

DISTRIBUTION.

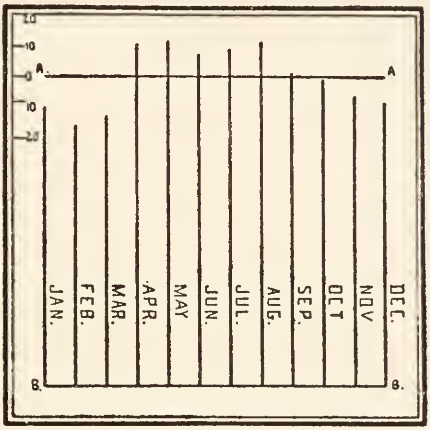

FIG. 1.

MONTHLY DISTRIBUTION.—Fig. 1 indicates very wide variation in the number of suicides occurring in the different months of the year—generally speaking, the heated months showing excesses and the cold ones deficiencies when compared with the normal. May and August show the greatest numbers, with the least for February, in spite of the fact that the shortness of the last-named month is taken into consideration.

It may be seen, by an inspection of the figure, that the increase in number for each month from February to August, and the decrease for the other months of the year, would give an almost perfectly regular *crescendo-diminuendo* to the occurrence curve were it not for the fact that April and May are raised out of their position by unusual excesses. Why April, which in its general weather characteristics is Elysian compared with its immediate predecessor, should show one-fourth more suicides, and May, which by common acclaim is one of the most delightful of the calendar, should present a number surpassed only by sweltering August, it is not easy to see. Yet such is the case for the five years covered by this study, and similar conditions have been demonstrated by other students of the subject. Morselli, in his exhaustive treatise for the European nations, finds that for thirty-two separate studies made by him the maximum numbers were in June eighteen times and in May eight times. In explanation of the fact he says, "Suicide is not influenced so much by the extreme heat of the advanced summer season as by the early spring and summer, which seize upon the organism not yet acclimatized and still under the influence of the cold season." There is little doubt that the end of winter brings with it a depleted condition of vitality, both nervous and physical; yet I am inclined to think that the

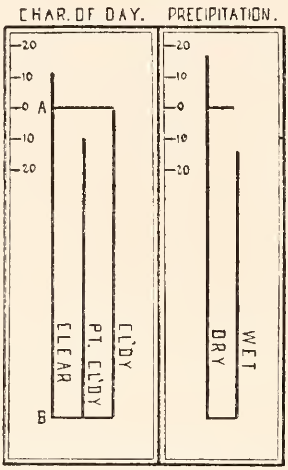

Fig. 2.

fact can not wholly account for the great increase in the later spring months. In the conclusion of this paper the condition is again alluded to, and at this point I would simply call attention to the fact that the increase comes with the season of the year when rejuvenating Nature is in her brightest mood.

Character of the Day and Precipitation.—The terms 'clear,' 'partly cloudy' and 'cloudy,' as used by the Weather Bureau's characterization of weather states, have a definite and technical meaning. The first is used to designate days on which the sun is obscured for three-tenths or less of the hours from sunrise to sunset; the second from four-tenths to seven-tenths of that period; and the third eight-tenths or more. (See Fig. 2.)

Under precipitation I have considered separately days which were absolutely free from rainfall or snowfall, and those on which there was either, without considering the amount.

The figure referred to discloses some unexpected facts—namely, that the clear, dry days show the greatest number of suicides, and the wet, partly cloudy days—the gloomiest of all weather—the least, and with differences too great to be attributed to accident or chance; in fact, thirty-one per cent. more on dry than on wet days, and twenty-one per cent. more on clear days than partly cloudy. As will be seen, on cloudy days the occurrence was about normal. What does this mean? Must fiction resign her right to ring in gloomy weather and blinding storms as a partial excuse for ending an existence made more unendurable by these? If such be the case, it is well that Dickens and Lytton and Poe are gone, for they would be robbed of a large number of their tragic climaxes. England has long been characterized as 'gloomy Britain,' and Montesquieu has called it the 'classic land of suicide,' stating that the 'excessive number of suicides for that country is due to its gloomy weather.' Statistics have shown, however, that the number is not excessive there, being less per million inhabitants than for any other important European nation. An interesting paper, appearing in the British magazine *Once a Week* (vol. xix.) over no signature (though the writer was evidently not a Scotchman), has a bearing upon the subject. It says:

"The idea that the prevalence of suicide in this country (England) is due to our bad weather is precisely one of those hasty and illogical inferences which are characteristic of the Gallic mind. The constant gloom of bad weather ought to acquaint us so thoroughly with moods of depression that suicide would never occur to us. Look at Scotland, for instance, where suicides are rare. Why are they rare? Simply because a succession of Scotch Sundays has so accustomed the people to prolonged despondency that any sudden misfortune can not sink their spirits any further. One has only to spend a dozen Sundays in Glasgow or Edinburgh to become inoculated against suicide. So far from London fogs driving people to jump off Waterloo Bridge, they ought to train the mind to bear any calamity. A man who has taught himself to eat prodigious quantities of opium feels scarcely any effect from other forms of intoxication. We can educate our mental susceptibilities as we can our muscles, and the more we educate them the more they are able to bear."

There are many truths beneath the jocular vein of this quotation, and the writer expressed more facts than perhaps he knew.

Certainly a comparison of suicides for Denver and New York City supports his theory, for in the former city, where cloudy and partly cloudy days are less than one-third as frequent as in the latter, we find suicide excessive during the gloomy weather. Yet the conditions there, both social and climatic, are so unusual as to give this fact little weight in a comprehensive study of suicides, and we must maintain that Vilemais's dictum that 'nine-tenths of the suicides occur in rainy or cloudy weather' is utterly unfounded upon fact, at least for the conditions covered by this study.

Temperature.—Fig. 3 seems to show plainly two things: (1) That the greatest excesses of suicide are found at the two extremes of the temperature scale, when the conditions entailed the maximum of actual misery, and (2) that the next greatest excesses occur during the pleasantest conditions of temperature. I would here, however, call attention to the fact that for all the figures the readings at the extremes of the conditions are based upon fewer data than those nearer the middle, hence are more liable to accidental error. For example, although the temperature group zero to five degrees shows an excess of two hundred and

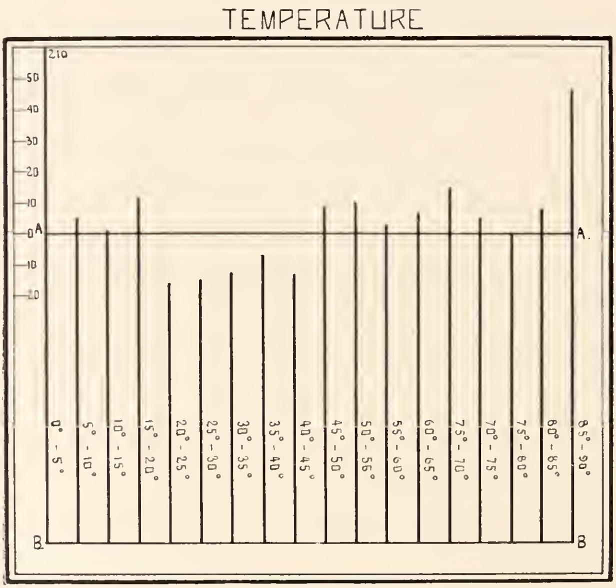

Fig. 3.

ten per cent., the condition occurred but twice in the five years studied, and the whole number of suicides was but eight, while the excess of fifteen per cent. for the group sixty-five to seventy degrees is based upon two hundred and sixty-eight. For this reason the value of the readings at the extremes of all the figures, except Fig. 1 and the upper limit of Fig. 5, at which point there were data enough to give validity to the findings, is lessened when compared with other points in the curves.

Taking this fact into consideration, the greatest numerical excesses in suicide occur in the temperature group from forty-five to seventy degrees. This places them within the category of most agreeable temperatures, for within those limits are found the monthly means of April, May, June, September and October. The deficiencies of suicide occur in the groups from twenty to forty-five degrees, conditions which are not generally considered most agreeable and within which are found the monthly means for the colder months of the year.

These results, however, are corroborative of the findings for the study of monthly occurrence which show deficiencies for those months. The excesses for extreme conditions of heat and cold are perhaps only what might be expected. In the thickly populated tenements of the city great heat becomes so oppressive as hardly to be endured, and at the other extreme of temperature, when the mercury of the ther-

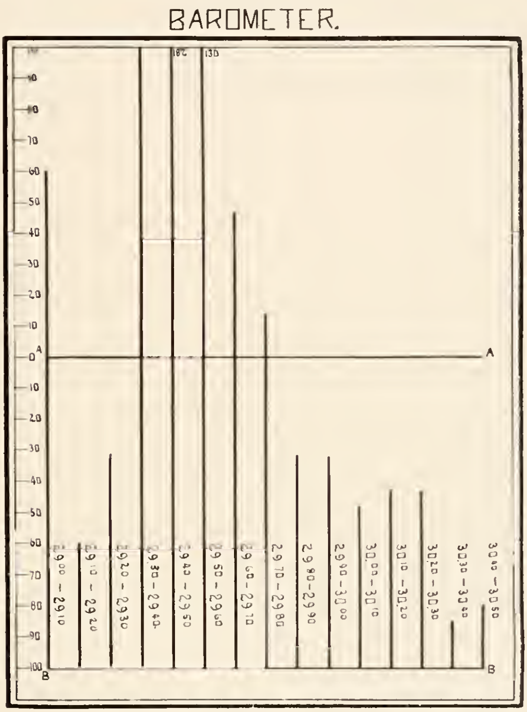

FIG. 4

mometer is only in the bulb, both personal misery and a feeling of sympathy for a dependent family might prompt one to self-destruction as the last resource.

This curve does not differ materially from that of the Assault and Battery,* except that in the latter it is shown that for the highest temperature ever experienced those misdemeanors, as recorded by the police, show deficiencies. For them the numbers increase regularly up

* See 'Conduct and the Weather,' Monograph Supplement No. 10, 'The Psychological Review.'

to a temperature of eighty-five degrees, but above that point they fall off very rapidly. This fact, however, is not hard to account for, since a considerable amount of energy is required to be objectionably out of order, and at such conditions of heat this seems hardly available.

Barometer.—Considering the liability that accidental conditions affect the validity of our curves at their extremes, the results shown in Fig. 4 prove conclusively that low conditions of pressure are accompanied by excesses in suicides, with corresponding deficiencies for the reverse barometrical readings. We can not, however, suppose that it is the actual density of the atmosphere which produces this marked effect. A difference of pressure as great as that between the two extremes for New York City would be experienced in going to the Adirondacks, and five times as great in a trip to Colorado, without producing tendencies to personal annihilation, so we must look for our explanation elsewhere. It is probably to be found in the relation which exists between atmospheric pressure and some other weather states—possibly storms. The peculiar mental and physiological conditions which prevail for a considerable period just preceding violent storms or marked changes of weather have long been recognized, and it may be that in them we have the solution. Persons afflicted with gout or rheumatism, or even corns, can 'feel' the approach of such meteorological conditions, and certain mental peculiarities are probably just as prevalent. Many weather proverbs are based upon the unusual activities of members of the animal kingdom at such times, and as a storm is often preceded by a low condition of the barometer, we have perhaps an explanation of their cause. More work, however, must be done to demonstrate this as a scientific fact.

Humidity.—The results of the study of suicide for this condition (Fig. 5) are in themselves conclusive, but directly opposite to those found in similar studies made for Assault and Battery, Deportment in the Public Schools and the New York City Penitentiary, and the behavior of the insane.* For suicide the excesses are for high humidities; for the others mentioned they were for low.

The showing for suicides seems to be what would be naturally expected if we were to theorize on the matter, as those unendurable 'sticky' days, when one feels it his prerogative to be 'out of sorts,' are usually of high humidity. There are some interesting conclusions to be drawn here by a comparison of this curve with that for precipitation. The latter showed deficiencies of suicide for rainy days, while this gives an excess for humid ones. Now, all rainy days are humid, but not all humid days are rainy, and our logical conclusion must be that the excesses shown by the present figure must have been for the humid variety, yet

* See 'Conduct and the Weather.'

without precipitation. Such precisely is the 'sticky' weather mentioned, and its effect must have been deadly to produce such results.

In accounting for the unusual number of assaults and misdemeanors in the public schools for low humidities, as discussed in the paper cited, the electrical potential of the atmosphere for such meteorological conditions was considered the cause. It is a fact conceded by scientists that at every point upon the earth's surface there are lines of electrical force extending off into space, and that the potential is roughly in a reverse ratio to the humidity prevailing at a given time. This electrical condition for regions of universally low humidity, as the altitudes of our western plateaus, is very marked and productive of no slight effects. These

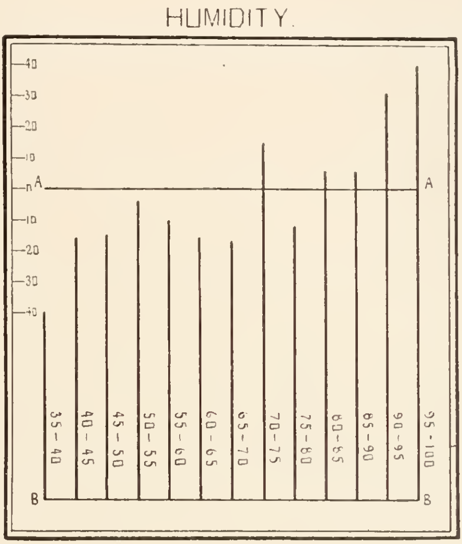

Fig. 5.

seem to be a mental and even physical exhilaration, productive of energy which in the long-run generally proves to be in excess of the normal healthy possibilities. The result is for those regions a tendency to overwork, especially mentally, with a resulting state of collapse. Although these conditions are not so marked for the higher humidities of the sea-level, they nevertheless exist to a degree, and without doubt in New York City there is less individual surplus energy when the humidity is relatively high than when relatively low. This would lead us to infer that, from the showing of this condition, suicide was excessive when energy was low. This relation of occurrence to available energy is reversed for certain of the figures, but other conditions enter in which are discussed in the conclusion of this paper.

Wind.—But little need be said upon the effect of this factor as shown by Fig. 6. The regularity of the increase of suicide with increase in movement of the wind is too marked to allow any other theory than that of a causal nexus. This effect seems to be much greater upon the suicide than upon any of the offenders mentioned in the study cited. It is, however, shown to be as great or even greater for all classes of crime in the Colorado climate, where wind is an important factor in the production of high electrical states. The other study, however, showed very slight wind effects for New York City, and their comparison with

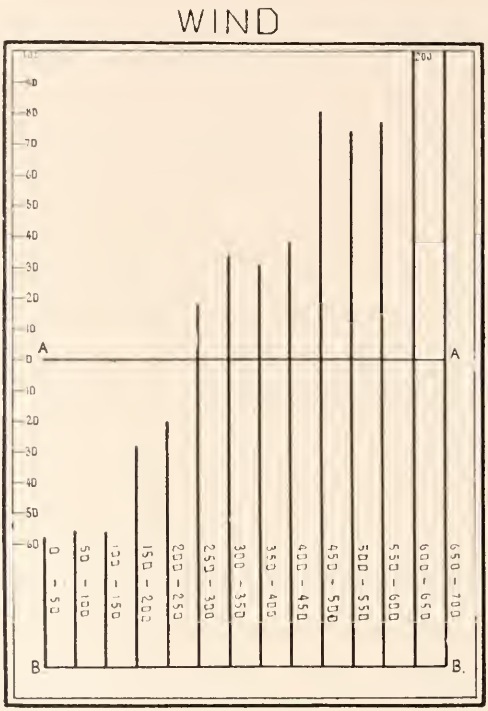

Fig. 6.

this would seem to prove that the mental states of the suicide and of the street brawler are very differently influenced by it.

It is difficult, in conclusion, to summarize the results of this study in such a manner as to be of much value or to bring forward theories which are certain of any long tenure of life. The whole method of the study is too new and untried, and the number of data inadequate. The bare facts revealed in the preceding paragraphs must prove of much more value than any hypothesis drawn from them at this stage of the investigation. Still, there are a few generalizations which seem worth noting, especially as they are based in part upon findings which are entirely contradictory to popular opinion with regard to the time chosen by the suicide for the final act.

The first is that suicide is excessive under those conditions of weather which are generally considered most exhilarating and delightful —that is, the later spring months and upon clear, dry days. Reference to Figs. 1 and 2 proves this conclusively for the number of data and the locality studied. It was also noted that there were the greatest numerical excesses for the most agreeable temperatures. Barometrical conditions can hardly be referred to the categories agreeable and disagreeable, but for humidity and wind the relation will hardly hold, since we have the greatest excesses during high humidities and great wind velocities, both of which are unpleasant. Yet these facts would not invalidate our first statement, for neither high winds nor great humidities bring a scowl upon the face of Nature that can be compared with that of a wet, drizzling day. In fact, a day may be bright, and be both windy and humid. Yet these latter conditions have effects peculiarly their own, as shown conclusively by the study of deportment already cited. They are, for wind, the production of a neurotic condition in which self-control is in a marked degree lessened, and for high humidities the production of a minimum of vital energy. The former is shown especially in the study of the school children, and the latter of the death rate. These facts make it possible for us to amend our statement that suicides are excessive during the most noticeably delightful conditions, by adding: coupled with especially devitalizing ones.

But this does not in any way account for the seemingly anomalous effect of bright weather. To me the only plausible hypothesis is that of contrast. Investigation has seemed to prove that very few suicides are committed on the 'spur of the moment.' The act is generally premeditated, and its consummation deferred, sometimes again and again. We can hardly doubt, either, that it is dreaded, and the hope entertained, even to the end, that it may not need to be. During the winter months that hope must be centred on the belief that when Nature smiles with the spring sunshine all will be well; on the gloomy day, when the morrow comes with its exhilarating brightness, the present cloud of unhappiness will be gone. The love of life is still strong, and the grave can not be sought while there is still hope for better things.

But spring comes with all its excess of life, and the morrow with its brightness, but do not bring to the poor unfortunate, unable to react to these forces as of yore, the hoped-for relief. He thinks of other springs when the bluebirds sang happier songs, and of other sunshine which had set his blood tingling. The drowning man had waited long for the straw; it came and he clutched it, but it sank beneath his weight.

RECENT PROGRESS IN AERIAL NAVIGATION.

By CHARLES H. COCHRANE, M. E.

THE recent successful trips of the Zeppelin airship make it appropriate to review and illustrate some of the less known attempts at aerial navigation. Somewhat similar in plan to Count von Zeppelin's enormous airship is the dirigible flying-machine shown in Fig. 1, with which at various times during 1897 and 1898 Dr. K. I. Danilewsky, of Charkov, Russia, made excursions. The object of making the balloon sausage-shaped was, of course, that its forward end might be brought toward the wind, and then, with the nose pointed upwards, as in the illustration, its under surface served somewhat as that of a kite. The wings were made about twelve feet in length, and it was found

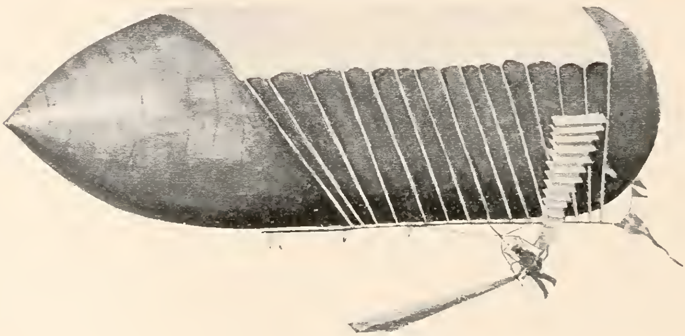

Fig. 1. Danilewsky's Dirigible Balloon.

possible to handle them so as to turn the balloon entirely around in the air, and also to keep it practically stationary in a moderate breeze.

M. de Santos Dumont has sailed about the Eiffel Tower in Paris in the dirigible balloon shown in Fig. 2. It was 65 feet long, 25 in diameter and contained 17,658 cubic feet of gas. He used a small petroleum engine for controlling the rudder and aeroplane. The reports are that he was able to navigate very much at will. Fig. 3 is another form of dirigible balloon tried by M. Dumont. This was also reasonably successful.

Fig. 4 represents a machine designed by Frederick R. Merritt, with windmill sails below and on both sides of his balloon, and a mechanism for feathering them in such a manner as to drive the craft either forwards or backwards.

Fig. 5 is a design of Theodore Liebrand. The cylinder is of aluminum, and the wings transform themselves into wheels when the machine runs along the ground. I have no record of the actual success of either Merritt's or Liebrand's inventions, or even of their trial.

Returning to the realm of actual experiment, in Figs. 6 and 7 are shown views of Carl F. Myers's 'sky-cycle.' Of this Mr. Myers

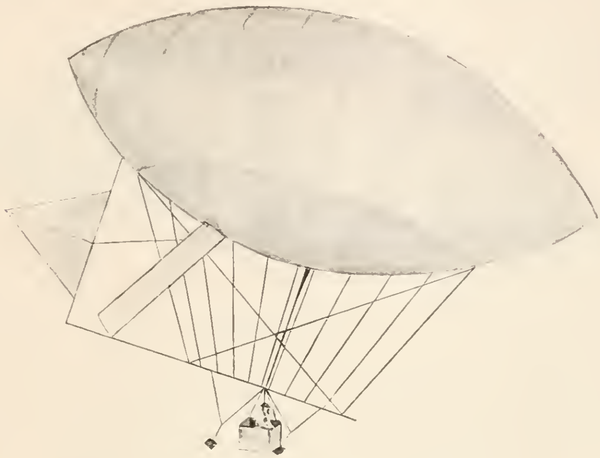

FIG. 2. SANTOS DUMONT'S DIRIGIBLE BALLOON (I).

FIG. 3. SANTOS DUMONT'S DIRIGIBLE BALLOON (II).

writes, under date of February 5, 1900, with the enthusiasm of the inventor:

"The sky-cycle, or gas-kite, is a hand and foot propelled air-ship, provided with revolving screw-sails, vibrating wings, movable aeroplanes and universal rudder—the object of the entire equipage being to test the relative advantages of all known systems for propulsion and guidance, and to attain practical experience in manipulating air craft. The operator and machinery are suspended below a peculiarly shaped gas-spindle, whose fabric has been treated by a special process, original with me, which enables it to retain hydrogen permanently during use. It has within a limited period made upwards of one hundred flights, embracing New York State, Massachusetts, New Hampshire, Maine,

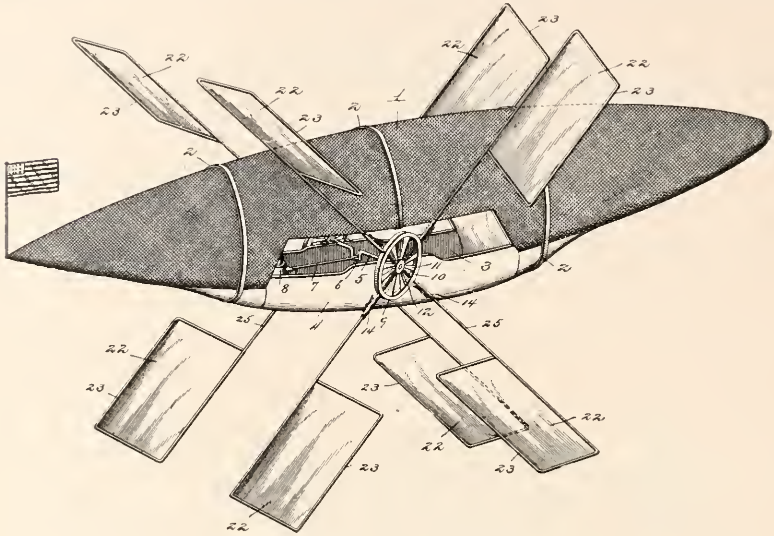

Fig. 4. Merritt's Flying Machine.

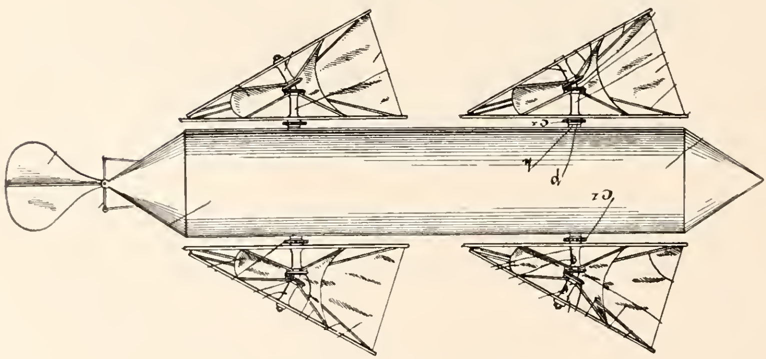

Fig. 5. Liebrand's Flying Machine.

Delaware, Connecticut, New Jersey, Pennsylvania, Maryland, Virginia, Tennessee, Ohio, Michigan and Illinois.

"Three machines only have been built, varying somewhat in form of spindle and extent of surface handled. As used at present, the screw, formerly fifteen feet diameter, has been reduced to eight feet, and the wings and rudder abandoned, the universal-jointed aeroplanes on each side having proved in every way superior for all evolutions.

"With practice acquired by use of the sky-cycle, and with some indicated variation in structure and equipment, including a light automotor engine of best type, there should be no great difficulty in accomplishing an overland transcontinental journey by two or three persons with this type of air craft in less time than the same trip could be made by the same party on the ground."

In Fig. 6 the gas-kite shown is a concavo-convex gas-vessel, like an upturned canoe. It is drawn forward by the screw-sail, which is rotated by hand and foot power. The steering is done by tipping to change the level or direction. In Fig. 7 the sky-cycle is shown tipping downward in the act of circling to the left in a descending spiral, the aeronaut using both screw-sail and small aeroplanes.

Jerome B. Blanchard, of Highlands, Col., patented in 1894 the aeroplane flying-machine shown in Fig. 8. He disdains the balloon

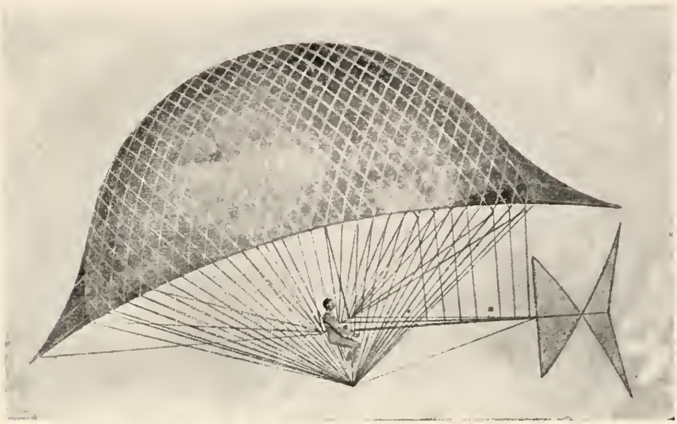

FIG. 6. MYERS'S SKY-CYCLE (I).

and depends entirely on the two aeroplanes and the speed of the aviator to maintain the vessel in the air. The plan is to start the machine along an elevated tramway until a lifting speed is acquired, and then to depend upon the muscular exertion of the occupant.

Of a more practical character is the 'trolley flyer' of Daniel C. Funcheon, of Valderde, Col., illustrated by Fig. 9. A drum is supported on a platform and hung from an aeroplane. Around the drum coils a wire that may be made to convey a current of electricity for propelling the mechanism. Of course, the machine would require propellers and balancing devices, which are not shown in the drawing.

Fig. 10 represents a machine actually built and tried by Arthur Steutzel, of Altona, Prussia, in 1896. The wings were eleven feet long, and were flapped by the power of a carbonic acid gas-motor in the receptacle below. The rudder was designed to maintain the course set, and the wire simply to support the machine at the start. When the motor developed one and a half horse-power the stroke of the wings was sufficient to raise it and cause a jump along the wire. The total weight of the apparatus was about seventy-five pounds, and the motor could be run to develop three horse-power for a little time, and with that power it flew along in an interesting manner.

In studying the principles of mechanical flight, many experimenters have made little flying toys and have launched them in the air to see how they worked. M. Pichancourt made a number of these, with twisted rubber as motive power, but no one of them ever sailed more than sixty-three feet. Prof. S. P. Langley had greater success in this

FIG. 7. MYERS'S SKY-CYCLE (II).

direction, and one of the rubber motor toys is shown in Fig. 11. I do not know how far it flew. Lawrence Hargrave made use of a tube of compressed air, on which were mounted wings that vibrated as long as the air furnished enough power. He built one of these, seven feet in length, that weighed only fifty-nine ounces, and it flew 350 feet. Another form of toy, designed to be thrown from a high station, is shown in Fig. 12. Several of these were built by James Means and launched from the top of a lighthouse in Boston harbor. The length was about six feet, and they sailed a considerable distance.

Mr. Beecher Moore, of Buffalo, N. Y., has originated the very interesting machine shown in Fig. 13. Mr. Moore states that the working model which he constructed was charged with a slow-burning mixture of saltpeter, sulphur and charcoal, and would fly about 500 feet, or until the mixture was burned out. He claims that it sails along evenly, balancing perfectly, and that it may be steered by the rudder. He prefers to fill the tank of the car with liquid air, on the ground that it furnishes a maximum of stored power with light weight. The air is exhausted and expanded through the nozzle at the top of the pipe. Mr. Moore says:

"The nozzle is placed at the top of the pipe, so that the push will act directly on the string of the kite and not push the car out of plumb, nor disturb the equilibrium of the machine. The kite is attached to the machine by wires, which allows it to balance itself automatically. This property would be destroyed if it was attached rigidly

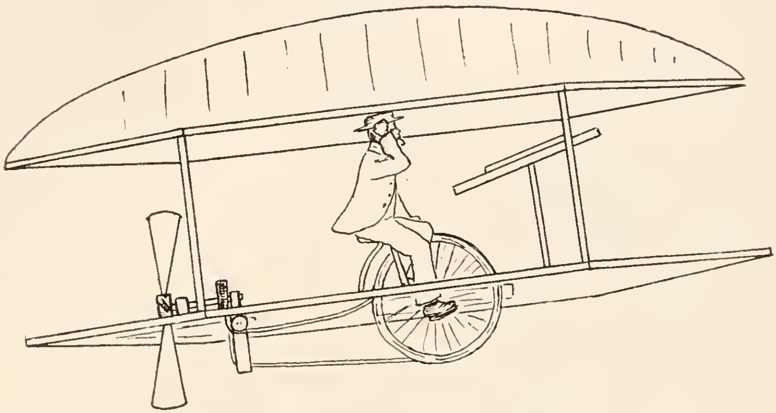

Fig. 8. Blanchard's Flying Machine.

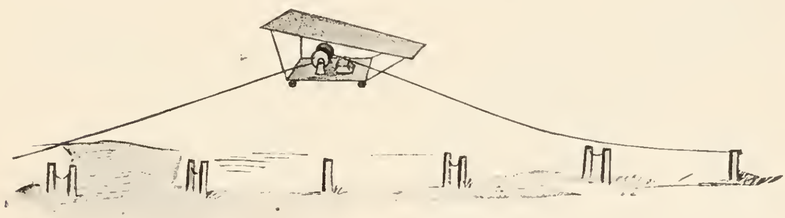

Fig. 9. Funcheon's 'Trolley Flyer.'

to the balance of the machine. The method of attaching the wires is original and adds to the stability of the kite. The wheels are not necessary for the locomotion of the machine in the air, but are necessary in starting and alighting. In starting the machine, it is placed in an open road, and when the power is applied it runs along on the ground, gathering speed and giving the kite lifting power. When the machine has attained the necessary speed, it will leave the ground at a slight angle and continue in the air as long as it is forced ahead at sufficient speed to sustain its weight on the aeroplane. In alighting, the power should be shut off slowly until the machine settles to the ground, where it would slow down and stop."

Mr. Moore is a strong advocate of the rocket-like form of propulsion for flying machines. He admits that it is wasteful as far as expense is concerned, but contends that it will make a machine go where propellers will fail. He claims that the propeller "is very wasteful of power from friction of the blades in the air, and from 'end stroke,' or currents of air set in motion in the wrong direction." He says further:

"I have studied and experimented extensively with small aeroplane

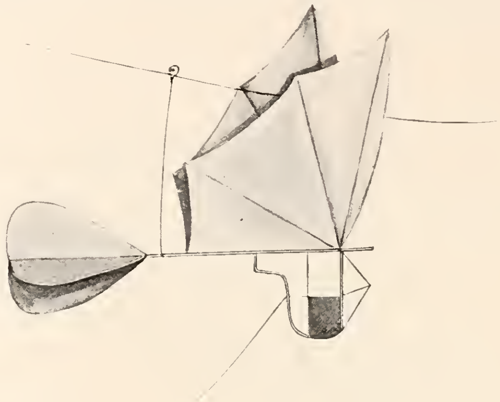

Fig. 10. Steutzel Flying Machine.

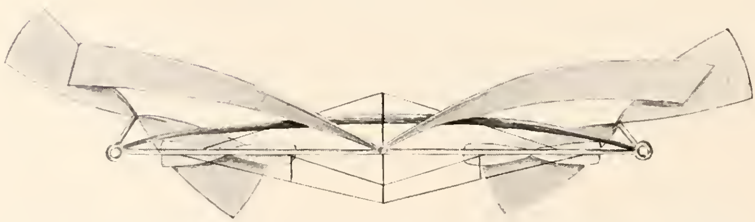

Fig. 11. Langley's Model for studying the Principles of Mechanical Flight.

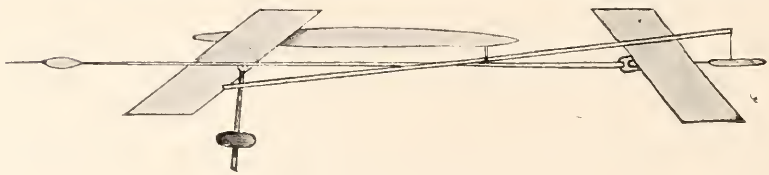

Fig. 12. Means's Model.

machines of every conceivable shape to test their balancing power, and have concluded that it is impossible to build a compact aeroplane machine that will balance and be under control in the air, with present known means. The aeroplane machine of the average inventor consists of aeroplanes elevated in various manners, and most of the weight arranged below to give them stability and keep them from upsetting.

This may appear all right in theory, but actual experiments will at once demonstrate that any compact aeroplane machine, with sufficient aeroplane surface to support the accompanying weight, will sway, turn sideways and upset, with all manner of erratic and unexpected movements.

Some four years ago M. Ader, a French engineer, attracted a great deal of attention with a machine styled the 'Avion.' It had a car running on four wheels, two propellers forward to pull it along, and

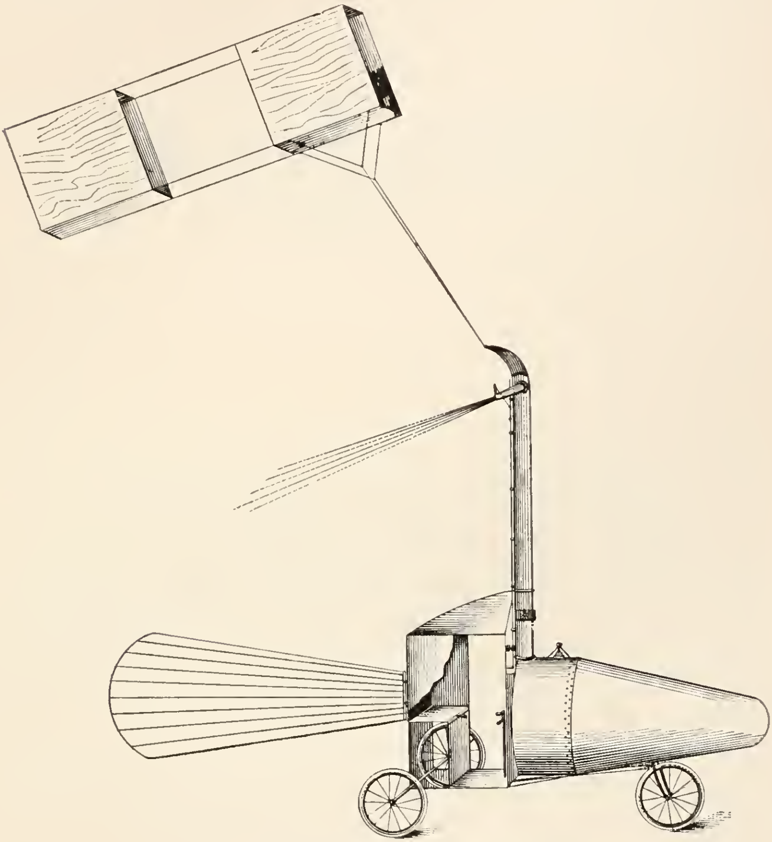

Fig. 13. Beecher Moore's Flying Machine.

two enormous bat-like wings. The wings were designed to assist in soaring and in sustaining the mechanical bird in flight, when enough speed was secured to carry it off the ground. The machine did fly a little, but, unfortunately, like Maxim's famous machine, described in the Popular Science Monthly a few years ago, broke down just as it demonstrated that it had enough lifting power to get off the track. Fig. 14 shows the 'Avion' as it was designed to appear in flight.

George L. O. Davidson, an English engineer, a year or two ago designed a bird-like machine, to be built of steel, and to sail along with spread wings, on the principle of a Lilienthal soaring apparatus, but I have never learned that the machine got beyond the stage of being represented in drawings.

This article would not be complete without a reference to Prof. S. P. Langley's aerodome, shown in Fig. 15. It has, however, been described so fully that it is only necessary to refer to it here.

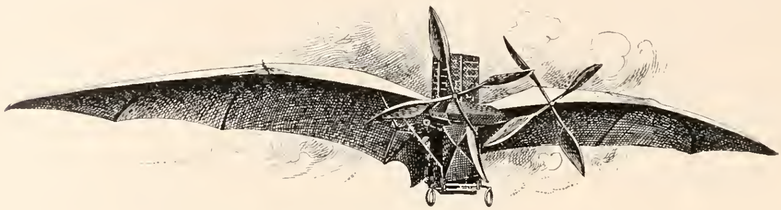

FIG. 14. 'THE AVION.'

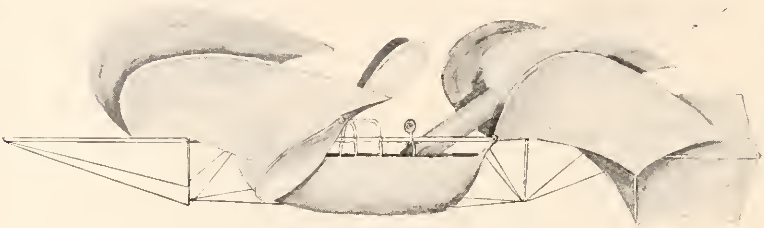

FIG. 15. LANGLEY'S AERODOME.

The conclusion may be fairly drawn from these brief descriptions of experiments in aerial navigation, that the aerodrome is supplanting the balloon, but that it can not as yet be used alone successfully. All the flying machines that depend solely upon a motive power and supporting planes are unable to carry any large supply of fuel, and descend after a short flight. The balloon can remain in the air a long time, but it is unwieldy. The practical inference is that some combination of the balloon and the aeroplane is necessary to produce a machine that will be of commercial use in aerial navigation.

THE FOREIGN TRADE OF THE UNITED STATES.*

BY FREDERIC EMORY,

CHIEF OF THE BUREAU OF FOREIGN COMMERCE.

DURING the calendar year just ended, the inundation of foreign markets by American goods proceeded on the lines indicated in previous issues of the 'Review of the World's Commerce,' with a constantly growing volume and force which have surmounted many difficult obstacles and offer a strong temptation to overconfidence in our capabilities as an exporting nation. At the present time, the United States may be said to be nearing the top wave of industrial eminence, and there is ample reason for the belief that the next few years will witness a great expansion in the sale of our more highly developed manufactures. But in the annual reports of our consular officers for the year 1900, there runs, along with a common note of satisfaction, a warning, here and there, of a more strenuous competition which, in the end, may counterbalance our superior advantages to a considerable extent and check our progress in the world's markets, unless we equip ourselves in the meantime for the ultimate phases of the struggle.

Nothing could well be more gratifying than the picture of our foreign trade as it is to-day by comparison with the figures of very recent years. It is all the more remarkable because our progress has been achieved with but little effort and by means not directed specifically to the promotion of foreign trade, but largely fortuitous, and springing from our intense absorption, for many years, in domestic industry and internal development. In other words, we have reached a surprising eminence in the exportation of manufactured goods, not because we were seeking that goal, but because, in developing our resources, in manufacturing for the home market, we attained an excellence and comparative cheapness of production which, to the astonishment of ourselves as well as of the world at large, has suddenly made us a formidable competitor—perhaps the most formidable of all—in the great international rivalry for trade.

The question for the future is whether we can permanently hold the position we seem about to gain, by means of what may be termed

* From advance proof sheets of the 'Review of the World's Commerce,' introductory to 'Commercial Relations of the United States,' 1900. The 'Review' will also be printed as a separate pamphlet. Applications for it, as also for the two bound volumes, 'Commercial Relations,' should be addressed to the Chief of the Bureau of Foreign Commerce, Department of State, Washington, U. S. A.

our purely domestic advantages of economy of production, greater labor efficiency and cheap raw materials, or whether we shall not have to fight hard against nations now falling behind us with weapons specially fashioned for controlling foreign trade—as, for example, more scientific export methods, better facilities of banking and transportation, more liberal credits, and manufacturing for particular markets with intelligent regard to climatic and race requirements. Many of our consuls still tell us that our commercial activity abroad is almost primitive in the details of trade competition, although of late our exporters have begun to send capable representatives to the more important trade centers; and the past few years have witnessed the creation of important trade organizations in the United States for the study of foreign commerce, the adoption of special courses of commerce at a number of our colleges, and the establishment of sample rooms and agencies for the sale of American goods at a few of the entrepôts of countries which offer a favorable field. Meanwhile, foreign manufacturers are introducing our labor-saving machinery or imitating it, and European economists are urging industrial reforms or legislative enactments to meet our threatening competition.

GROWTH OF MANUFACTURED EXPORTS.

During the year ended December 31, 1900, according to United States Treasury returns,* the imports of the United States amounted in round numbers to $830,000,000, an increase of over $30,000,000 compared with 1899, while the exports aggregated $1,478,000,000, an increase of $202,480,000. The exports in 1900 exceeded the imports by $648,900,000. Of the exports, the percentage of manufactured goods rose to 31.54† for 1900, against 30.39 in 1899, 24.96 in 1898, and 24.93 in 1895. Of the imports, nearly 45 per cent., it is estimated by the Treasury, were materials, either crude or partly made up, for use in our manufacturing industries, an increase of over 35 per cent. in 1899 and 1900, as compared with the entire period from 1890 to 1898. In other words, our industrial growth continued in 1900 at a rapid pace, enabling us to take less finished goods from other countries and to furnish more.

PREDOMINANCE IN IRON AND STEEL.

The most striking fact in our export development is the remarkable growth of the foreign demand for our iron and steel, our exports amounting to nearly $130,000,000 in 1900, against $32,000,000 in 1895.

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* Preliminary figures from the Bureau of Statistics, December, 1900.

† Later returns give the percentage as 30.38. This decline is attributed to the increase in the proportion of agricultural exports at the end of the year; also to the decrease in exports of copper ingots and cotton cloths, the latter mainly to the Chinese Empire.

In an article in the New York 'Evening Post' of January 12, 1901, Mr. Andrew Carnegie says the United States has not only supplied its own wants, 'but is competing to supply the wants of the world, not only in steel, but in the thousand and one articles of which steel is the chief component part,' and expresses the opinion that the increasing demand from the world at large 'can be met only by the United States.' "The influence of our steel-making capacity," adds Mr. Carnegie, "must be marvelous, for the nation which makes the cheapest steel has the other nations at its feet as far as manufacturing is concerned in most of its branches. The cheapest steel means the cheapest ships, the cheapest machinery, the cheapest thousand and one articles of which steel is the base."

CHEAPNESS OF AMERICAN GOODS.

It is the relative cheapness of American steel that has given it preeminence, and it is the same with other products that are winning their way abroad. Economy of production is the master key that unlocks for us markets that seemed a little while ago to be inexorably closed. This economy of production implies not merely low prices to the foreign consumer, but a greater degree of excellence, a superior adaptation to his wants. As has been pointed out in the 'Reviews,' as well as elsewhere, the American workingman, though receiving higher wages, produces, with labor-saving machinery, at a lower unit of cost, and his greater application and ingenuity enable him to avail himself effectively of the most recent inventions and appliances for improving the quality of his special line of work. The American factory system is highly organized and more efficient than any other, and, if our export trade were as well developed, there would be little to fear. The only lesson our manufacturers need to learn, it would seem, is the necessity of manufacturing especially for foreign trade; and the great increase of requests for information from our consuls as to the kinds of goods wanted in particular markets, and also of manufacturing processes employed in this or that line of industry, encourages the hope that there is beginning to be a general perception of this important fact.

BRITISH ESTIMATES OF AMERICAN PROGRESS.

It is evident that foreign observers are keenly alive to the greater efficiency of our industrial methods, and are seeking earnestly to profit by them. A writer in the London 'Times' of December 29, 1900, attributes the American manufacturer's advantages over the British largely to the consideration shown to young men and the willingness to utilize their energy and enterprise. He lays stress upon the fact that it is customary for American fathers "to discuss their business affairs with their sons in a way that is quite surprising to an Englishman," and adds:

> A good many years ago, I spent a few evenings with some students of one of the large American colleges. I was new to America then, and heard with surprise these college youths discussing questions that arose out of the business in which their fathers were engaged. If we compare this with what generally happens when lads of our own public schools or young men at our own universities meet together—when any mention of the paternal shop would be looked on as the worst of bad form—I think perhaps there will be seen one of the reasons why Americans are fitted to control business at an earlier age than is usual in this country.

The American youth, as pointed out, obtains his business education from practical experience and social intercourse, and this form of education is held to be 'immeasurably above the mere learning of lessons which too often goes by the name of education.' Another reason for the adaptability of American youth to business is stated to be the public-school system, which is 'more truly educational, less pedagogic.' In conclusion, the 'Times' correspondent says:

> To me, it appears one of the most disquieting factors in the problem before us (industrial competition) that the United States have trained a body of young men who are determined to make their country great, and who have been educated to a living, practical interest in the things needful to that end.

The 'Times,' commenting editorially on these views and upon others expressed in a previous series of articles, says: "The threatened competition [of United States manufacturers] in markets hitherto our own comes from efficiency in production such as has never before been seen," and accepts the view that this efficiency is to be ascribed, to a large extent, to the practical self-education of Americans, which enables them generally to enter business 'with a stock of knowledge of which the young Englishman fresh from the university or a public school has not an inkling.' Further on the 'Times' says:

> In the interesting analysis of the causes at work adverse to England, something might be said of the great intelligence and zeal put into affairs. The American man of business takes his pleasure in what he is doing, and never fails when he is traveling to look out for hints to be applied when he returns home. Not afraid to admit that he is 'in pork' or 'in grain,' if the fact be so, he is curious as to all that affects his business, and he is open to new ideas in a way which is unusual with us. 'What has succeeded in the past will not succeed in the future' is a working maxim with the best men of business, who are ready to throw their experience as well as their antiquated machinery on the scrap heap. There are some signs of a change in this respect in this country; but the idea that there is something respectable, solid and satisfactory in doing in the mill, workshop and counting house what one's father did dies hard.

The London 'Spectator' of December 29, 1900, quotes 'a competent writer' in a British trade paper as saying:

> From a careful calculation, made after comparing notes with other observers,

and taking the figure 1 to $1\frac{1}{4}$ as representing the producing capacity of the ordinary British workman, I consider the Swiss-German as fairly represented by $1\frac{3}{4}$ and the Yankee by $2\frac{1}{4}$.

In an article entitled 'America's Changed International Position,' the London 'Statist' of January 5, 1901, also dwells upon the superiority of our methods of production as enabling us to take advantage of the needs of Europe and to respond to an increased demand for manufactured goods. "All at once," says the 'Statist,' "the United States became a keen competitor in the markets of the world with ourselves and with our continental rivals, and, in all reasonable probability, the competition will grow more eager as the years pass." The 'Statist,' in fact, predicts 'a great outburst of new enterprise in the United States.'

CONCENTRATION OF CAPITAL IN THE UNITED STATES.

Lord Rosebery is quoted by cable as having said in a speech before a British Chamber of Commerce, January 16, 1901, that the chief rivals to be feared by Great Britain 'are America and Germany.' "The alertness of the Americans," he continued, "their incalculable natural resources, their acuteness, their enterprise, their vast population, which will in all probability within the next twenty years reach 100,000,000, make them very formidable competitors with ourselves. And with the Germans, their slow but sure persistency, their scientific methods, and their conquering spirit, devoted as these qualities are at this moment to preparation for trade warfare, make them also, in my judgment, little less redoubtable than the Americans. There is one feature of the American competition which seems to me especially formidable, and, as I have not seen it largely noticed, perhaps you will excuse me for calling attention to it. We are daily reminded of the gigantic fortunes which are accumulated in America, fortunes to which nothing in this country bears any relation whatever, and which in themselves constitute an enormous commercial force. The Americans, as it appears, are scarcely satisfied with these individual fortunes, but use them by combination in trusts, to make a capital and a power which, wielded as it is by one or two minds, is almost irresistible, and that, as it seems to me, if concentrated upon Great Britain as an engine in the trade warfare, is a danger which we cannot afford to disregard. Suppose a trust of many millions, of a few men combined so to compete with any trade in this country by underselling all its products, even at a considerable loss to themselves, and we can see in that what are the possibilities of the commercial outcome of the immediate future."

It has been evident for some time that the United States, not content with having solved that part of the problem of economy of production which relates to processes of manufacture and the utilization of labor, has been drifting instinctively towards the larger question of the concentration of capital as the logical development of the same general idea of reducing cost and increasing the margin of profit. The question is larger because it has a more direct and more general bearing upon the economic and social life of the nation, upon the interests, real or imagined, of the whole body politic. We have to do with it here only because of its relation to and possible effect upon our foreign trade, and it is interesting to know that so thoughtful an observer as Lord Rosebery perceives in the simplification of the use of capital in the United States which is going on—it may be said experimentally, to a large extent as yet—a tremendous power in the commercial rivalry of the world.

GERMAN VIEWS OF AMERICAN COMPETITION.

Germany, as well as Great Britain, seems fully sensible of the seriousness of American competition. In a recent issue, the Hamburger 'Fremdenblatt'* points out that the United States, which ten years ago exported more than 80 per cent. of agricultural products and less than a fifth of manufactured goods, to-day draws nearly a third of its entire exports from the products of its factories. "In other words, the Union is marching with gigantic strides towards conversion from an agricultural to an industrial nation." "Does not the rapid increase of the United States in the value of industrial exports," the 'Fremdenblatt' asks, "constitute an imminent danger from all competing nations?" Continuing, the 'Fremdenblatt' says:

> If we now turn to an investigation of all the elements which have produced this tremendous, this almost incredible, revolution in the world's situation, it is impossible within our present limits to consider all the factors which are of importance to German interests as well as essential to a comprehensive conclusion. Competent experts, well informed as to the industrial and export conditions which prevail in the United States, have established the following facts:
>
> The steel manufactories of the United States, which two decades ago were in their infancy, to-day control the markets of the world, dictate either directly or indirectly the prices of iron and steel in all countries, and partly through the richness of their supply of iron ores and coal, partly by the use of labor-saving machinery and skilful, effective means of transportation, have attained a position to not only compete with the older iron and steel-producing countries, but even to profitably export their products to England.
>
> American tools, especially hatchets, axes, files, saws, boring implements, etc., enjoy, by reason of their excellent quality, the best reputation, and, in spite of their higher price, stand above competition in nearly the whole world. Also in sewing machines, bicycles and agricultural implements of every kind, the United States has begun to drive England and Germany from the world's

* Article translated by Consul-General Mason. See 'Advance Sheets' No. 934 (January 14, 1901).

markets, especially that of Russia, which may be partly attributed to the fact that American firms are protected in their own market from foreign competition and can thus sell their manufactures cheaper abroad than at home.

A remarkable change has also taken place in the field of boot and shoe production. Hardly more than ten years ago the United States imported shoes from Europe—especially women's footwear from Austria, while other grades were made of leather imported from England and Germany. To-day, it not only makes its entire supply of leather at home and exports it in considerable quantities, but it floods Europe with ready-made shoe depots in Paris and even in the principal cities of Germany.

That the United States, by reason of its richness in mineral oils and aided by its unrivaled facilities for refining and transporting this international necessity, controls the petroleum trade of the world and is held in check only by Russia is well known, and the fact is only cited here in order to include this weighty factor in the calculation. The experience of the past few months proves that within a not far distant period, the coal of the United States will play the same rôle in the markets of the world. The Union has reversed the old adage, "It is ridiculous to carry coals to Newcastle," for to-day anthracite coals from Pennsylvania are actually exported to England.

Incidentally, it may be remarked that the typewriting machine with which this article is written, as well as the thousands—nay, hundreds of thousands—of others that are in use throughout the world, were made in America; that it stands on an American table, in an office furnished with American desks, bookcases and chairs, which cannot be made in Europe of equal quality, so practical and convenient, for a similar price. The list of such articles, apparently unimportant in themselves, but in their aggregate number and value of the highest significance, could be extended indefinitely. But it would seem more interesting and characteristic to cite the fact that an American syndicate is now planning, and has even taken the initial steps in a scheme, to take in hand the whole sleeping-car service of Europe, to improve it and make it cheaper than is now possible. Moreover, American manufacturers of underclothing, gloves and men's clothing, as well as women's cloaks—all articles which a few years ago were exported in vast quantities from Europe to the United States—are already beginning to calculate how they can place their surplus output in European markets.

The 'Fremdenblatt's' conclusion is that Europe "must fight Americanism with its own methods; the battle must be fought with their weapons, and wherever possible their weapons must be bettered and improved by us. Or, to speak with other and more practical words, Germany—Europe—must adopt improved and progressive methods in every department of industry; must use more, and more effective, machinery. Manufacturers as well as merchants must go to America, send thither their assistants and workingmen, not merely to superficially observe the methods there employed, but to study them thoroughly, to adopt them, and wherever possible to improve upon them, just as the Americans have done and are still doing in Europe."

SERVICES OF UNITED STATES CONSULS.

Dr. Vosberg-Rekow, head of the German bureau for the preparation of commercial treaties, attributes the remarkable growth of exports of American manufactures to Europe, in part, to the activity of our consular service. "The United States," he says, "has covered Europe with a network of consulates and makes its consuls at the same time inspectors of our exports and vigilant sentinels, who spy out every trade opening or advantage and promptly report it." Dr. Vosberg-Rekow also dwells upon the eminently practical character of American industrial and business methods. "Germany's industrial advancement," he says, "is principally due to the thoroughness of her technical education. It is strengthened by the continuous substituting of machinery and machine tools for hand labor. Still, in this respect, the English industry in some branches is ahead of us. It is worthy of note that in this evolution, too, the United States has the foremost place and has made gigantic strides, not only in applying machine tools, but in inventing and manufacturing them, so that to-day she supplies us. This signalizes in an extraordinary degree American intelligence. Thus, the Americans, though wanting our superior technical education, thanks to their practical eye, improve upon our methods and apparatus. Theirs is rather the activity of an experimentalist than that of a trained craftsman; but a clever faiseur, if he but have assurance and luck, may distance the educated master. The Americans have no thorough education; nor do they possess a modern industrial system as we Europeans understand the term. The American applies himself to a single branch or to a specialty, with utter disregard of European methods and their results; he devotes to his work an amount of energy which stupefies Europeans; and, for awhile, he succeeds in driving us out of the line of articles on which he has centered his energy. Against such peculiar activity a general trade policy is quite ineffectual; we must put ourselves in condition to counteract this artificially forced growth of specialized industry."

EDUCATION IN BUSINESS.

Thus we find that expert opinion in Great Britain and Germany coincides in the conclusion that Americans, too eager to be up and doing to apply themselves to preparatory study or to what may be termed a general scheme of education and culture for industry and trade, have, nevertheless, worked out in practise a degree of actual efficiency, not learned from books, which gives them a distinct advantage. It is not to be denied, upon the other hand, that technical schools and special courses of commercial education might greatly enhance our capabilities, if care were taken to prevent them from usurping too far the practical business or industrial training which seems to be the secret of our success thus far. In the more and more strenuous competition which is evidently waiting us, our manufacturers, exporters and trade representatives abroad will need to be provided with a variety of information which cannot be acquired except by academic instruction. The knowledge gained in the workshop or the counting house will not suffice to meet a rivalry which is seeking to equip itself, so far as it can, with our machinery, our industrial and trade methods—with everything, in short, that now gives us supremacy—and will add to these the mastery of details of trade conditions and industrial processes throughout the world, which we are only beginning to study.

FINANCIAL INDEPENDENCE OF THE UNITED STATES.

There is another feature of American influence in the world's markets which is, perhaps, even more notable than our industrial progress, and that is our suddenly acquired financial independence. The 'Hamburger Fremdenblatt' article previously quoted from points out that it is the logical result of our growth in industry and trade and especially of our successful competition in foreign markets. As soon as American industries, through various causes, found themselves in a favorable financial condition, "they likewise undertook the task of freeing themselves from foreign capital—in other words, of reclaiming the industrial securities which were in European hands." "The change in the condition of the United States," adds the 'Fremdenblatt' "can best be characterized by the statement that the industries, trade, agriculture, railroads and finances of the Union each and all climbed, one upon another, through and by each other, steadily upward. And to what a height they have climbed!"

During the past year, the point was reached where the United States became a lender of money to other countries instead of a borrower from them. "Speaking roughly," says the London 'Statist' (January 5, 1901), "the holdings of American securities in Europe now are immensely smaller than they were ten years ago, and the purchases have been made by the Americans out of the vast savings accumulated, first, during the anxious period from 1890 to 1896, and, secondly, during the prosperous period that has followed. Many countries, however, are able to buy back their own securities without being in a position to take an important place in the international investment market. For example, Spain has bought back a very large proportion of her own securities. In the United States, not only has the buying back of American securities been on the great scale indicated, but during the past year or two, American capitalists have lent largely to Europe. At the end of 1899, when there was great pressure in the money markets of Europe, about four millions of gold were allowed to be shipped from New York to London; and during the past year it will be recollected that gold was sent in considerable amounts, while about five millions sterling were invested in [British] Government funds. German Government funds were also bought amounting to about four millions sterling. Russia was able to borrow in order to purchase railway material. And it is understood that the United States was willing to lend likewise to Switzerland and to other governments. This is the most dramatic change that has occurred for a very long time."

"The succession of extraordinary creditor balances," says the 'New York Journal of Commerce,' of January 10, 1901, "has virtually revolutionized our financial relations with the European centers. In a very important sense, we have become the creditor nation of the world. From a chronic condition of dependence upon the banking forces of London, Paris and Berlin, we find those centers now dependent upon the large floating balances of the United States, subject to our lending ability in periods of exigency, carrying the largest stock of gold in the world and holding the largest resource for dealing with crises in international finance. Three of the foremost European governments—England, Germany and Russia—have found it necessary to come to New York for important loans, and the two former have not applied in vain. Thus, if this city may not be said to have yet become the financial center of the world, yet we may incontestably claim a foremost rank among the few metropolitan cities which have won that distinction."

"One of the most important financial features of the year," says 'Bradstreet's' (January 5, 1901), in its review of the stock-market in 1900, "was the placing in Wall Street and with American investors of issues of British consols, German Government bonds, and loans by Russia, Sweden, and other countries, giving point to the feeling that our market has taken the lead in the financial world."

THE FUTURE OF INTERNATIONAL COMPETITION.

Summed up, therefore, the general conclusion of competent foreign authorities, as well as of our own, is that the commercial expansion of the United States is no longer problematical, but a fact of constantly enlarging proportions which opens up new vistas in the struggle for ascendency among the industrial powers. Prolific as it has been of great surprises, it is doubtful whether similar phenomena will spring from its undemonstrated forces. It would seem, now that the causes of our unlooked-for triumphs are known and are being carefully weighed and studied, that the future will be one of fruition, of the gradual maturing of our powers, rather than of sudden blossoming of some novel capacity of competition. The day, perhaps, is not distant when the more intelligent of our rivals will be able to meet us upon more nearly equal terms and when, as has already been indicated, it will be necessary to supplement our natural advantages and our highly developed industrial efficiency with the appliances of education, of special training, of technical skill, of more scientific methods of extending trade, which have already secured rich returns—to Germany, for example—in quarters of the globe where our goods, as yet, have made but little if any headway.

GENERAL SUMMARY OF TRADE.

When we come to survey the field of international competition, as described by our consuls and in the light of comments by foreign economists and trade authorities, we find some highly significant indications of the probable course of trade currents within the next few years. As to the general march of our commercial expansion in the immediate future, the reports of the consuls emphasize the conclusions to be drawn from the most recent figures of the United States Treasury. According to a statement issued by the Bureau of Statistics of that Department for the decade ended with the calendar year 1900, our imports, which in 1890 were $823,397,726, were in 1900 $829,052,116, an increase of less than 1 per cent. in the decade; while our exports, which in 1890 were $857,502,548, were in 1900 $1,478,050,854, an increase of 72.4 per cent. In 1890, the excess of exports over imports was $5,654,390; in 1900, it was $648,998,738.

"In our trade relations with the various parts of the world," continues this statement, "the change is equally striking. From Europe, we have reduced our imports in the decade from $474,000,000 to $439,000,000, while in the same time we have increased our exports from $682,000,000 to $1,111,000,000. From North America, imports fell from $151,000,000 in 1890 to $131,000,000 in 1900, while our exports to North America increased during that time from $95,000,000 to $202,000,000. From South America, the imports increased from $101,000,000 in 1890 to $102,000,000 in 1900, while to South America our exports increased from $35,000,000 to $41,000,000. From Asia, the imports into the United States increased from $69,000,000 in 1890 to $123,000,000 in 1900, while to Asia our exports in the same time increased from $23,000,000 to $61,000,000. From Oceania, the importations in 1890 were $23,000,000 and in 1900 $23,000,000, while to Oceania our exports in 1890 were $17,000,000 and in 1900 $40,000,000. From Africa, importations increased from $3,000,000 in 1890 to $9,000,000 in 1900, and exportations to Africa increased from $4,500,000 in 1890 to $22,000,000 in 1900."

The changes in the movements to and from the continents are attributed by the Bureau of Statistics to two great causes: First, the increase at home of manufactures which were formerly drawn chiefly from abroad; and, second, the diversification of products, by which markets are made for many articles which formerly were produced or exported in but small quantities. "From Europe, to which we are accustomed to look for manufactures, our imports have fallen over $35,000,000, while Europe has largely increased her consumption of our cotton-seed oil, oleomargarine, paraffin, manufactures of iron and steel, copper, and agricultural machinery, as well as foodstuffs and cotton, our exports to that grand division having increased $428,000,000 since 1890. From North America, the imports have fallen $20,000,000, due chiefly to the falling off of sugar production in the West Indies, the imports from Cuba alone having decreased from $54,000,000 in 1890 to $27,000,000 in 1900. To North America, the exports have increased meantime over $100,000,000, the growth being largely manufactures and foodstuffs, a considerable portion of the latter being presumably re-exported thence to Europe. From South America, the imports have increased in quantity, especially in coffee and rubber, but decreased proportionately in price, so that the total increase in value in the decade is but $1,000,000, while in exports the increase is $6,500,000, chiefly in manufactures. From Asia, the importations have increased more than $50,000,000, the increase being chiefly in sugar and raw materials required by our manufacturers, such as silk, hemp, jute and tin; while to Asia the increase in our exports has been nearly $40,000,000, principally in manufactures and raw cotton. From Oceania, the imports show little increase, though this is due in part to the absence of statistics of importations from Hawaii in the last half of the year 1900; while to Oceania, there is an increase in our exports of more than $20,000,000, chiefly in manufactured articles. From Africa, the increase in imports is $6,000,000, principally in manufacturers' materials, of which raw cotton forms the most important item; while our exports to Africa increased meantime $17,000,000, chiefly in manufactures."

The following tables show the imports and exports of the United States by grand divisions in the calendar years 1890 and 1900. In the figures showing the distribution by continents in 1900, the December distribution is estimated, though the grand total of imports and exports for 1900 is based upon the complete figures of the Bureau of Statistics:

Grand Divisions.	Exports from United States.		Imports into United States.	
	1890.	1900.	1890.	1900.
Europe	$682,585,856	$1,111,456,000	$474,656,257	$439,500,000
North America	95,517,863	202,486,000	151,490,330	131,200,000
South America	34,722,122	41,384,000	100,959,799	102,000,000
Asia	22,854,028	60,598,000	68,340,309	122,800,000
Oceania	17,375,745	39,956,000	23,781,018	23,400,000
Africa	4,446,934	22,170,000	3,169,086	9,900,000

NEW CURRENTS OF TRADE.

Besides the surprising development of our sales of manufactured goods in the most advanced industrial countries of Europe, which may be said to have introduced an entirely new element into Old World trade, we find other phases of commercial expansion which were quite as unexpected and are likely to profoundly affect our economic, and perhaps our political, future. The rapid growth of cotton manufacturing in our Southern States, for example, could not have been anticipated a few years ago, although it seemed probable to those familiar with the peculiar advantages of the South for engaging in this industry that some day that section would emerge from its position of dependence upon outside markets for the consumption of its cotton and create its own home markets by the erection of mills. Within the years 1889-1899, inclusive, according to Mr. A. B. Shepperson, of New York,* the number of spindles in the South increased 190½ per cent., against 11.4 in our Northern States, 4 1-3 per cent. in Great Britain, 30.6 per cent. in continental Europe, 71 per cent. in India. "In the percentage of increase of spindles and of consumption of cotton" (206½ per cent. in Southern and 29 per cent. in Northern mills), says Mr. Shepperson, "the South makes the best showing of the countries compared, while India is a good second."†

There are now nearly 4,000,000 spindles in the South, against 1,360,000 in 1889, and new mills are constantly being built,‡ although the past year has witnessed depression in the industry due to the troubles in China. The entrance of the South into oriental trade is almost as novel a feature of our expansion as any that have been indicated, and it is one that seems likely to have a most important bearing upon our social and political evolution, as well as upon our influence in international trade. The South has suddenly acquired a great stake in the affairs of the Far East, and what this may mean in the adjustment of our relations with other countries having large

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* Cotton Facts, December, 1899.

† Increase of India in number of spindles, 71 per cent.; in consumption of cotton, 88½ per cent.

‡ "The current year," says Prof. Henry M. Wilson, of Raleigh, N. C., in an article in the 'Textile Manufacturers' Journal' of December 20, 1900, "has witnessed greater strides in cotton manufacturing in the South than last year, when the growth of the industry was considered phenomenal. New spindles and looms have been added, new mills built, and others projected at a rate that causes the careful observer of the South's progress to gaze with amazement upon such activity. Nowhere in the world is the interest being taken in cotton manufacturing as here in the South, where most of the staple is produced. From returns made to the New Orleans Cotton Exchange, the number of new spindles added this year in old mills, new mills and in mills under construction is 1,456,897. New looms added to these same mills number 27,613."

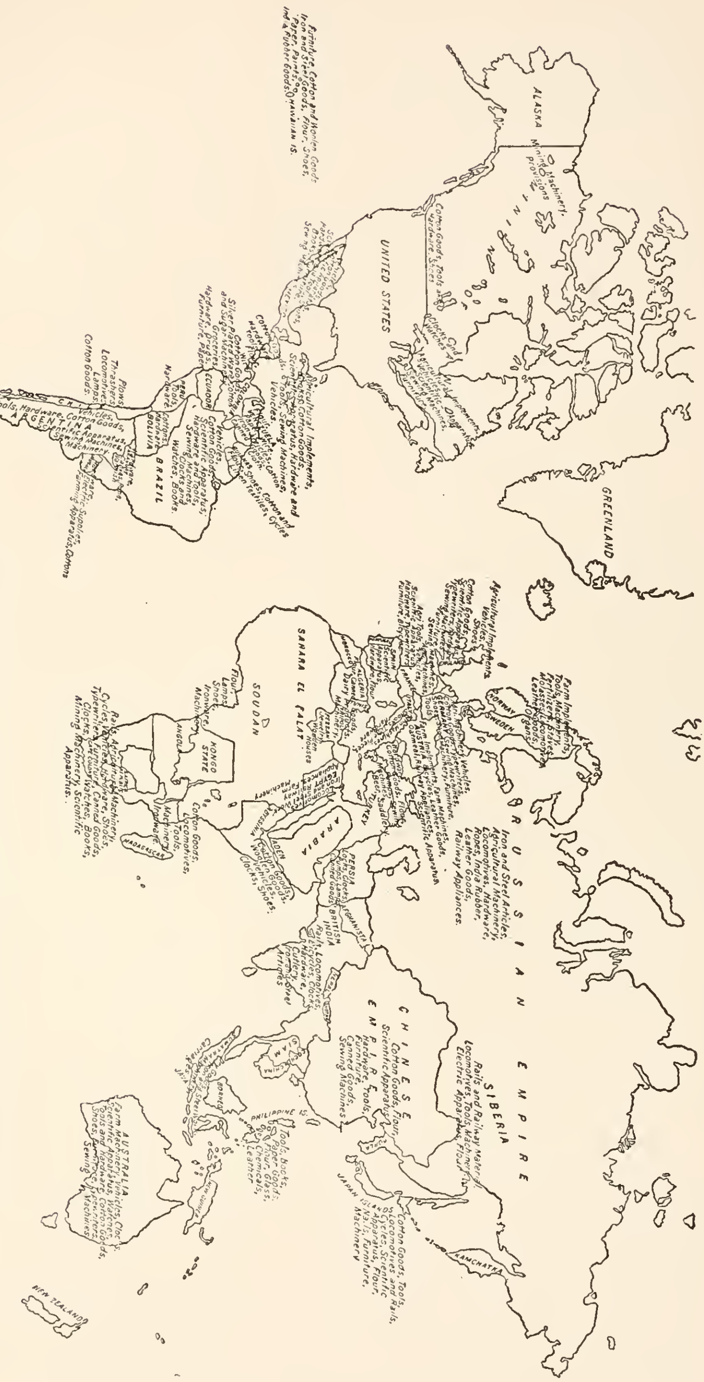
interests there and in shaping our international policies is a question which only the future can answer. In a memorial from the cotton manufacturers of the South addressed to the Secretary of State in November last, commending the 'open-door' policy in China, the statement is made that a large part of the production of the cotton drills and sheetings manufactured in Southern mills is exported to North China, and that "the prohibition or interference in China by any European government would tend to seriously injure, not only the cotton-manufacturing industries, but other important products of the United States which are being shipped to China. For the protection and perpetuity of these commercial relations," it is added, "we earnestly pray that the Administration will take such action as may be proper under existing conditions. It is not only the manufacturers of cotton goods that would be seriously affected, but the Southern planter and cotton grower, who finds a ready cash sale for his products at his very door; and also the thousands of employees and laboring classes who are engaged in the cotton mills and depend on the success of these manufacturing industries for a livelihood."

The developments of the past two years in consequence of our acquisition of the Hawaiian and Philippine islands have brought another factor into prominence in our commercial development, which may be potential of unlooked-for results. The Pacific slope is rapidly being converted from a mere outpost of trade into a great hive of commerce.* Not only San Francisco, but Port Townsend, Seattle, Tacoma and Portland, are becoming entrepôts of Oriental and South Pacific commerce, and San Diego seems likely to be an important factor in the development of trade with the west coast of Latin America.

The growth of sea-borne commerce at these points means much for the great extent of country tributary to them and promises to work marked changes in the industrial condition of the vast region west of the Rocky Mountains. In a similar way, our southern group of States may find a sweeping readjustment of their economic relation to the rest of the Union in the fact that Cuba and Porto Rico now offer them easy and convenient stepping stones to Latin American trade.

Even in the now familiar conditions affecting the Atlantic seaboard, which, as we have seen, have recently produced a great increase in our export trade, a new element appears in the statement of our consul in Sierra Leone, Mr. Williams, that, in a few years, West Africa will offer a market for our goods 'only second in importance

* Exports from ports on the Pacific coast (excluding Alaska) which amounted to some $36,800,000 in the fiscal year 1895, rose to $75,300,000 in 1898, and, though the total fell to $57,600,000 in 1899, it rose again to $71,600,000 in 1900 (years ended June 30).



UNITED STATES MANUFACTURES IN THE WORLD'S MARKETS.

to that of China.' East Africa and South Africa have already shown a marked preference for certain lines of American manufactures, but West Africa is for our exporters a new and more accessible market, the possibilities of which have heretofore attracted but little attention.

DISTRIBUTION OF OUR EXPORTS.

A glance at the accompanying map of the world, showing the distribution of our exports of manufactures, reveals the significant fact that, as yet, the widest range of consumption of our goods is found in the leading industrial countries, such as Great Britain, Germany, France, and their willingness conjoined with their greater capacity to take our products raises the interesting question whether our activity in competing for neutral markets, such as China, Africa, South America, etc., is not, for the present, restrained by the fact that our energies are largely employed in manufacturing for the European demand. The seriousness of our competition in the development of trade in countries which, as yet, are but imperfectly exploited will begin to be fully felt, it would seem, only when the European demand shall have slackened or we shall have more than met its requirements. In that case, our exporters would undoubtedly address themselves more systematically and with greater energy to trade regions which our European rivals are now so industriously seeking to control. There is food for thought also in the possible consequences to our European trade of a rivalry on our part which may be so crushing as to greatly impair the purchasing power of those who are now our best customers. If we permanently cripple their chief industries, we deprive them, to a greater or less extent, of the means of buying from us, and the consumption of our food supplies and our raw materials, as well as of our finished goods, may be greatly curtailed. The solution of the problem may perhaps be found in the gradual specialization of commerce and industry, according to the peculiar capacity of each competing nation—the survival, in other words, of the fittest conditions for this or that country—and the gradual subsidence of competition into healthful exchange.

THE PLANET EROS.

By Professor SOLON I. BAILEY,
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EROS is the name of a small planet discovered in 1898, by Witt, of Berlin. It does not appear to be altogether certain that it really belongs to the group of minor planets, usually known as planetoids or asteroids. With the exception of Eros, all known asteroids move in orbits whose mean distances are greater than that of Mars and less than that of Jupiter. The mean distance from the sun of Mars is 141 million miles, and that of Jupiter is 483 million miles, while the distances of the asteroids vary in round numbers between 200 and 400 million miles. The mean distance of Eros, however, is only 135 million miles, which is less than that of Mars. In spite of this very important difference, Eros has been placed among the great band of asteroids, among whom he numbers 433. To belong to the celestial 400 is perhaps more of misfortune than of honor, for the number of this plebeian band has already waxed so great that they have become a care which threatens in the future to balance the benefits which they bring to astronomy. Nevertheless, the history of this numerous family is sufficiently full of interest, and throws light upon the way in which we should regard them.

In 1772, Bode announced the so-called law which bears his name. The law may be stated as follows: If to a series of 4's, beginning at the second, the numbers 3, 6, 12, 24, etc., be added, the resulting numbers divided by 10 will approximately express the distance of the planets from the sun in terms of the distance of our earth taken as unity. The law gave fairly well the distances of all the planets known at that time, except that it called for a planet between Mars and Jupiter, where nothing was then known to exist. When, a few years later, in 1784, Uranus was discovered and was found to conform closely to the law, the impression was deepened that the missing member of the solar system must somehow be supplied or explained, and an association of astronomers was formed to hunt for it. At that time the discovery of a small body, such as one of the asteroids, was no easy matter, and the honor of finding the first did not fall to one of the associates, but to Piazzi, a Sicilian astronomer, who discovered it while making a star catalogue. It was perhaps fitting that a century which was to be signalized by the discovery of some 450 new but small worlds, where one had been sought, should be properly opened: Ceres, the first asteroid, was found on the first day of the nineteenth century. Bode's law, therefore, appeared to have found confirmation here, for, though there was no single great planet, as elsewhere, nevertheless the small army of fragments seemed to point to some abortive attempt of Nature to form a world in the usual order, or else to an explosion of one already formed. In either case the distance of the 'mean asteroid' might be expected to follow the law, which it was found approximately to do. It seems a pity that the law, having survived so many tests, should go to pieces at last on what was perhaps the final test which remained to be applied. When Neptune was discovered, however, in 1846, it did not conform to the law at all. The following table gives a comparison between the true distances and those which result from Bode's law, the distance of the earth being taken as unity:

Planet.	Distance.	Bode.	Difference.	Period.
Mercury	0.39	0.4	—0.01	3 months.
Venus	0.72	0.7	+0.02	7.4 "
Earth	1.00	1.0	0.00	1.0 years.
Mars	1.52	1.6	—0.08	1.9 "
Mean Asteroid	2.65	2.8	—1.15	....
Jupiter	5.20	5.2	0.00	11.9 years.
Saturn	9.54	10.0	—0.46	29.5 "
Uranus	19.18	19.6	—0.42	84.0 "
Neptune	30.05	38.8	—8.75	164.8 "

The discovery of asteroids has been much simplified by the increase of star maps, and especially by the advances in celestial photography. One feature, which is incidental to the duration of the photographic exposure, renders the detection of such objects comparatively easy. When a photographic plate is exposed to the sky in a camera or telescope, if there is no clockwork, so that the instrument remains at rest, the images of the stars are drawn out into lines or trails. Ordinarily, however, the instrument is kept in motion by a driving clock, so that it exactly follows the stars in their apparent daily motion, and the images of the stars result as circular dots on the plate. An asteroid, however, from its nearness has so rapid an apparent motion among the stars that, if an exposure is made of an hour or more, its image is spread out in a line, while the images of stars remain circular. On some of the plates, for example, made with the great Bruce photographic telescope at Arequipa, several hundred thousand stars appear. On one of these plates, which had an exposure of four hours, seven asteroid trails were found. If these asteroids had formed circular images, similar to those of the stars, their detection among the several hundred thousand images on the plate would have been an enormous labor and would have required other photographs of the same region for comparison. To pick out the trails, however, is the work of an hour. The finding of the images on the photographs is only a small part of the work involved. First, one must know whether the object seen is new or old. This implies tables giving the positions of all known asteroids, the computation of which involves a great amount of labor, and, in most cases, the results in themselves seem to be of small value. With the greater telescopes and more sensitive plates of the future, it seems probable, unless some kind Providence prevents it, that the number will become so great that astronomers will grow weary of the enormous labor involved in making ephemerides of them all. Twenty-two of them are, as Professor Young expresses it, 'endowed.' These were discovered by Professor Watson, who, at his death, left a fund to bear the expense of taking care of them. These favored ones will evidently be followed carefully, however unobserved their less aristocratic sisters go sweeping on in their neglected orbits.

It is probable that all the larger asteroids have already been found. Professor Barnard has made many micrometric measurements of the diameters of the largest of these baby worlds, using the great telescopes of the Lick and Yerkes observatories. He has recently published in the 'Monthly Notices' of the Royal Astronomical Society the following results:

Asteroid.	Diameter.	Albedo.
Ceres........................	477 miles.	0.67
Pallas.......................	304 "	0.88
Juno.........................	120 "	1.67
Vesta........................	239 "	2.77

The albedo, or light-reflecting power, is referred to that of Mars as unity. The values in the third column are derived from the measured diameters and the known brightness of the asteroids. Vesta, though not the largest by the above measures, is the brightest of them all, and is sometimes visible to the naked eye. Probably none, except the four given above, has a diameter as great as 100 miles, and the vast majority perhaps not more than ten or twenty miles. Eros itself, at its nearest approach, will perhaps present a disc of sufficient size to permit measurements in the most powerful instruments. Its diameter is probably not more than twenty-five miles, though no precise determination has yet been made. On such a world the force of superficial gravity would be about one three-hundredth of that at the surface of the earth, and a person might almost throw a stone with sufficient velocity to make it fly off into space and become an independent planet. To make up a world even one-hundredth as large as the earth would take hundreds of thousands of such worlds.

On the night of August 13, 1898, Herr Witt made a photograph of the region near β Aquarii, with an exposure of two hours. He wished to obtain an observation of a known asteroid which had not been observed for nine years, and which his calculations assigned to that region. When developed and examined on the following day, the plate not only showed the object desired, and also a second known asteroid, but a faint and long trail of some unknown object. From its rapid motion it was at first thought to be a comet, but an examination on the following night with a visual telescope revealed its true nature. As soon as the well-known computer of minor planet orbits, Herr Berberich, had computed its approximate orbit, the astonishing nature of the new planet became apparent. Of all the previously known members of the solar system, with the obvious exception of our moon, Venus and Mars approach nearest to the earth. Venus is distant from us at the most favorable times about twenty-five million miles, and Mars thirty-five million miles. Eros, however, approaches the earth at the most favorable oppositions within less than fourteen million miles, so that he is our nearest celestial neighbor. This leads to a solution, under better conditions perhaps than ever before granted, of that fundamental problem in astronomy, the distance of the sun, or, in other words, the determination of the solar parallax. In order to determine the orbit and position of a planet, certain quantities must be found, based upon at least three observations of the planet's place in the sky. It is, however, highly desirable to have more than three observations of the planet's position and to have them widely separated in time.

The following elements for Eros were computed by Dr. S. C. Chandler, and were based on the observations of 1898, combined with those of the Harvard photographs made in the years 1893, 1894 and 1896:

EPOCH 1898, AUGUST 31.5, GREENWICH MEAN TIME.

Mean Anomaly	221°	35′	45.″6	
Perihelion Distance of Ascending Node	177	37	56. 0	1898.0
Longitude of Ascending Node	303	31	57. 1	1898.0
Inclination of Orbit to Ecliptic	10	50	11. 8	1898.0
Angle whose Sin is the Eccentricity	12	52	9. 8	
Mean Daily Motion	2015.″2326			
Logarithm of Semi-major Axis	0.1637876			
Period of Revolution around Sun	643^{d}.10			

Later observations will doubtless slightly modify these results, but they are sufficiently precise for our purpose. These elements were published in December, 1898, and well illustrate the enormous photographic resources which at the present time are in the possession of the Harvard Observatory. Twenty years ago, the present Director, Prof. Edward C. Pickering, began photographing the heavens, and at the present time there are in the Observatory more than 100,000 photographs of the sky made during those years. Some of these are on a large scale, and are of special objects, but many thousands of them are charts on so small a scale that the entire sky has been photographed many times. On nearly all these plates stars are shown to the tenth magnitude, and in many cases stars as faint as the fifteenth or sixteenth magnitude appear. The early elements of Eros showed that the planet made a close approach to the earth in 1894, and a search was promptly instituted on the Harvard photographs. At first the available observations were insufficient to give the elements with the accuracy which was necessary in order to determine the planet's

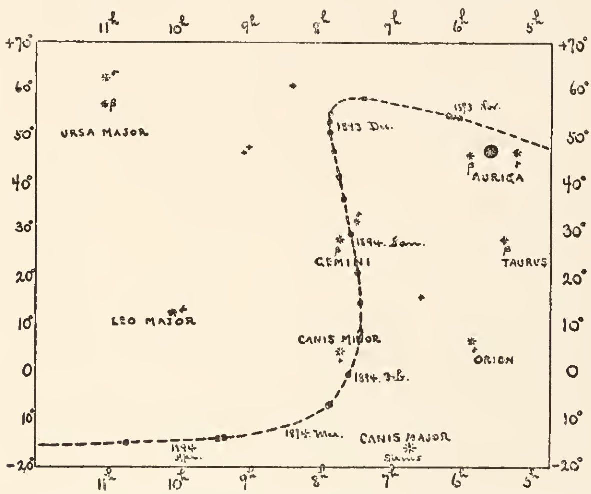

FIG. 1. PATH OF EROS IN 1893 AND 1894. THE CIRCULAR DOTS REPRESENT THE POSITIONS WHICH WERE DETERMINED FROM THE HARVARD PHOTOGRAPHS.

position in 1894. An error of 1″ in the mean daily motion would change the right ascension in 1894 by about half an hour. On this account no image of the planet was found on the photographs first examined. By an examination, however, of plates made in 1896 Mrs. Fleming found several images of Eros, and Mr. Chandler then provided a corrected ephemeris, by means of which the planet was readily found on plates made in 1893 and 1894. Thus several years' history of this remarkable object was at once presented to the astronomical world.

While the mean distance of Eros is 135 million miles, its aphelion distance is 166 millions and its perihelion distance 105 millions. Since this planet is sometimes within and sometimes without the orbit of Mars, it might be expected that at favorable times it would approach nearer to Mars than to the earth. Owing to the large inclination of the planes of the two planets, and the unfavorable position of the line in which the planes intersect, this is not the case, as was pointed out by Mr. Crommelin. Eros does not approach Mars nearer than twenty million miles, so that the Martians, if such exist, have no advantage in this line of research.

At his approach in 1894, the brightness of Eros was computed by Professor Pickering to have been about the seventh magnitude. This places it just beyond the reach of the naked eye, even at the most favorable oppositions. During the recent opposition Eros was thirty million miles distant, and fainter than the ninth magnitude.

E. von Oppolzer has recently announced that Eros undergoes, within a few hours, variations in light amounting to a whole magni-

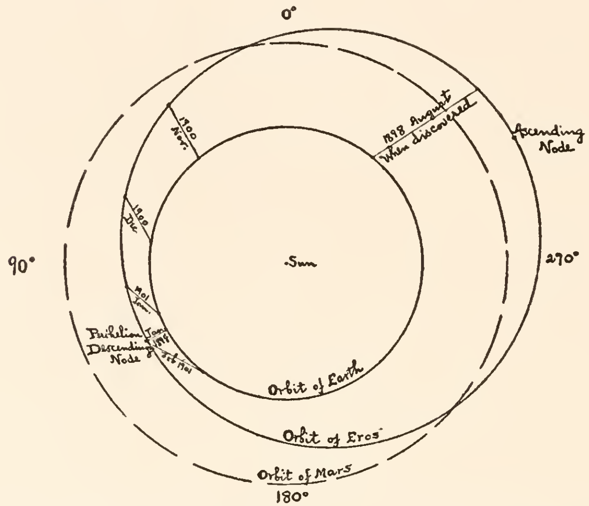

Fig. 2. Orbits of Eros, Earth and Mars. Relative Positions of Eros and Earth.

tude. This variation has been confirmed at the Harvard Observatory, where there are observations, visual and photographic, extending back over eight years, sufficient to establish the period with precision. The variability of Eros is doubtless due to its axial revolution, and may be caused by the unequal light-reflecting power of different parts of its surface.

From the elements and diagram, it may be seen that the distance from perihelion, or the point nearest the sun, to the descending node, or the point where the planet passes through the plane of the earth's orbit, is less than three degrees. This is fortunate, for otherwise the planet's distance would be increased. The longitude of the planet's perihelion is 121°. The earth's longitude—or the sun's longitude, as seen from the earth, plus 180°—is 121° on January 21. In 1894, the planet was in perihelion on January 22, only a few hours later than the earth arrived at the same longitude; so that the opposition at that time was nearly as favorable as can ever occur. Since the period of Eros is $643^d.10$, it will be easy to compute when the planet will again come to perihelion near the date January 21. The relation between the periods of Eros and the earth is such that a close approach will always be followed in seven years by one not so good, but yet favorable. This is illustrated by the near approach of 1894 and the less favorable opposition of 1901. Seven revolutions of the earth take $2556^d.8$, and four revolutions of Eros, $2572^d.4$. Hence every seventh year the position of Eros will be repeated, with respect to the earth, within $15^d.6$. So that if Eros arrived at perihelion one day later than the earth reached the same longitude in 1894, it would arrive there about seventeen days later in 1901, thirty-two days later in 1908, etc. It is evident that by following this series no close approach would come again till far into the next century. This series includes one-fourth of the perihelion returns of Eros. Three other series will include the remainder. They may be reckoned from that of 1895, when it occurred eighty-seven days earlier than the earth reached the same longitude, that of 1897, 175 days earlier, and that of 1899, 262 days earlier. Beginning with the difference of eighty-seven days in 1895, the number decreases by $15^d.6$ every seven years, so that in 1931 Eros will arrive at perihelion about ten days ahead of the earth, and in 1938 about six days later. This pair of oppositions appear to be the best which will occur during the next half century. The series which begins in 1897 with a difference of 175 days would apparently give a close approach after about three quarters of a century, and the remaining series much later still. It seems, therefore, that not till the latter part of the present century can so favorable an opposition recur, as that of 1894, which was lost except for the Harvard photographs. These conclusions may, however, be modified by a study of the perturbations of Eros by the other planets, which have not been considered in the above computations.

During the last few months great attention has been given to Eros at fifty of the leading observatories of the world. Professor Campbell, Director of the Lick Observatory, says that for two or three months fully half the resources of that institution have been devoted to this object. The positions of 700 fundamental stars have been determined by the meridian circle, and photographs made, which will be measured at the Observatory of Columbia University under the direction of Dr. Rees. At the Harvard Observatory several hundred photographs have been taken, and very extended photometric observations made. Owing to the exceptional conditions which prevail at the Arequipa branch of the observatory and the power of the Bruce photographic telescope, it is probable that Eros can be photographed there after it has been lost sight of at other observatories. At least, the first determination of its position at the recent opposition was made from a photograph obtained there by Dr. Stewart. The interest shown by these two institutions is equaled by that of many other observatories in Europe and the United States. The chief object of these labors is the determination of the solar parallax, which is the angle subtended at the sun by the earth's radius, and which is a measure of his distance. The methods which are in use for the solution of this problem may be divided into three groups, geometrical, gravitational and physical. The present investigation belongs to the first of these. The natural and direct method for measuring the sun's distance would be to select two stations on the earth, whose distance apart must be known, and from them measure the angle which that distance subtends at the sun itself. If the distance is the earth's radius the measured angle is the solar parallax. In fact, however, this apparently easy and direct method has now no value whatever, since the angle concerned is too small to give the best results, and also the sun is a very difficult object on which to make measurements of precision. Some other, nearer and more suitable object must be sought, and, in quest of the most exact results possible, astronomers have observed Venus, when in transit across the sun's face, Mars near opposition and various asteroids. Of these different geometrical methods, observations of the asteroids appear to have furnished the best results, so that the discovery of Eros comes at a most fortunate time to give astronomers an opportunity of testing this method under the most favorable conditions. It must be remembered, however, that the recent opposition of Eros was not an especially favorable one, and it is not certain that better results will be obtained at this time than have been secured in recent years by Dr. Gill at the Cape of Good Hope, in cooperation with Dr. Elkins, of Yale, and others. That work depended upon heliometric observations of the asteroids Iris, Victoria and Sappho, whose least distances from the earth are 0.84, 0.82 and 0.84 astronomical units. At the recent opposition the distance of Eros was little more than a third as great, and this in itself gives Eros an enormous advantage. It has been feared, however, that the faintness and rapid motion of Eros would prevent observations of the highest precision, which might be sufficient to balance the advantage which its nearness gave. Probably the difficulties on these accounts have not proved so great as was at first feared. Even if the present determination yields no better results than have been obtained before, it will make a very valuable check on previous determinations, and bring out the best methods to be pursued at some later and more favorable opposition. In this connection it may be of interest to recall that Halley, who first pointed out the possibility of determining the solar parallax by observations of the transits of Venus, well knew when he developed the methods that he himself could not live to see the experiment tried, since he was then sixty-three years of age, and the next transit of Venus did not come for forty-two years. Perhaps few of the observers who are so enthusiastically at work on Eros at this opposition will be alive to make observations at a really close approach of that interesting body.

At the Paris meeting of the International Astrophotographic Congress, in August, 1900, a committee was appointed to suggest the most favorable course to be pursued. The committee later advised that work be done by the micrometer, the heliometer and by photographs. The observations in each case give the distance of Eros in seconds of arc from adjacent stars. The simplest case is where simultaneous observations are made by observers at widely separated stations. Let A and B (Fig. 3) be two stations on the earth. The observer at A will see Eros projected on the celestial sphere at E^1, and the observer at B, at

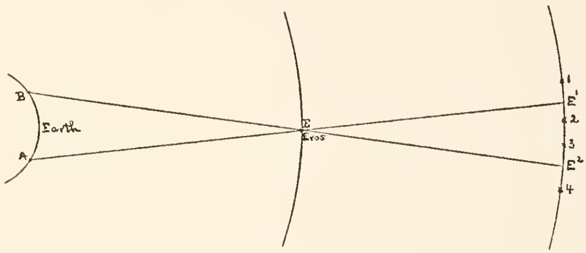

Fig. 3. Parallax of Eros.

E^2. It is only necessary for each observer to measure the distance in seconds of arc between Eros and some adjacent stars, as 1, 2, 3 and 4. The positions of the stars must be known with the greatest precision, so that the observations give the value of the arc E^1E^2, which equals the angle AEB. We have then the necessary material for computing the distance of Eros from the earth in miles. Given this and the orbit of Eros, the distances of the earth and all the other planets from the sun in miles follow from the known laws of gravitation. The distance AB may lie in a north and south direction, or in an east and west direction, or more probably in a combination of the two. In the first case there must be two observers, widely separated, as, for example, at Arequipa, Peru, latitude south 16°, and Helsingfors, Finland, north 50°. In the second case there may be two stations, as, one in Europe and the other in the United States, or the whole work may be done at one station by allowing the earth's diurnal motion to carry the observer to a new position. Suppose, for example, that one observation is made when the planet is rising in the east, and another twelve hours later, when it is about to set in the west. In the meantime, the observer will have been carried to a position 8,000 miles removed from that which he occupied in the morning. Each of the three methods has certain objections and difficulties. Simultaneous observations are difficult or impossible to obtain. Between the different observations both earth and Eros are sweeping along in their orbits, and this introduces complications which must be allowed for with great care. Also the size of the earth is not perfectly known, nor the distance apart of any two stations upon its surface, though the error introduced from this cause is very small.

For the determination of the position of Eros on each day during opposition, as recommended by the Paris committee, the precise positions of very many stars must be known. A few of these have already been determined, but most of them must be measured at the present time. For this purpose the positions of several hundred stars will be determined and the highest precision at different observatories with the meridian circle, and, from these as standards, many hundreds more, by photographs. For the positions of Eros itself with relation to these stars, no doubt the micrometer, the heliometer and the photograph will be used, and a comparison of the results by these three instruments will be of the greatest interest.

Observations of Eros, made during the recent opposition, or in the future, will doubtless give the most exact determination of the solar parallax possible by the geometrical method, applied to any known member of the solar system. Indeed, Eros, at the most favorable times, is perhaps as good an object as can be desired. If it came still nearer to the earth, its motion would doubtless be more rapid, so that little would be gained. According to Professor Newcomb, Eros comes 'about as near to us as observations can advantageously be made.' Nevertheless, it is doubtful whether any geometrical determination of the solar parallax will ever be accepted as final. When the astronomical world was preparing to observe the transit of Venus in 1874, Leverrier refused to take any part in it, declaring that the determination by gravitational means would make all geometrical methods of no further value. This may be true for the future, but it will not lessen, for the present, at least, the high value of the determinations now going on.

The solar parallax is about 8″.80, correct within approximately 0″.01. That is, the distance of the sun is about 92,897,000 miles, correct within 100,000 or 150,000 miles. It is difficult to appreciate an angle of 0″.01, within which limit the determination must come to be of value. A foot rule forms an angle of 0″.01, when placed at a distance of 20,626,481 feet, or over 3,900 miles. If the present work shall reduce the margin of doubt, astronomers will be well paid for their efforts.

Aside from the determination of the solar parallax, Professor Pickering has pointed out that Eros furnishes an opportunity for the investigation of several interesting photometric problems. These are: the determination of the planet's diameter; a test of the law that the light varies inversely as the square of the distance; a test of the existence of an absorbing medium within the solar system, and a test of the law connecting the phase angle of a planet with the variation in brightness.

Thus Eros, the tiny asteroid, whose total area is little larger than the State of Rhode Island, is for the moment of more importance in the eyes of the astronomical world than the greatest planet which moves about the sun.

DISCUSSION AND CORRESPONDENCE.

WHAT THE UNIVERSITY OF CHICAGO STANDS FOR.

At the time of Princeton's celebration in 1896, one of her loyal alumni undertook to show what Princeton has stood for and stands for. "The name Princeton," he remarked, "is supposed to be synonymous with the stiffest intellectual conservatism." The philosophical temper dominates at Princeton, just as the literary spirit characterizes Harvard. If the question be asked, What the University of Chicago stands for? one may answer without hesitation, *for the scientific method!*

The scientific cast of mind is ascendent in the halls and laboratories of this new university of the West; or, at least, one may affirm that it is becoming so. It is due in part to the presence of so many specialists who have received their professional training in Germany and have brought back something of the German scholar's aptitude for investigative work.

Even in the Divinity School the influence of the scientific spirit is felt by both teachers and students. In the work of advanced students, as in the departments of physical science, the paramount idea or aim is the acquisition of a method by which truth may be found, and they are characterized by a willingness to go wherever truth may lead them. Theology is not the fixed thing that it was formerly imagined to be. The professed aim of the Department of Systematic Theology is "to reduce to a scientific system, and maintain on scientific principles, the teaching of Scripture in the light of such other sources of theological knowledge as enter into the progressive self-revelation of God to mankind." Mysticism is at a discount in Dr. Northrup's classrooms.

Of scholastic traditions Chicago has none as yet, but it has a certain definite purpose or policy distinct from that of the old college. The University of Chicago stands for another educational ideal.

The old college aimed to give the student a liberal education, as it is called, a wider mental horizon. Intellectual discipline was emphasized. Some good results were attained, for the man who took the four years' course was unquestionably benefited by the process. There were, however, some defects in the system. While the culture of the old college tended to make his thinking more clear-cut and logical, it did not go far enough, in that no postgraduate work was provided. Its alumni went forth into the world and, after three years of professional employment, they received the degree of A. M., without further study or even an examination.

The humanities are not neglected at the new University of Chicago—their disciplinary value is recognized and prized; but at the same time research is emphasized, and advanced students are encouraged and assisted to engage in original investigation. To enlarge the borders of knowledge is the end in view. The way chosen is through specialization. In chemistry, candidates for the much-coveted degree of Ph.D. must take two or three years of laboratory work under the supervision of a university instructor; and the thesis, embodying the results of their researches, 'must be a real contribution to knowledge.' A few sentences describing the work in geology may be quoted:

"The aim of this department is to provide systematic training in geology. . . . The endeavor is to furnish this training in such a form as to contribute to a liberal education, and at the same time to prepare for professional and investigative work in the science. The cultural purpose predominates in the earlier courses, and the investigative and professional in the later; but both have a place in all and find their realization in a common method of treatment. While it is not expected that more than a small percentage of those who take the earlier courses will have professional or investigative work in view, it is believed that they will derive the largest and most distinctive returns from such shaping of the work. That special mental and moral discipline which is appropriate to the science can be secured only by wrestling with its problems as they actually present themselves to the investigator. A radically different discipline is secured from handling the subject in the simple didactic method. It is believed that those who enter upon any of the courses with an intelligent appreciation of the science as a growing body of truth and a progressive field of intellectual endeavor will desire to come into touch with its working methods and controlling spirit."

In his address before the Baptist Social Union of Chicago, Nov. 5, 1891, Dr. W. R. Harper set forth what might be expected of the new University of Chicago. Much has been accomplished along the lines indicated. Two or three passages in this notable utterance are worth repeating:

"In these days of specialists, the man who has passed through college has, after all, but a smattering of things. Possibly before his course is completed, and certainly at the close of it, he should have a chance to take some special subject and give it the continuous attention of months. Concentration on a given line, before graduation, should be encouraged. . . . The college-system, as we all understand it, is not intended primarily to stock the pupil's mind with knowledge, but rather to develop it, to make it able to receive and apply truth from every source; in brief, *to open* the mind. . . . But it is not sufficient simply to be open to accept truth when it presents itself; to adopt new or modified methods, when they have been suggested by others. A university may not stop with this. Shall you not expect contributions, and these not small ones, to the sum of human knowledge? Shall you not expect a spirit pervading every department of the university life which will lead men from the lowest to the highest department *to investigate and to experiment?* A deal of truth, known for ages, if it is to exert any influence to-day, must be restated. Such restatement makes it practically new truth, and the contribution of the man who has done this is only less than that of him who first formulated it. Old forms of statement in every line of work have lost their force; they have been worn smooth, till now they are really valueless."

Hence the need, not only of specialists and laboratories, but of an endowed University Press for the publication of books and periodicals. This want has been supplied by the admirably edited journals of the University, which contain articles summing up the results of studies and experiments pursued in numerous lines of intellectual activity. Usually the head professor of the department is the editor, aided by his associates and by eminent scholars in other universities of America and Europe. It is not necessary to dwell on the merits of the 'Botanical Gazette,' the 'Journal of Geology,' the 'Journal of Political Economy' and the other monthlies and quarterlies issued from the University of Chicago Press. The value of this series is appreciated, and their success is a credit to American scholarship.

The keynote of the university spirit is devotion to the cause of truth for its own sake. This mental attitude was well described in Professor Chamberlin's convocation address (April 1, 1893) on 'The Mission of the Scientific Spirit':

"Simple observation is incapable of disentangling intricate phenomena and of discriminating with precision the several agencies and their varying results. Even when it discerns the agencies, the complexity of the combination baffles all efforts to evaluate the measure and degree of participation. In the varying degrees of participation of causes lies the greatest peril to safe conclusions.

"But by the devices of experimentation, each factor may be disentangled from its complex associations and made to reveal itself in its simple and naked reality. Experimentation, by its creative processes, opens a new world of observation; a world devised and controlled solely for the disentanglement of truth. The new potency thus added to observation and induction gave birth to modern science. By its aid the mass of crude facts previously gathered were purified and perfected and increased by manifold additions. Upon this relatively pure, solid truth a trustworthy superstructure was built by the inductive method. But even the inductive method, potential as it is, would have fallen short of trustworthy results, were it not furnished with facts verified by searching experimental tests."

The investigator must be a lover not only of the truth, but of 'the pure and exact truth.' Hence the necessity for the scientific method, which may be defined in brief as a process for the purification of truth from error. A fuller statement is given by Sir William Turner in his address before the British Association in 1900:

"Scientific method consists, therefore, in close observation, frequently repeated, so as to eliminate the possibility of erroneous seeing; in experiments checked and controlled in every direction in which fallacies might arise; in continuous reflection on the appearances and phenomena observed, and in logically reasoning out their meaning and the conclusions to be drawn from them."

The scientific method, then, is something more than diligence and accuracy. It is not suddenly acquired. It has been a slow growth in the race—a growth to which Aristotle, Euclid, Bacon, Galileo, Newton, Kant, Darwin and many others contributed. And it is a slow growth in the individual. Some persons of intellectual tastes never acquire it. The Oriental mind is weak in this direction. It is claimed that Americans have less of the scientific spirit than the Germans. The work of the old college did not tend to develop the scientific habit of mind in the student. Said Professor Remsen, in his convocation address (Oct. 2, 1894) on 'The Chemical Laboratory':

"If the experience of twenty-one years in teaching in college and university in this country is worth anything, your speaker, who has during that time had to deal with many students from all parts of the country, is justified in asserting that the minds of students who enter college are very far from being scientific, and the same can be said of most of them fresh from the colleges. By a scientific mind is meant one that tends to deal with questions objectively, to judge things on their merits, and that does not tend to prejudge every question by the aid of ideas formed independently of the things themselves."

Since the scientific spirit is not quickly and easily acquired, means are provided to foster its development. The laboratory is the especial place for experimentation in pure science. In other fields data must be sought elsewhere. In sociology it is the world of men and women. The student who tried working behind a counter in a big department store made a sociological experiment where she might learn by experience and observation the condition of clerks and cash-girls as she could not in the class-room.

The aim of the scholarly investigator is to reach results that can be expressed in some tangible shape or tabulated form, and his conclusions must be accompanied by the evidence on which they rest. There is too much of assumption in the thinking of the average student.

It has been said that "the one factor which has made the German university what it is to-day is its docent system." The docent system cannot be transplanted to our soil the same as it is in Germany. The conditions are different here. It is a factor, however, to be counted upon to foster scientific investigation among us.

Much, too, may be expected of the fellowship plan. It serves a useful purpose in affording exceptional opportunities to men possessed of the love of science and displaying proficiency in laboratory methods. The presence of a large body of fellows and scholars tends to raise the standard of intellectual work in general to a high grade of excellence. The offer of a substantial stipend is not without effect in stimulating effort. The fellowship is also in the nature of a stepping-stone to an instructorship—an inducement calculated to arouse the desire to excel.

Besides this incentive is another—that of environment, of association with an inspiring teacher and the companionship of skilled workers. "While it is true," says Professor Nef, "to a great extent that the power of scientific investigation is inborn and not acquired, it is also certain that a proper atmosphere must exist for its development. It requires inspiration and example to kindle into flame the spark which may exist in men beginning their life-work."

The influences of departmental clubs, with their learned papers and discussions, is a factor making for critical scholarship. Another agency that promotes the acquisition of the scientific method is the Seminar. As it is only a recent growth in American universities, a fuller description of it is needed.

The professed aim of the Seminar is 'initiation into the methods of research.' To the scientist life presents itself as a series of problems, and these problems are to be grappled with and solved. The right way of attacking these problems the graduate student learns in the Seminar by contact with trained workers. He must get a first-hand acquaintance with his subject, whether literary, historical or scientific, by going to the sources. He must learn from instructors the recognized tests and principles of investigation and then apply them. He must learn to suspend judgment until full information is obtained.

Under the Seminar system the members meet once a week for a two-hours' session, usually Monday afternoons. The student works largely by himself, spending weeks or months gathering material for a report, which is subjected to criticism by other members of the Seminar and by the professor in charge. Thus he learns what defective work is. While patience and industry are necessary for the production of a satisfactory report, it is not enough 'to lead laborious days.' The subject must be treated in a scholarly manner; and, if possible, some new light thrown on it and old errors corrected.

The Latin Seminar may be taken as an illustration—*The Comparative Syntax of the Greek and Latin Verb,* under Professor Hale. The aim and plan of procedure are thus outlined for the autumn, winter and spring quarters of 1899-1900, two hours a week:

"The principal object of the Seminar will be the study of unsettled problems in the syntax of the Latin verb. In necessary connection with this object, however, a considerable amount of study will be given to the syntax of the Greek verb as it appears in the earliest Greek literature.

"Owing to the advanced character and difficulty of syntactical problems, the independent work of the members of the Seminar will not begin until after preliminary lectures and discussions have made clear the general attitudes and methods of various schools of workers in syntax in the past and present, and the fundamental principles that must now be recognized as properly governing investigation. Several books of Homer and plays of Plautus will next be read, with reference solely to the syntax of the verb. An analysis will then be made by each member of the Seminar of the treatment of the syntax of the verb in one of the more important grammars or treatises, after which he will devote himself to a special problem, or group of problems. A considerable amount of reading in the literature will be expected for the systematic and exhaustive collection of evidence in a definite field. Reports of the results of work upon special problems and of reading for the collection of materials will be presented from time to time at meetings of the Seminar."

So to produce scholarly workers in the various fields of learning is the function of the University—to train specialists, to make critics in the higher sense, to furnish investigators who will enter fresh fields and give the world the fruits of their researches. It is for this kind of work that the University of Chicago stands—not merely to impart what is already known, but to seek and find new knowledge. This is the province of a university as conceived by President Harper. It is a high ideal that he holds up: "The true university is the center of thought on every problem connected with human life and work, and the first obligation resting upon the individual members which compose it is that of research and investigation."

EUGENE PARSONS.

THE POPULATION OF THE UNITED STATES DURING THE NEXT TEN CENTURIES.

Dr. H. S. Pritchett published in the November number of the Popular Science Monthly his estimate of the future population of the United States, based upon the past rates of increase. He found a comparatively simple equation which represented the census enumerations very closely, and, applying that to the future, he finds that the rate of increase, which was 32 per cent. per decade in 1790 and 24 in 1880, will be 13 in 1990, but will not have sunk to less than 3 for another thousand years and will not be zero for an indefinite time. He does not seem to have taken into consideration the density of population and what we might call the saturation point, or the maximum population which can be fed. A population far below its saturation point will increase rapidly, but when it saturates the land there is no increase, and as we approach our saturation point our rate will rapidly diminish to zero.

We do not know what our saturation point is under the present conditions of food production; but we produce far more than is needed for our twenty people per square mile. Nor can we estimate our future saturation point, for no one can presume to predict what science will enable us to do in the way of food production, other than what, by present methods, can be forced from the soil. We can only estimate our limit, basing it upon the known densities in countries which have always been populated to their limit.

The saturation point rises with civilization just as the saturation point of air for water rises with the temperature. Cultivated land is said to produce 1,600 times as much food as an equal area of hunting land. Denmark, for instance, could support but 500 paleolithic people, and when their culture rose to the level of the present Patagonians, 1,000 could exist, and 1,500 of those on the level of the natives of Hudson's Bay. In the pastoral stage each family requires 2,000 acres, and France could not support 50,000 of such people. For centuries after the Norman conquest the whole of Europe could not support 100 millions, or about 25 per square mile, while now there are 81.

When civilization is arrested, the saturation point remains stationary. China, for instance, is said to have had 400 millions for many centuries. When food can be imported and paid for by manufactured goods, the population can go beyond the saturation point. Great Britain, for instance, is said to import one-third of her food, and her 300 people per mile is supersaturation. When the countries from which she buys food are populated to the point that they have no surplus for sale, her population must decrease to the number she can feed, which is now 200 per mile. Should her factories fail through foreign competition, so that she cannot buy, she will also decrease in population, just as Ireland has done since the beginning of the last century, when England destroyed Irish industries to strengthen her own. English supersaturation is limited only by her power to buy and import.

America was saturated by savages in pre-Columbian times, and they were constantly at war for more room; but the land has always been far from saturation for civilized whites. Though we now export enough food for a large population, we cannot produce very much more, for all the useful land is now taken up. Fully 60 per cent. of the desert lands west of the 100th degree of longitude will never have water on it, and that alone will forever prevent us being as densely populated as Europe. Perhaps we can now support fully 125 millions, or 34 per mile, a point which Dr. Pritchett calculates we shall reach in 1925, at our present rate. By that time we shall have farms on 10 or 15 per cent. of the arid lands, the limit of possible irrigation, and perhaps then we can support 200 millions, the calculated population for 1950; but it is difficult to see how we can feed 500 millions, our calculated numbers a little over a century hence, for that would be a density of about 125 per mile—far greater than Europe.

It is also difficult to see how science is to produce food indefinitely, for the real basis of food production is the soil and vegetation, such as the changing of cellulose into starches and sugars. The possible limit is the amount of the sun's energy we can capture through vegetation. The calculated population of a thousand years hence, 41 billions, or 11,000 per mile, is not at present conceivable.

There is a law of population, that its increase depends upon its density, irrespective of the birth rate; hence at the saturation point the death rate must equal the birth rate, as at present in China, where the large birth rate is compensated by frightful destruction of life, awful pestilences, famines, universal infanticide and judicial executions for every felony. Our civilization will never tolerate such mortality, nor can the surplus migrate, as it has been doing from Europe for four hundred years. Yet we need have no fear of future famines and pestilence due to overcrowding and so necessary in India and China, for the solution of the problem will come of its own accord in a natural limitation of the size of families by prevention of conception or some other means, a process already begun, as many have already pointed out. The average number of children in English families is already less than four. By the time we have reached our maximum growth it is quite likely that the number of children in American families will be less than three, or just enough to compensate for unavoidable deaths and still keep the population stationary. The deliberations of the Malthusian societies may appear very absurd, but they are merely discussing things which are sure to come about naturally and not artificially.

Thus Dr. Pritchett's estimates of our future population of 11,000 per square mile, being based upon the rates of increase in a country far below its saturation point, it seems that a better formula could have been obtained by taking the increases in European countries which probably have been saturated since the glacial times and supersaturated ever since they became maritime powers and could import food. Thus England had 5½ millions in 1650, and only 6½ millions in 1750, and less than 9 millions in 1800; since then, through food importations due to commerce, her rate of increase has been about 13 per cent. per decade. Our rate, as above stated, was 32 per cent. in 1800, 24 per cent. in 1880, and the time it will be 13 may be long before 1990, and it is quite likely to be zero within a century or two.

Our country will never contain more people than it can feed, and the struggle for existence or the stress of life will not be a particle more severe than now. Since the first paleolithic man appeared on the scene, Europe has supported as many men as she could and has thus been at the saturation point, ever on the verge of over-population, needing famines, wars of expansion and other forms of deaths, so that there has always been the same struggle for existence we see now, and that struggle can never be more severe than it has always been there. The course of civilization would even justify a prediction that life will be made easier, so that posterity may pity us as we pity our savage ancestors in their terrible struggle for existence.

Chas. E. Woodruff, U. S. A.
Fort Riley, Kan., Jan. 30, 1901.

THE ORIGIN OF MEN OF GENIUS.

To the Editor: I have been much interested in Havelock Ellis's 'Study of British Genius,' for the reason that his conclusions are so nearly paralleled by a study of a like character for several of the continental countries reported by me in the latest number of the 'Conservative Review.' Mr. Ellis says, among other things: "When we survey the field of investigation I have here briefly summarized, the most striking fact we encounter is the extraordinary extent to which British men and women of genius have been produced by the highest and smallest social classes, and the minute part which has been played by the 'teeming masses' in building up British civilization. In the article above referred to it is shown that 'The nobility, the office-holding class and the liberal professions in no community form so much as a tenth part of the population, yet from this small minority seventy-eight per cent. of the primates of Italian and German literature, eighty per cent. of Spanish and sixty-nine per cent. of English were descended.' The fecundity of the different parts of French territory, like that of Great Britain, has been very unequal. "If we examine the nativity of French writers according to their geographical distribution . . . we find that the northern and eastern parts have been most prolific. (Is this the result of the comparatively large Teutonic intermixture?) Taking France by Provinces, Ile de France heads the list with 1,572 names out of a total of 5,617. Next in order comes Normandy with 413 names. The adjacent districts of Picardy and Artois furnish 373; Provence gives us a register of 295 names; Lorraine, 240; Touraine, Anjou and Maine, 207. All others fall below 200. Except in a general way, it cannot be known what relation these figures bear to the total population, as no census of France was taken until comparatively recent times. If we make an estimate on the present basis of inhabitants, the relation of the districts will be somewhat changed. Ile de France will still stand at the head, but the second place will be taken by French Switzerland, the third by Provence and the fourth by the Orleannais."

The religious milieu is a factor of very considerable importance. "It is well known that among French writers in all departments Geneva has produced a much larger proportion than would be expected from the number of its inhabitants. For more than four centuries it has been a Protestant city, while the rest of French territory has been for the most part Roman Catholic. It is worthy of remark, too, that in Germany, including by this designation its territory linguistically and not politically, the Catholic portions of Bavaria and Austria have given birth to a relatively small number of persons who are entitled to the highest rank in letters. It has already been shown that, in the product of men of science, the religion of a country seems to play an important part. We are justified in drawing the same inference in regard to literature."

One more quotation that bears on the preponderating influence of what may be called *centers of civilization*, and I have done: "Of fifty-five eminent Italian *literati*, twenty-three were born in large cities, and most of the remainder in small municipalities, though, strange to say, not one had Rome as his birthplace. Of the fifty Spaniards who are generally regarded as holding the highest rank in the literature of Spain, sixteen were born in Madrid, and a large proportion of the remainder in cities of the first rank, several of which contain universities. The *coryphei* of German literature seem at first sight to make an exception to the conclusions that naturally spring from the above-stated facts. The great writers are quite evenly distributed over what now constitutes the empire and Switzerland. Three large cities are the birthplace of three great writers each; two, of two each; while the rest have produced but one each. This calculation embraces about thirty who stand confessedly at the head; yet if we increase the number the results are not widely different. Here again the importance of the environment is strikingly made prominent. During the last five centuries Germany has had a large number of capitals, many of which the reigning monarchs tried with more or less success to make centers of art and literature."

Chas. W. Super.

Athens, O.

SCIENTIFIC LITERATURE.

KANT AND THE NEBULAR HYPOTHESIS.

Professor Hastie, of Glasgow, has added to his long list of editions and translations a book which he calls 'Kant's Cosmogony' (Macmillan). It forms a substantial addition to our knowledge in two distinct fields. In the first place, on the philosophical side, it throws important light upon some early phases of Kant's thought and upon the problems he was revolving years before he began the critical philosophy. In the second place, it contains a most interesting and, in many respects, valuable apparatus dealing with a chapter in the history of the interaction between scientific investigation and metaphysical speculation. Dr. Hastie's translation of Kant's 'Universal Natural History and Theory of the Heavens' forms the main central portion of the book. Around this he has grouped other material, making a most convenient collection. His own introduction contains an account of the status of Kant's nebular hypothesis, of its place in the lifework of this thinker, of its relation to other cosmogonies, of its later influence and fortunes, and the like, while he has added appendices affording useful sidelights on the whole discussion. In one of these, Thomas Wright, of Durham, a forgotten English physicist, is conclusively proved to be, so far as our present knowledge goes, the forerunner of Kant and the other writers, to whom we owe the first adumbrations of the view now generally accepted regarding the ultimate nature of the physical universe. A portrait of this worthy is reproduced. Dr. Hastie shows, too, how Kant was a forerunner of Darwin. And in this connection, though not directly, he hints the great difference in standpoint between the static science of the eighteenth, and the dynamic science of the nineteenth, century. "Give me matter and I will build a world out of it. Can we truly claim such a vantage ground in speaking of the least plant or insect? Must we not here stop at the first step, from our ignorance of the real inner constitution of the object? The structure of plants and animals exhibits an adaptation for which the universal and necessary laws of nature are insufficient." So Kant wrote, from the static standpoint. But his own view, all unknown to him, already involved dynamic categories. For its scholarship in the history of thought, for its clear knowledge of the scope and meaning of scientific advance, and for its eminent fairness of spirit, this book is to be strongly commended. The volume is dedicated to Lord Kelvin, as one of the men of science who have done full justice to Kant's attainments in the domain of 'the astronomical view of the universe.'

KNOWLEDGE AND BELIEF.

Judging from the author's remarks in his preface, Mr. F. S. Turner's 'Knowledge, Belief and Certitude' (Macmillan) has long been in preparation. As a result the argument is clearly stated, the various points following upon one another consecutively. The book furnishes a typical specimen of English philosophical writing. Indulging in no flights of speculation, the writer keeps firm grasp on what he sees, and so is able to give an account of himself which any intelligent reader can master. In fact, his book commends itself as a serviceable introduction to the problems with which science and philosophy deal. It is divided into two 'Books.' The first considers 'Abstract Knowledge.' Under this head consciousness is distinguished from knowledge; and on analysis, the latter is found to possess three fundamental 'certitudes': self, other selves and the external world. Science comes under review next, and a most interesting and, in the main, sensible, account is given of its nature, as of its self-imposed limitations. This fills about 180 pages. Modern psychology is next brought to book. Here Mr. Turner cannot be said to achieve the same success. He makes certain good points. For example, he proposes the question, 'In what is called physiological psychology, what share of the discoveries belong to psychology proper?' In replying he shows that, ultimately, a very narrow line separates psychology from philosophy—a truth which some recent developments in psychology make patent. We do not think that in his chapter on 'Psychological Analysis' Mr. Turner preserves his customary reserve and balance. This appears plainly in the portion devoted to Wundt, where sympathy with the historical position of this psychologist lacks decidedly. The First Book, which is much the longer, concludes with a review of philosophy. Here the author manages to say some fresh and pertinent things: "Philosophy is necessary monistic. If philosophical speculation leads to dualistic conclusions, these really conduct to the sceptical conclusion—that the problem is insoluble." He infers that philosophy has no better or higher 'Knowledge' than the sciences. In this connection, his treatment of scientific conceptions in philosophy deserves praise. Book Second deals with 'Real Knowledge,' knowledge of 'ends'; concludes with a summary of negative inferences, and a final proof that all knowledge is, ultimately, belief. The work is to be commended as an original expression of its writer's own views and difficulties. Its reception in certain circles of dogmatic philosophy ought to be watched with interest. No scientific man will be disposed to find much fault with its sober methods.

MALARIA IN ITALY.

A TRANSLATION by Dr. Eyre of Professor Celli's interesting book upon 'Malaria' * has recently appeared and is most timely. The treatise admirably illustrates the revolution that has been recently wrought in the theories of the epidemiology and prophylaxis of the disease. Professor Celli not only describes the parasites causing the various kinds of malaria afflicting vertebrate animals, but also considers with great fulness the general causes of predisposition to malaria and the various methods that have been suggested for preventing the access of malaria germs to the human organism. The fact that the mosquito has been proved guilty of inoculating human beings with this terrible disease has revealed many opportunities for public sanitation. Not the least interesting part of Professor Celli's book is the portion dealing with the economic and social aspects of malaria in Italy. The great influence of the disease upon the welfare of the Italian people has never been more strikingly portrayed. The mean mortality from malaria in Italy is about 15,000 per year, and it is said that from 1877 to the end of 1897 more than 300,000 cases of malaria occurred in the army alone. A specially interesting section deals with the relation of rice fields to the particular kind of mosquito responsible for malarial infection. It is shown that the rice fields, with their clear and slowly running waters and their typical swamp vegetation, afford peculiarly favorable localities for the breeding of Anopheles, the malaria-bearing mosquito, and that the cultivation of rice has done much to render malaria endemic in certain regions. The author discusses very frankly certain social conditions that expose unduly a large class of the population to malaria. The pictures of the huts in which the peasants of the Campagna live (pp. 174-6) are a striking witness to the truth of his strictures. Taking the book as a whole, it can be fairly claimed that the latest researches upon

* Longmans, Green & Co.

malaria and the conclusions to which they lead are presented in a clear and popular fashion, and will be found both interesting and intelligible by the general reader, albeit the translation stumbles not a little.

BOTANY.

The *Botanische Centralblatt* has hitherto been published in two series, in which were included original articles and reviews without classification. Chiefly as a result of the representations of a committee of the Society for Plant Physiology and Morphology, this journal announces that, beginning with 1901, the main series will contain only reviews and notices of new literature, while all original articles will be relegated to the 'Beihefte,' each to be subscribed for separately. In order to secure more adequate notice of American papers, two associate editors from America will be added to the staff, and similar arrangements will probably be made in England and other countries. The committee entrusted with the details of arrangement and selection of the American editors consists of Drs. W. G. Farlow, W. F. Ganong, D. T. MacDougal, William Trelease and D. H. Campbell. This action on the part of the *Centralblatt* implies a most notable advance toward securing a better bibliography of botanical literature.

The completion of 'Die Naturlichen Pflanzenfamilien,' under the editorship of Dr. A. Engler, of the Berlin Botanic Garden, is followed by the announcement that he will undertake the management of a second great systematic work, 'Das Pflanzenreich,' which will consist of a series of monographs of the flora of the world. All the important literature dealing with the taxonomy, distribution, organography, anatomy, morphology of the flower and history of development will be cited at the head of the monograph of each family. General matter will be written in German, but all technical descriptions will be in Latin. Synonyms will be cited in chronological order. More than thirty of the collaborators have already taken up the work of preparation and agreed upon rules of nomenclature. The more recently established families will be fully illustrated. This great work will be produced under the auspices of the Prussian Academy of Sciences by the aid of the Department of Education of Prussia. Monographs upon the banana family *(Musaceae)*, by Dr. Karl Schumann; the screw pines *(Pandanaceae)*, by Dr. O. Warburg, and the cat-tail family (*Typhaceae)* and burreeds *(Sparganiaceae)*, by Dr. P. Graebner, have already appeared. It is to be said that an examination of these papers does not carry out the promise of the prospectus in the matter of rigidity of rules of citation.

The noble discontent of the science teacher in the schools with the text-books in botany is calling out a constant stream of elementary texts, the latest of which is by Prof. L. H. Bailey (The Macmillan Company). The subject is taken up in three main sections, dealing with the general anatomy, growth and reproduction, relations to environment and minute structure. Much useful horticultural practise is brought before the young student, but the text is decidedly sketchy in many places, and the book can hardly be said to place proper stress upon exact morphology, although with all Professor Bailey's books it will prove interesting reading to the beginner in botany. In the matter of introducing incidental and immaterial illustrations, much might be said in the way of adverse criticism.

TRAVEL AND EXPLORATION.

The Ascent of Mt. St. Elias by H. R. H. Luigi, Duke of the Abruzzi, a work published by the Stokes Company, of New York, records the accomplishment of a feat in mountain climbing which is well worth the handsome and profusely illustrated volume brought out in March last year. As a book, it is almost a masterpiece of the bookmaker's art. The appendices are the most valuable portion of the book, and future travelers in such regions will do well to consult the valuable hints of the chapter upon equipment. Mr. W. D. Wilcox, already a favorite authority upon 'Our Switzerland,' has really given us a continuation of his former work in 'The Rockies of Canada,' published by the Putnams of New York. He treats this wonderful mountain region from the standpoint of the enthusiast, having spent many seasons in the acquisition of his experience. It is easy to see that he is more of a 'mountain lover' than a sportsman, in spite of his creditable accounts of the hunting and fishing to be found in this part of terra incognita. Some space is also given to the character of the Indians. It is almost a pity that he has adopted the 'diary' style, as it detracts somewhat from the literary character of the work.

The past year has been productive of many volumes bearing upon the East and its problems. The most helpful of these works, two volumes which should be read together, are 'China's Open Door,' by Hon. R. Wildman, and 'The Crisis in China,' by a group of authors, most of them well known. The first volume is the most readable account of the dreary history of China that we have had up to the present time. The bright introduction by the Hon. Charles Denby is a very fitting opening chapter to the volume. It is published by Lothrop, of Boston. The other volume was issued by the Harpers, and discusses the vexed problems of China from various points of view; some of them, curiously enough, having been answered by the disposing power of events, others showing a helpful insight, which it is a pity the 'powers' did not follow. Another volume on America in the East, by W. E. Griffis, published by Barnes & Co., of New York, consists of a delightful series of 'Fourth of July' orations gathered into book form, mainly from the 'Outlook.' From the author's standpoint, Americans have apparently left little for any one else to do in China, Japan and Korea. The last chapters are the best because the most serious. We should remember that while the world moves largely through the influence of enthusiasts, we shall not conquer in the East as much by arms, as by brains and virtue. Still another work published or rather republished by Barnes & Co. is written by an able naval officer, Engineer John D. Ford. Its pleasant accounts of his visits to various portions of the Asiatic coast are well worth the new edition which is brought down to date by a sketch of the Battle of Manila.

A valuable book on the Colombian and Venezuelan republics, prepared by our minister and envoy to these countries, Hon. W. L. Scruggs, is timely, because of its practical hints, its comprehensive study of physical conditions and its descriptions of the magnificent mountain scenery and the luxuriant tropical life. The book will be more attractive to the real student than to the popular reader. Another volume of a different character, rather more of a journalistic effort, on the broader subject of South America, is published by F. G. Carpenter. It is a collection of letters, first published in newspapers and then gathered in more permanent form. The book is a pleasant companion, even if the sketches are somewhat superficial, as is apt to be the case with the traveler away from his authorities. The frontispiece is in rather bad taste, as it is a composition picture of the 'Pretty Girls of Chile.' The volume is printed by the Saalfield Co., of Akron, Ohio.

THE PROGRESS OF SCIENCE.

It is now possible to make a fairly definite statement regarding the enforced resignation of Professor Ross from Leland Stanford Junior University and the subsequent events. Professors are reappointed annually at Stanford, and Professor Ross received his appointment last year somewhat late and after a warning. He attributed this to Mrs. Stanford's disapproval of his economic teachings, and presented his resignation, to take effect at the end of the present academic year. The resignation was accepted on November 14 and Professor Ross published in the daily papers a statement attributing the trouble to Mrs. Stanford's dissatisfaction with his economic views, especially on coolie emigration and municipal ownership. Owing to this publication, Professor Ross's connection with the university was terminated. President Jordan has stated that he was not dismissed on account of his views on Oriental immigration, or on any economic question, but because, in the judgment of the university authorities, he was not the proper man for the place he held. Unfortunately, the affair did not terminate with the retirement of Professor Ross. On the morning after its announcement, Professor Howard, of the Department of History, lectured to his students on the subject, blaming more or less directly the university authorities for their attitude. After an interval of two months, Professor Howard was asked to apologize or resign. He resigned; and as a protest Professor Hudson, of the Department of English, and Professor Little, of the Department of Mathematics, also resigned. These being, in brief, the facts of the case, there has been much private and public discussion as to whether academic freedom has been infringed by the authorities of Stanford University. Thus a committee of the San Francisco alumni has prepared a report upholding the action of the university, while, with substantially the same evidence before it, a committee of three economists has published a pamphlet, supporting Professor Ross in his claim that he has been unjustly treated. It is not true, as has been alleged, that President Jordan acted against his will, under the authority of Mrs. Stanford. The question reduces itself to the more general one as to whether university authorities must retain a professor when his methods are regarded as harmful to the institution.

Professor Ross evidently has the qualities of the reformer rather than of the judicial expert. His stump speeches and illustrated pamphlet supporting free silver in the campaign of 1896 injured the university, and his published writings and his lectures before his classes are extreme in their rhetorical opposition to the wealth and conditions that made Stanford University possible. Thus, if we glance through his articles, we find them strewn with statements such as 'the lawlessness, the insolence and the rapacity of private interests'; "Under the ascendency of the rich and leisured, property becomes more sacred than person, moral standards vary with pecuniary status, and it is felt that 'God will think twice before he damns a person of quality.'" The question is not as to the truth or falsehood of Professor Ross's views, nor as to the desirability of having reformers and even fanatics in the land; it is whether the university, to its own injury, should lend them its authority, whether the professor should have not only the right to investigate and communicate his results to his peers, but should also be free to involve a university in partisan conflicts. At Stanford the question is complicated by the fact that Mrs. Stanford has so recently given to the university the vast fortune—twenty-seven million dollars—collected by the late Senator Stanford. Professor Ross's teachings being repeated to her, perhaps in a distorted form, she is reported to have said: 'He calls my husband a thief.' Now, it is evident that a university cannot be a proprietary institution, controlled by a rich man or a group of rich men, who dictate the teachings of the professors. But it is equally true that the university professor must work in harmony with certain well-defined traditions. When people unite to accomplish any end, each must sacrifice something of his own freedom. When Mr. Gladstone appeared to be suddenly converted to the advocacy of Irish home rule, his opponents read his thousands of speeches to convict him of inconsistency. Nothing was found in favor of home rule, but neither was there found anything against it. For thirty years, apparently, Mr. Gladstone had been considering the subject, but had been careful not to give rise to dissensions in the Liberal party until he was prepared to make home rule the issue. This is simply an illustration of the fact that the more responsible the position of a man, the more careful must he be in giving expression to views which the man without authority may proclaim on the street corners. When Professor Ross says that teachers are unproductive laborers retained by the idle enjoyers of a parasitic organization to intimidate, beguile and cajole the exploited majority, it seems evident that this is no longer academic freedom of speech, but simply a statement of unfitness for an academic position.

While the troubles at Stanford University are being widely discussed in the United States, English men of science are disturbed by the dismissal of a number of professors from the Royal Engineering College at Coopers Hill. This institution trains engineers for the Civil Service in India, and is under the control of the India Office. The president is an army officer who does not take part in the teaching, and is supposed to act under the direction of a board of visitors. The teaching staff, it appears, has no control of the curriculum or of the general conduct of the college. Under these circumstances, an unsatisfactory state of affairs was reported by a board of enquiry and more than half the teaching staff was somewhat curtly dismissed. Their request for an enquiry having been refused by the Secretary of State for India, a number of leading men of science united in a memorial asking for such an enquiry, and a deputation waited upon Lord George Hamilton to urge it. This deputation, which included Lord Kelvin, Lord Lister, Lord Rayleigh and other leading men of science, called attention to the fact that the college was self-supporting and that there was no need, on the score of economy, for such sweeping dismissals, whereas the abolition of professorships of physics and chemistry would greatly weaken the scientific standing of the college and the training it could give to students of engineering. Lord George Hamilton's reply does not appear to have satisfied the deputation or the English scientific press, and the matter has been called up in Parliament.

The second annual meeting of the Association of Universities was held at Chicago on February 26, 27 and 28. This association is composed of fourteen leading American universities and holds an annual meeting for the discussion of problems of common interest, it being expected that the president of each university, or his representative, will be in attendance. All the universities were represented at the Chicago meeting. Reporters and the general public are excluded from the sessions, and there is consequently opportunity for free discussion. At the recent meeting three topics were chiefly discussed. Prof. Ira Remsen, of the Johns Hopkins University, introduced the subject of migration among graduate students, the general opinion being that it was an advantage for the student to attend more than a single university. Prof. W. F. Magie, of Princeton University, introduced a discussion on the type of examination for the doctor's degree, while Prof. W. R. Newbold, of the University of Pennsylvania, introduced the related subject of the extent to which the candidate should be required to show knowledge of subjects not immediately connected with his major subject. The consensus of opinion here seemed to be that the student should not be examined on courses he has taken, but on the subject of his work or research at the end of his university residence. The third subject for discussion, introduced by Prof. H. P. Judson, of the University of Chicago, was on fellowships: and here it seemed to be the general opinion that the provision for university fellowships is so large that there is danger that men will proceed to investigation who are not competent to do the best work. The plan, suggested by a committee of the American Association for the Advancement of Science, that a week be set aside for the meetings of scientific and learned societies was unanimously approved. Columbia University has, in accordance with the suggestion of this committee, altered its schedule for next year, so that the first full week after Christmas may be used for a Convocation Week, and it is to be hoped that other institutions will unite in this movement, and that our various societies will next year meet during the week with which the new year begins. As Christmas occurs this year on Wednesday, there is scarcely time for the meetings during that week, and it will consequently be necessary to hold them the following week.

The bill establishing a National Bureau of Standards, which was passed by Congress in the closing hours of the session, is a measure of unusual importance for science and for industry. As we have already pointed out, such an institution has long been urgently needed. Germany expends $116,000 annually on its corresponding institutions, and it is not difficult to trace an immediate connection between its Reichsanstalt and the supremacy of German scientific instruments and the increasing manufactures and export trade of the nation. Great Britain has recently been persuaded by the British Association and the Royal Society to extend its work, and is now erecting a new physical laboratory, while it provides $62,000 annually for the cost of its different institutions engaged in standardizing and experimental tests. In the United States the sum of only $10,400 has hitherto been set aside for the Bureau of Standard Weights and Measures, which has now been converted into a National Bureau of Standards. For the bureau a building is to be erected which may cost $250,000, though only $100,000 is at present appropriated; $25,000 is allowed for land and $10,000 for equipment. The salaries amount to over $27,000 annually and the sum of $5,000 is given for current expenses. The bureau has been inaugurated under the most favorable auspices. Urged by scientific men and societies, on the one hand, and by engineers and manufacturers, on the other, the bill passed both Houses of Congress almost without opposition. This was in large measure due to Secretary Gage and to the Hon. James H. Southard, chairman of the Committee on Coinage, Weights and Measures, who gave the measure careful consideration and, impressed with its importance, used every effort to secure its passage. President McKinley has already appointed a most excellent director in Professor Stratton, who has now leave of absence from the University of Chicago to take charge of the Bureau of Weights and Measures, and it is certain that the other officers will be selected with equal wisdom.

The establishment of a National Bureau of Standards was the most important scientific measure passed by Congress, but scientific work in many directions was enlarged by increased appropriations, especially in the U. S. Geological Survey and in the U. S. Department of Agriculture. In the latter a reorganization was effected, a number of divisions being united to form four bureaus—Plant Industry, Forestry, Chemistry and Soils. The chiefs of these bureaus receive salaries of $3,000, an increase of $500, and the salaries of some of the scientific experts are increased. Congress did not, however, find time to attend to the affairs of the U. S. Naval Observatory. An amendment was introduced in the naval appropriation bill by Senator Chandler which creates a board of visitors and requires the superintendent to be a line officer of the navy. So far from being a reform, this is distinctly a backward step. The board of visitors which has been created has no power, and with this board, the naval officer, who is superintendent, and the astronomical director, the Observatory has no real head. This amendment was rejected by the House of Representatives, but, after strenuous resistance by the House conferees, was finally passed, with a proviso that the present state of affairs should continue only 'until further legislation by Congress.' It is to be hoped that this legislation will not be long delayed and that the bill introduced by Senator Morgan will be passed at the next session of Congress. In the meanwhile the unfortunate state of affairs at the Observatory is emphasized by the fact that the superintendent has placed the astronomical director under arrest for trial by court martial, owing, it is alleged, to his having used influence against the superintendent.

A new star has appeared in the constellation Perseus. It is the most striking object of its class which has been seen for three centuries. Its position is, R. A. 3h. 24m. 24s., Dec. North, 43° 33′ 42″, which is near that of the famous bright variable star, Persei (Algol). This *Nova* was discovered and announced by Anderson, of Edinburgh, and when found by him on the night of February 21 was of about the third magnitude. By the following night it had risen to the first magnitude and was one of the brightest stars in the evening sky. Such an object, in an especially well-observed region of the sky, could not easily escape notice, and it was independently discovered by probably a dozen observers in different countries. At the Harvard Observatory a careful record is kept of the sky from week to week by means of photographs, which are taken at frequent intervals. Some of these photographs are made with lenses of such short focal length and wide field that the whole sky would be covered by about fifty plates. The announcement of the *Nova* was received there February 22. The latest photographs of the region of Perseus had been made on the night of February 19. One of these showed stars as faint as the eleventh magnitude, but the *Nova* did not appear upon it. On February 19, therefore, it was fainter, at least, than the eleventh magnitude. On February 21 its magnitude was 2.7, but by February 25 it had fallen to 1.1. At the present time (March 9) it is of about the fourth magnitude and may be expected to disappear from view by the naked eye within a few days. The astronomical world is to-day so well equipped for research in the line of spectrum analysis and the present object is so suitable for such investigation that we may expect a more satisfactory study of this new star than has ever before been obtained of any similar object. There will doubtless be abundant materials for learning the smallest changes during a portion of the life history of this star; but, for the period of the increase of light, from the instant it became visible till it reached its maximum, the observations may prove to be few. On this account it is fortunate that at the Harvard Observatory photographs of the spectrum were obtained on February 22 and February 23. On these dates the spectrum was not the typical one which we have learned to expect for Novæ, but instead was of the Orion type, consisting of a strong, continuous spectrum crossed by dark lines. Between February 23 and February 24, however, a wonderful transformation took place. Since the latter date the spectrum has consisted in large part of the bright and dark bands which are characteristic of the spectra of Novæ.

The first new star of which there is authentic record appeared 134 B. C. During the two thousand years which have since elapsed, nineteen more have been noted, making about one per century. This can by no means represent the true number of such stars which have appeared during that time. Doubtless only a few of the brightest have been seen. Of the twenty on record, thirteen belong to the century just ended, and six to the last decade, five of which were found on Harvard photographs. Of all the stars visible in the largest telescopes, not more than one in ten thousand can be seen by the naked eye. Thirteen of the Novæ were bright enough to be seen by the unaided vision. At the same rate for the fainter stars, if we may assume that the number of Novæ corresponds in some degree to the whole number of stars for the different magnitudes, several thousand new stars must have escaped observation during each century. No entirely satisfactory explanation has yet been given of these remarkable objects. From dark, or at least from extremely faint bodies, they suddenly blaze up and slowly fade away. Any theory which aims to explain the phenomena must at least account for certain leading facts. The increase of light is very sudden and very great. The decrease is slower and sometimes irregular, but no collision can have occurred such as would change a solid body into a gaseous, otherwise ages, not weeks, would be required for the cooling. The spectrum is generally composite, composed of bright and dark lines or bands. The bright bands are displaced toward the red, the dark bands toward the violet. If this separation is due to the relative motions of two gaseous masses, the velocities concerned appear to exceed those found elsewhere in the universe. The *Nova* sometimes remains as a permanent telescopic object with the spectrum of a planetary nebula. The problem might be somewhat simplified if the broadening of the lines could be due to the Zeeman effect from the presence of a strong magnetic field. It appears probable that the phenomena are due either to some outburst in the dark world itself, or else to the collisions of a solid dark world passing through a dense meteor swarm. It is to be hoped that a discussion of all the materials, which will be obtained at the different observatories during the next few weeks, may serve to formulate a theory of new stars which will receive the general approval of the scientific world.

The investigations on agricultural soils which are being conducted in this country are probably unsurpassed in quality and extent by those of any country, unless it be Russia, where a very systematic and extensive line of investigations, including a survey and classification of the soils of the whole country has been in progress for a number of years. The work in this country has been carried on mainly by a number of the agricultural experiment stations and the Division of Soils of the National Department of Agriculture. The report of the Field Operations of the Division of Soils for 1899, by Prof. Milton Whitney and a number of his assistants, lately issued, is a report of progress in surveying the soils of the United States. During the year areas aggregating about 720,000 acres were studied in the field and mapped. This work has been largely confined to localities in New Mexico, Utah and Colorado, and a special feature made of studies on the accumulation of alkali in the soil and its causes, means of ameliorating these conditions, and similar problems relating to alkali soils. A variety of local conditions were met with, which call for specific treatment. In a number of regions reconnoitered, the present accumulation of alkali, which has frequently nearly reached the limit of tolerance of plants, is attributed to lack of good natural drainage. The evaporation in these arid or semi-arid regions is unusually great, and with insufficient rainfall and injudicious irrigation tends to an accumulation of the alkali salts near the surface. With good natural drainage and proper application of irrigation water these salts would be in a measure washed out of the soil and the soil moisture maintained at nearly the same concentration as the water supply. But, in some cases, the irrigation water itself has become so charged with alkali as to call for the exercise of judgment in its use. "It may be perfectly safe to use water of a relatively high salt content on certain well-drained soils, when it would be ruinous to allow the same water to be used on a properly-drained soil containing a high salt content." The maps which accompany the report make it possible to determine the limit of the salt content of the water which it would be safe to use in the localities reconnoitered. The seepage waters are mentioned as another frequent cause of increase of the alkali in the soil. For instance, in the Salt Lake Valley, the oldest of the modern irrigated districts, the lower levels, which were formerly the most productive soils of the valley, have been damaged and in some cases ruined by seepage waters and alkali. In general, where the conditions are favorable and the expense would be warranted, underdrainage with tile is recommended as a remedy for excessive alkali in the soil. This remedy is considered entirely practical for reclaiming extensive areas, which at present have become nearly or quite worthless.

We record with regret the following deaths, which have occurred during the month: Dr. George M. Dawson, the eminent director of the Geological Survey of Canada, died on March 2 at the early age of fifty-one years, after an illness of only two days. He was well-known for his important contributions to the geology of Canada and for his conduct of the geological survey and of various commissions. Prof. G. F. Fitzgerald, who has held since 1881 the chair of experimental philosophy in the University of Dublin, and is well known for his researches on magnetism and in other directions, died on February 21 at the age of forty-nine years. Dr. Walter Myers died from yellow fever in Brazil, whither he had gone from the Liverpool School of Tropical Medicine to investigate the disease. He was only twenty-nine years of age. Dr. Jacob Georg Agardh, the eminent Swedish phycologist, died at Lund, on January 17, aged eighty-eight years. The death is also announced, in his seventieth year, of Dr. Bernhardt Danckelmann, for the last thirty-five years director of the Prussian Royal Academy of Forestry at Eberswalde. He was one of the first to advocate the training of foresters in special colleges, and was the author of important works on forestry.—The degree of LL.D. has been conferred by St. Andrew's University on Mr. Alexander Agassiz, of Harvard University, and by the University of Pennsylvania on President Henry S. Pritchett, of the Massachusetts Institute of Technology.—The Cullum Medal of the American Geographical Society has been conferred on President T. C. Mendenhall, of the Worcester Polytechnic Institute.—The Amsterdam Society for the Advancement of Natural Science and Medicine has awarded its gold Swammerdam medal for 1900 to Professor Gegenbaur, of Heidelberg.—Mr. J. E. Spurr, of the U. S. Geological Survey, has accepted an invitation of the Turkish Government to make an investigation of the mineral resources of the country.

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THE NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS.

Astronomy

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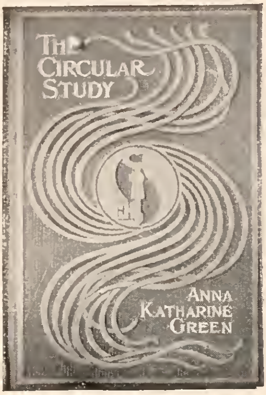

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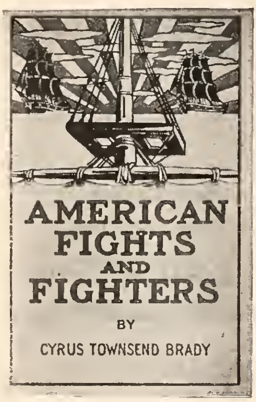

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Here is character indeed, a wealth of it, not superficially smart, but such character as only a knowledge of life deep and true could produce. Indeed, in "Kim," for the first time, Mr. Kipling has united in a story the militant strength that has always stamped his prose with the rarer and profounder insight of his poetry.

In the World of Graft

Result of a Painstaking Journey through the Haunts of Thieves and Tramps.

By JOSIAH FLYNT


A TYPICAL "GRAFTER"

What does the criminal think of society?

What are his relations to the constituted authorities?

Can he be held in efficient control?

What measures are necessary to relieve society of much of the danger and loss from the criminal classes?

These questions are discussed and answered by Mr. Flynt with candor. For fifteen years he has studied the criminal classes all over the world and is recognized as the highest authority on this subject. His methods of investigation are original. He lives among criminals and is generally supposed by them to be a "shover of the queer," or distributor of counterfeit money. It is because he has their confidence that he learns their real attitude to the problems above propounded. What he saw and what he learned during a long tour of investigation in Chicago, New York, Boston, Philadelphia, and elsewhere in the spring of 1900 will be told in McClure's Magazine during the coming year. The papers will give not only his own views but those of the criminals, who tell what they do, how they are able to do it, and how they think crime could be suppressed. This is the first time the criminal has had a chance to speak his mind to the public, though he does so unwittingly.

The Newest Science

PROFESSOR HAECKEL IN HIS LABORATORY

The very latest discoveries in science, the newest improvements, and the most important application in novel ways, all that represents the progress of the world in this great branch of human endeavor will be found in our pages.

UNSOLVED PROBLEMS IN CHEMISTRY.

By **PROFESSOR IRA REMSEN**, of Johns Hopkins University.

THE REICHSANSTALT.—**Germany's Laboratory of Applied Science.**

THE BOTTOM OF THE SEA.

From material furnished by **SIR JOHN MURRAY.**

THE NEW NIAGARA.

By **ROLLIN LYNDE HARTT.** The wonders in mechanics achieved by the falling waters.

More Dolly Dialogues

By

ANTHONY HOPE

Dainty, adorable Dolly is born again! Rarely does an author make a success so sudden, so complete, and so permanent as that of Anthony Hope in the "Dolly Dialogues." Now the writer has returned to his allegiance, and in "More Dolly Dialogues" we find that delightful woman and her clever interlocutor—not more, for that were impossible—but just as brilliant, just as elliptic, just as spontaneous, just as piquant, as amusing and demure, — in a word, just as fascinating as of old. The series will be illustrated throughout by Howard Chandler Christy, a master in depicting society scenes.

DETAIL FROM DRAWING BY CHRISTY

JEFFERSON DAVIS

Within the Gates

By ELIZABETH STUART PHELPS

It is long since Elizabeth Stuart Phelps (Mrs. Ward) stirred the hearts of men and women by her study of immortality, "The Gates Ajar." But the vital interest of the subject to every thinking being has waxed rather than waned. To-day, perhaps, as never before, many question and doubt as to what the future may bring to the soul. Mrs. Ward has developed her maturer ideas in a new work. In a drama entitled "Within the Gates," she treats with profound power a theme of dominating importance: the life lived beyond the tomb. This work will win the thoughtful attention of all readers.

Dramatic Episodes in our History

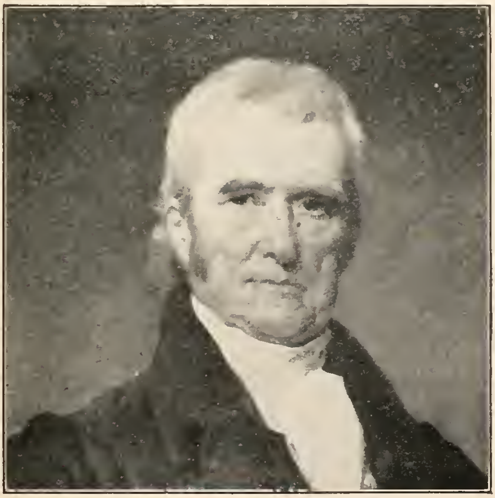
A Series of Papers about Great Men and Events Written with Vividness and Dramatic Intensity.

By IDA M. TARBELL

Author of "A Life of Napoleon Bonaparte," "A Life of Lincoln," etc.

The first of these articles will deal with the "MAKING OF THE CONSTITUTION." It tells simply and clearly the story of the Great Struggle which for more than three months of the summer of 1789 went on in the city of Philadelphia when some of the greatest men this country has produced sought to adjust the conflicting interests of the thirteen states in the confederation and their no less conflicting individual opinions of how a free government should be administered so that a more solid Union, ensuring life, liberty; and the pursuit of happiness, might be obtained. A more critical battle was never fought in any land. It abounds in dramatic moments when all seems lost, in moments of peril when freedom seems doomed. Great sacrifices, noble compromises, brilliant strategy characterize it. Miss Tarbell's article traces the struggle through its whole exciting course and shows how finally triumph was achieved.

Trial of Aaron Burr



CHIEF JUSTICE JOHN MARSHALL

No state trial in the History of the United States has called together so many and so varied a company of personages or hung on such romantic and varied schemes as that of Aaron Burr. The astounding conspiracy as it came out in the trial before Chief Justice Marshall in Richmond, Virginia, is reviewed in a vivid narrative by Miss Tarbell.

"Next to the Ground"

By MARTHA McCULLOCH-WILLIAMS

These stories carry to the reader the atmosphere of the earth, they are redolent of the soil; they breathe of the fields and the woods, and the life therein. In them we grow to know in detail the real being of the creatures about us. The writing is surcharged with a wonderful sympathy. One knows that the author is true in her every word, and one realizes that she speaks out of an experience long-continued and very tender, in which she was the dear friend of bees and birds, of hounds and horses, of the ground and its tillers.

Disbanding the Armies

Two Popular Articles on a Critical Period in our History.

By IDA M. TARBELL

THE GRAND REVIEW AT WASHINGTON, 1865

The Union Army

We are apt to forget that one of the greatest feats in history was performed by the Government of the United States. At the close of the Civil War the Administration in Washington disbanded the Federal Forces. The army numbered a million of men and that vast body of soldiers laid down their arms and returned to the pursuits of peace, without any disturbance, without unseemly confusion. That event is unique in history and it will receive treatment, thorough and full of interest, in a forthcoming issue of the magazine.

CONFEDERATE SOLDIERS GOING HOME. *From a war-time sketch.*

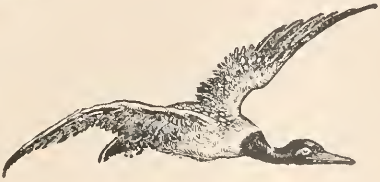
The Confederate Army

A theme of equal interest, but a theme of infinite sadness, is that which tells of the Confederates' return home at the close of the war. The broken remnant of an army that fought for years with unsurpassed skill and bravery was finally disbanded after Appomattox, and the men of the South, war-worn and sick at heart, went back to find at home, under another guise, a continuation of war's rigors. Miss Tarbell has written an affecting story of these soldiers and their return to desolate homes.

People of the Woods

By W. D. HULBERT

**THE LOON,
THE DEER,
THE BEAVER,
AND OTHERS**

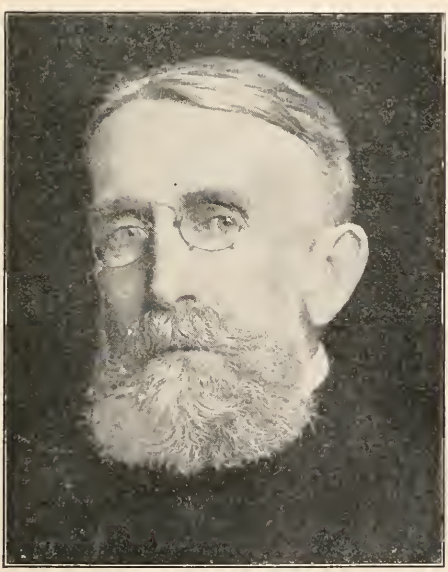


These are the stories of animal life by one who has lived long in the woods and has been the playfellow of some, and the keen observer of others. Mr. Hulbert not only knows his friends intimately, but he writes of them with inimitable charm. His stories are not only absolutely correct, but they hold an intellectual mirror up to nature whereby we may know them from their own standpoint so far as this is possible.

Great Character Sketches

A Series of Papers dealing in a masterly way with the Personality of Leading Men of our time by those most competent to write them.

SOME FORTHCOMING ARTICLES



ANDREW D. WHITE
(By courtesy of Harper Bros.)

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The Most Useful Citizen of New York.
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National Geographic Magazine

Is edited by the following staff:

Its contributors are the leading men of our country. It is the official publication of the *National Geographic Society*. Applications for membership in the Society should be addressed to the SECRETARY, NATIONAL GEOGRAPHIC SOCIETY, WASHINGTON, D. C. Subscriptions for the Magazine may be sent to the TREASURER, NATIONAL GEOGRAPHIC SOCIETY, WASHINGTON, D. C., or to

McClure, Phillips & Co., Publishers, New York

25 cents a copy. *$2.50 a year.*

Those who have read the excellent articles on China by William Barclay Parsons, which have appeared in the last two issues of the *Popular Science Monthly*, will appreciate the book, about to be issued, under the title of "An American Engineer in China," from which the articles were taken. It is a volume that has authority. It instructs without seeming to do so. Mr. Parsons is well known as an engineer and it was because of his high rank in his profession that he was selected to head the party of American engineers who were to open up the interior of China to American trade. The book grew out of his experiences in that land of paradoxes. His party made their way into and through parts of China practically unknown to white men. He accomplished more than discovery: he secured an exact knowledge of the country, its people and its availability for American enterprise. Many photographs illumine the text of the work. It is published at $1.50 by McClure, Phillips & Co., New York.

THE POPULAR SCIENCE MONTHLY

Established in 1872 by Messrs. D. Appleton and Company, and Dr. E. L. Youmans

The Popular Science Monthly is published by Messrs. McClure, Phillips and Co., New York, and edited by Prof. J. McKeen Cattell, of Columbia University, with the assistance of Dr. E. L. Thorndike, also of Columbia University.

The fifty-six volumes of the journal already published have performed an important service for the advancement and diffusion of knowledge. Its issues have each month carried to all parts of the country reliable information in regard to the advances of science, widening and deepening everywhere an intelligent interest in scientific subjects. The journal represented the doctrine of evolution before its tenets were generally accepted; it has done much to diffuse knowledge of physical science and of the applications of science; it has been a factor in the development which has reformed our entire educational system from the kindergarten to the university; its contributors have included many of the world's greatest men of science.

The Popular Science Monthly aims to represent fully and accurately the advance of science; to permit the leading men of science to bring their work before the largest public; to set a standard to the popular press in its treatment of scientific topics; and to secure the general interest in science that is needed for its adequate recognition and support.

A journal with these aims is necessary, both to men of science and to the general public. It brings men of science into contact with those whose sympathy and help they need, while it enables the general public to follow intelligently the progress of science and its contributions to civilization. This double service of The Popular Science Monthly is fully recognized; it has the largest circulation of any scientific journal in the world, and it is conducted with the support of the leading men of science, including in America:

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THE POPULAR SCIENCE MONTHLY.

EDITED BY J. McKEEN CATTELL.

CONTENTS:

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McClure's Magazine for 1901

For 1901 McClure's Magazine will be, as it has always been, the expositor of everything most vital, fresh and significant in literature, and the life of the world; and it will fill its place more brilliantly than ever before. Its programme offers fiction, studies of nature, biography, historical matter, and records of discoveries, inventions and explorations—all of the highest value.

As before, it exemplifies the advantages of keeping clear of ruts and grooves. No writer is too new, no matter too unprecedented, if the writer and the matter have real claims on the world's attention, for McClure's Magazine.

RUDYARD KIPLING'S "KIM"

The Important Literary Event of the New Year

Illustration for "KIM." From the bas-relief modelled by J. Lockwood Kipling.

The publication of Mr. Kipling's new novel, "KIM," in McClure's Magazine is unquestionably the literary event of the year. It is like to be the literary event of a decade, for we are lucky when two such masterpieces of fiction appear within ten years of each other.

India is Mr. Kipling's own peculiar field—because he is first in it and the rest nowhere, and because delightful as he has been when showing us life in other lands, he is never such a wizard as when he deals with the country of his birth. "Kim," his new hero, is like himself, "native-born," a little Irish lad who babbled the heathen's speech ere he came "to the white man's tongue." The secrets of India are Kim's, and he initiates us into the mysteiies of the temples, and the ways of Brahmin households, and the strange life of wild Himalayan mountaineers. But fascinating as is all this wonderful background it moves us mainly as people and places and events affect Kim's adventurous, varying fortunes, and the happiness of the beautiful old lama whose "disciple" and guardian Kim chooses to be.

So it is that the orphan son of Sergeant Kimball O'Hara sets forth wide India "for to see," and stumbles upon his father's old regiment, and pulls some of the manifold strings of the strange complicated Secret Service that holds all India as in a net, and qualifies for its "Great Game." Disguises and secrets and dangerous missions have a captivating fascination for Kim, and that is where he is like the rest of us.

The scenes are crowded with such wonderful characters however, people who are such living and enchanting companions, that it is the highest possible evidence of the lovableness of the two central figures that they hold our allegiance and attention over all the company and all the wonders of the setting. It is a great story of adventure and an illuminating analysis of varied human character.

Recollections of the Stage

Descriptions of People and Events of the Mimic World.

By CLARA MORRIS

Clara Morris' high fame will still be heightened by the remarkable memoirs that appear in McClure's this year. As an actress she has shown not only temperament and histrionic power, but a rare mental grasp and phenomenal psychological insight, and the most wonderful thing in her history is that now she should be able to give admirable expression to her rich gifts through literature. Her work is almost alone among reminiscences of the stage, inasmuch as it is so natural, frank, and at bottom so intellectual. The intellectuality is in the unconscious grasp of her strong mind, and the singular emotional responsiveness of the writer, her humor and her sympathy (again and again she makes one laugh and cry in the same breath) are the outcome of both brain and heart.

She has known the most prominent people connected with the stage since the beginning of her career, and gives us further acquaintance with such people as John Wilkes Booth, Augustin Daly, Lawrence Barrett, Charles Kean and Edwin Booth. The first article will be found in this issue.

Illustration for one of Josephine Dodge Daskam's Child Stories.

Drawn by Charles L. Hinton.

Some People of Chicago

By EDITH WYATT

Miss Wyatt is one of the most brilliant of the young writers McClure's has introduced to the public. Stories of hers—all dealing with related classes of Chicago people—will continue for some time to come. Miss Wyatt has a fund of dry humor and satire, and an originality that takes her completely out of the beaten track. Her Chicagoans have appeared in no other fiction, and are less typical of their city than of the wide American world where we have all known their like. Her grasp of character is the result of a sympathy that exercises itself in these stories on some kinds of people that are rarely viewed both sympathetically and honestly. Her truthfulness is delicious, and the result of it and her fairness is a widening of the sense of human fellowship.

"Within the Gates"

A Drama of Terrestrial and Celestial Life.

By ELIZABETH STUART PHELPS

The "Gates Ajar" stirred the world when Elizabeth Stuart Phelps was a young writer near the beginning of her career; twice since she has carried further her divinations of the future life,—in "Beyond the Gates" and "The Gates Between," and still the theme has kept its lifelong hold upon her. In "Within the Gates" she feels that she has now unfolded her final message upon it. "Within the Gates" throbs with the same intense feeling, the same imagination that have ever moved this ardent woman's thousands of readers. The story, the human story of love and suffering is powerful, independent of all its consoling doctrine.

Stories of the Stock Exchange

By EDWIN LEFÈVRE

Illustration for one of the Wall Street Stories.
Drawn by Henry Hutt.

Wall Street is as dramatic a field for fiction as modern life affords. It would appear in modern stories more frequently if brokers and speculators were more literary, or if outsiders better understood its intricate inner life. Mr. Edwin Lefèvre, who knows the whole game, has found a rich field for his stories of universal interest. He understands the place to its heart, and can tell the tales of triumph and despair, of human weakness and strength, and caprice and passion that it abundantly furnishes.

Colonial Fights and Fighters

By CYRUS TOWNSEND BRADY

Archdeacon Brady is warming people to our early history who never before found out how interesting our colonial period is. The dramatic stories of the early fighters Mr. Brady tells so thrillingly are sustained by scholarly original research, and throw light as well as give entertainment. The result is that these articles have attracted much attention from various classes of readers.

"Next to the Ground"

Descriptions of Life on a Tennessee Farm.

By MARTHA McCULLOCH-WILLIAMS

There are other than sentimental ways of loving nature; the strongest way brings an almost physical hunger for the good green earth, a longing to get "next to the ground" and revel in Nature's roughnesses and homeliness, as well as in her more delicate beauties. Mrs. Williams brings it all to us in her remarkable records of life, vegetable, human, animal and insect life, on a Tennessee farm. She writes delightfully, but the wonder of her book is her manifold limitless knowledge of her subject. She is not scientific, but science will be her debtor for some of this delicious first hand observation.

Once More the Delectable Dolly

Being more Dialogues by ANTHONY HOPE

"More Dolly Dialogues" is a rallying cry sure to call together a large, a choice, and a merry company. Dolly both cheers and inebriates everyone but the ladies who are unwise enough to enter the social lists against her. The years have not faded her looks, nor marriage quenched her high spirits, nor the lessons of life lessened her interest in her gowns. So she is just as much fun as ever, and perhaps a little more. Certainly we never saw her to such advantage as in Mr. Howard Christy's beautiful and abundant pictures. Mr. Anthony Hope has given his readers many kinds of good entertainment, but not another of his heroines holds Dolly's place in the public heart.

Drawn by Howard Chandler Christy.

People of the Woods

Stories of Denizens of the Forest.

Mr. W. D. Hurlbert has told our readers about the porcupine; it is not accounted an ingratiating animal, but in his society it proved a mighty entertaining one. He is to introduce us to other of the wood's inhabitants, —to the loon, and deer, and several more,—and his consummate knowledge of his friends, his native easy humor and sympathy, insure us of pleasure in their company, as well as make certain that we will end by knowing a good deal more than we did in beginning this social round.

In the Wake of Science

To maintain a record of actual scientific development, to set forth the plans and prospects of investigators, to explain new inventions of great importance, and to keep our readers in constant touch with the best progress in scientific knowledge is our constant aim. We have secured a number of articles which will throw light on what is being done here and in Europe along this important line of human effort. Some of these articles will be :

UNSOLVED PROBLEMS IN CHEMISTRY

By PROFESSOR IRA REMSEN, of Johns Hopkins University.

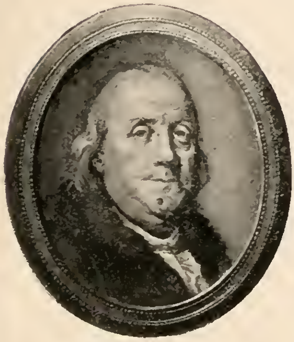
THE REICHSANSTALT.—Germany's Laboratory of Applied Science.

THE NEW NIAGARA.—By ROLLIN LYNDE HARTT.

The wonders in mechanics achieved by the falling waters.

Dramatic Episodes in American History

By IDA M. TARBELL



BENJAMIN FRANKLIN

Our historical records are to be enriched by a series of papers from Miss Tarbell, setting forth some of the most dramatic episodes in American history. The first of those will tell of the long battle over the Constitution that filled the summer of 1787. It was a vital struggle where patriotism and interest and conflicting opinion had to ferment violently before that marvellous Constitution, the most remarkable governmental document the world has seen, was brought forth. It was a stupendous and stirring time, and Miss Tarbell brings it vividly and comprehensively before us.

In another article, gathered together in one effective narrative, the facts of the State trial of Aaron Burr are given. No other trial our country has ever seen has moved the feelings and imaginations of men as did this one, and all the startling story lives here again.

Disbanding the Armies

By IDA M. TARBELL

At the close of the Civil War European observers anticipated for the United States many troubles as resultant from the disbanding of the great armies. Nothing in our history has more impressed the Old World than the orderly, quiet absorption of our soldiers into civil life. Miss Ida M. Tarbell, who has done so much valuable historical work, has now prepared the full story of the War Department's achievements in disbanding a million Union soldiers and turning them into peaceful, busy citizens. Within a year this was accomplished, and an element in the situation that Miss Tarbell sets forth with some fullness was the material progress of the North during the very time of war. Another article will tell of the disbanding of the Confederate army.

The material for these papers has been drawn from a very wide variety of original sources (as indeed, it had to be, since no historian has more than scratched this field before) including living people and governmental records.

Political Pen Portraits

By WILLIAM ALLEN WHITE

Mr. White has uncommon gifts for the pen portraiture that has recently won him so much attention and applause. His insight, sympathy, humor and shrewdness have been demonstrated in his pictures of Mr. Bryan and Mr. Hanna ; and his trenchant, vivid style exactly serves his purpose. Other papers on public men are to follow, and they will be illustrated by drawings from life and from photographs.

A forthcoming article will deal with Richard Croker, who has been more prominently brought before the national public in the last six months than ever before. Mr. White treats of the Tammany leader with candor and throws new light on his remarkable career.

RICHARD CROKER
From a photograph specially taken.

Some Men and Methods that are Making for Reform in New York City

By GOVERNOR THEODORE ROOSEVELT

Vice-President elect of the United States.

JACOB A. RIIS

Mr. Roosevelt has written an article for McClure's Magazine, dealing with those forces which are making for civic righteousness, the moral and social elevation of the poor and depraved in New York City, and in particular with a few individuals who have been most prominent in the work. He has some very plain things to say in his characteristic manner. Throughout his career he has himself been one of the foremost leaders of reform, and his official positions have been such as to give him intimate knowledge of the grave problems that confront those who are unselfishly seeking the upbuilding of society. It is because he has this knowledge that he is so competent to speak of what has been done, what remains to be done, and the men and methods who have been and are working to solve the problem. This article is scheduled for an early number.

"The World of Graft"

By JOSIAH FLYNT

About a year ago, through an arrangement made with McClure's Magazine, Mr. Josiah Flynt, well known as the author of "Tramping with Tramps," collaborator with Francis Walton in "The True Stories from the Under World" and generally recognized as the best authority on the subject of criminals, from the standpoint of one who has lived amongst them and studied their ways, undertook an investigation of several months into the status of the criminal classes in the leading cities of the United States. The realm of the criminal is "the world of graft," a phrase largely of his own coining.

The point which Mr. Flynt had chiefly in view was to ascertain as closely as possible the view which the criminal entertains of the ruling powers of society, and his actual relations with them. Incidentally he got the criminal's opinion on the present system of repressing crime, and his theory as to how crime could best be suppressed were it desirable from the criminal standpoint to do so.

During these long months of investigation, Mr. Flynt lived on terms of intimacy with all sorts and conditions of criminals, and it is a remarkable coincidence that the result of his labors was being prepared for publication just at the time the moral reform wave swept over New York City, after the November elections. These articles discuss the situation in several cities in the frankest manner; they deal not only with conditions, but with individuals both in office and those who should be outside the pale of the law, but who are protected by those employed to suppress crime. We feel certain that these articles will arouse an unusual amount of interest, and will prove of extraordinary value to the public. They reveal a situation not flattering to civic pride, but one that cannot be ignored.

Adventures of a Merry Monarch

By ROBERT BARR

Illustration for one of Robert Barr's "Jimmy" Stories.
Drawn by Edmund J. Sullivan.

Mr. Robert Barr can tell many kinds of stories and can place them in many lands, but after all he is not a Scotchman for nothing, and he shines with an accession of brilliancy in recounting mad tales of that adventurous and humorous gentleman, James V of Scotland. "Jimmy" he was in the familiar talk of his humbler subjects, and Jimmy he must always be to the readers of these lively records.

Short Fiction

There is scarcely a writer of fiction who is not a contributor to our pages. For the coming year we shall have some remarkable stories by well-known writers as well as some by unknown writers. It is our pride to have given the first stepping stone to many successful writers of the present day. Some of our writers are :

HAMLIN GARLAND	G. K. TURNER
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Art in the Magazine

Each month will be found in our pages pictures by some of the American artists who have already achieved fame : Howard Pyle, Louis Loeb, Frederic Remington, Albert Herter, Kenyon Cox, F. V. DuMond, Orson Lowell, Howard Chandler Christy, W. R. Leigh, the Misses Cowles, George Varian, W. H. Hyde, Jay Hambidge, A. I. Keller, H. Reuterdahl, Thomas Fogarty, Lucius Hitchcock, Charles R. Knight, Harry Fenn, H. R. Poore, E. L. Blumenschein.

The work of the younger illustrators, many of whom have first made their appearance in McCLURE's—Henry Hutt, Walter Glackens, Charles L. Hinton, Arthur Heming, F. Y. Cory, Ellen Bernard Thompson, Bertha Corson Day, Frederic Gruger, Harrison Fisher, R. M. Reay, Will Grefe, C. D. Williams—will be a feature of the Magazine for the coming year. As in writers, so in artists, we are always on the lookout for the new note.

Illustration drawn by Albert Sterner.

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The Popular Science Monthly is published by Messrs. McClure, Phillips and Co., New York, and edited by Prof. J. McKeen Cattell, of Columbia University, with the assistance of Dr. E. L. Thorndike, also of Columbia University.

The fifty-six volumes of the journal already published have performed an important service for the advancement and diffusion of knowledge. Its issues have each month carried to all parts of the country reliable information in regard to the advances of science, widening and deepening everywhere an intelligent interest in scientific subjects. The journal represented the doctrine of evolution before its tenets were generally accepted; it has done much to diffuse knowledge of physical science and of the applications of science; it has been a factor in the development which has reformed our entire educational system from the kindergarten to the university; its contributors have included many of the world's greatest men of science.

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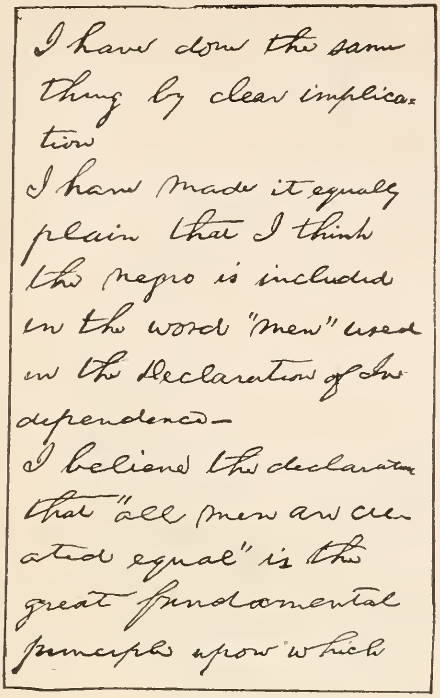

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