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J. MCKEEN CATTELL

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PRESENT PROBLEMS IN RADIOACTIVITY.*

BY PROFESSOR E. RUTHERFORD,

MCGILL UNIVERSITY.

SINCE the initial discovery by Becquerel of the spontaneous emission of new types of radiation from uranium, our knowledge of the phenomena exhibited by uranium and the other radioactive bodies has grown with great and ever increasing rapidity, and a very large mass of experimental facts has now been accumulated. It would be impossible within the limits of this article to review even briefly the more important experimental facts connected with the subject and, in addition, such a review is rendered unnecessary by the recent publication of several treatises† in which the main facts of radioactivity have been dealt with in a fairly complete manner.

In the present article an attempt will be made to discuss the more important problems that have arisen during the development of the subject and to indicate what, in the opinion of the writer, are the subjects which will call for further investigation in the immediate future.

Nature of the Radiations.

The characteristic radiations from the radioactive bodies are very complex, and a large amount of investigation has been necessary to

* Address given to the International Congress of Arts and Science, St. Louis, 1904.

† Mme. Curie, 'Thèse présentée à la Faculté des Sciences,' Paris, 1903. H. Becquerel, 'Recherches sur une propriété nouvelle de la matière,' Typographie de Firmin Didot et Cie,' Paris, 1903. E. Rutherford, 'Radioactivity,' Cambridge University Press, 1904. F. Soddy, 'Radioactivity,' Electrician Co., London, 1904.

isolate the different kinds of rays and to determine their specific characters. The rays from the three most studied radio-elements, uranium, thorium and radium, can be separated into three distinct types, known as the α , β , and γ rays.

The nature of the α and β rays has been deduced from observations of the deflection of the path of the rays by a magnetic and electric field. According to the electromagnetic theory, a radiation which is deflectable by a magnetic or electric field must consist of a flight of charged particles. If the amount of deflection of the rays from their path is measured when both a magnetic and an electric field of known strength are applied, the value of the velocity of the particles and the ratio e/m , of the charge e carried by the particle to its apparent mass m , can be determined. From the direction of the deviation, the sign of the electric charge carried by the particle can be deduced.

Examined in this way, the β rays have been shown to consist of negatively charged particles projected with a velocity approaching that of light. The experiments of Becquerel and Kaufmann have shown that the β rays are identical with the cathode rays produced in a vacuum tube. This relationship has been established by showing that the value of e/m is the same for the two kinds of rays. In both cases the value of e/m has been found to be about 10^7 electromagnetic units, while the corresponding value of e/m for hydrogen atoms set free in the electrolysis of water is 10^4 . If the charge on the β particle—or electron, as it has been termed—is the same as that carried by the hydrogen atom, this result shows that the apparent mass of the electron at slow speeds is about $1/1000$ of that of the hydrogen atom. The β particles from the radio-elements are expelled with a much greater speed than the cathode ray particles in a vacuum tube. The velocities of the β particles from radium are not all the same, but vary between 10^{10} and 3×10^{10} cms. per second. The swifter particles move with a velocity of at least 95 per cent. of that of light. The emission by radium of electrons with high but different velocities has been utilized by Kaufmann to determine the variation of e/m with speed. He found that the value of e/m decreased with increase of velocity, showing that the apparent mass increased with the speed. By comparison of the experimental results with the mathematical theory of a moving charge, he deduced that the mass of the electrons was in all probability electromagnetic in origin, *i. e.*, the apparent mass could be explained purely in terms of electricity in motion without the necessity of a material nucleus on which the charge was distributed. J. J. Thomson, Heaviside and others have shown that a moving charged sphere increases in apparent mass with the speed and that, for speeds small compared with the velocity of light, the increase of mass $m = 2e^2/3a$ where e is the

charge carried by the body and a the radius of the conducting sphere over which the electricity is distributed. Kaufmann deduced that the value of $e/m = 1.86 \times 10^7$ for electrons of slow velocity. If the mass of the electrons is electrical in origin, it is seen that $a = 10^{-13}$ cms., since the value of $e = 3.4 \times 10^{10}$ electrostatic units. The results of various methods of determination agree in fixing the diameter of an atom as about 10^{-8} cms. The apparent diameter of an electron is thus minute compared with that of the atom itself.

The highest velocity of the radium electrons measured by Kaufmann was, as we have seen, 95 per cent. of the velocity of light. The power that electrons have of penetrating solid matter increases rapidly with the velocity, and some of those expelled from radium are able to penetrate through more than 3 mms. of lead. It is probable that a few of the electrons from radium move with a velocity still greater than the highest value observed by Kaufmann, and it is important to determine the value of e/m and the velocity of such electrons. According to the mathematical theory, the mass of the electron increases rapidly as the speed of light is approached and should be infinitely great when the velocity of light is reached. This leads to the conclusion that no charged body can be made to move with a velocity greater than that of light. This result is of great importance and requires further experimental verification. A close study of the high speed electrons from radium may throw further light on this question.

Only a brief statement of our knowledge of electrons has been given in this paper. A more complete and detailed account of both theory and experiment will be given by my colleague, Dr. Langevin, in his address on 'Physics of the Electron.'

The α Rays.

The β rays are readily deflected by a magnetic field, but a very intense magnetic field is required to deflect appreciably the α rays. The writer showed by the electric method that the rays of radium were deflected both by a magnetic and electric field, and deduced the velocity of projection of the particles and the ratio, e/m , of the charge to the mass. The direction of deflection of the α rays is opposite in sense to that of the β rays. Since the β rays carry a negative charge, the α particles thus behave as if they carried a positive charge. The magnetic deflection of these rays was confirmed by Becquerel and Des Coudres, using the photographic method, while the latter, in addition, showed their deflection in an electric field and deduced the value of the velocity and e/m . The values obtained by Rutherford and Des Coudres were in very good agreement, considering the difficulty of obtaining a measurable deviation.

Observer.	Value of Velocity.	Value of e/m .
Rutherford	2.5×10^9 cms. per sec.	6×10^3 electromagnetic units.
Des Coudres	1.6×10^9 cms. per sec.	6×10^3 electromagnetic units.

Now the value e/m for the hydrogen atom is 10^4 . On the assumption that the α particle carries the same charge as the hydrogen atom, this result shows that the apparent mass of the α particle is about twice that of the hydrogen atom. If the α particle consists of any known kind of matter, this result indicates that it is the atom either of hydrogen or of helium. The α particles thus consist of heavy bodies projected with great velocity, whose mass is of the same order of magnitude as the helium atom and at least 2,000 times as great as the apparent mass of the β particle or electron.

If the α particles carry a positive charge, it is to be expected that the particles, falling on a body of sufficient thickness to absorb them, will, under suitable conditions, give it a positive charge, while the substance from which they are projected acquires a negative charge. The corresponding effect has been observed for the β rays. The β particles from radium communicate a negative charge to the body on which they fall, while the radium from which they are emitted acquires a positive charge. This effect has been very strikingly shown by a simple experiment of Strutt. The radium compound, sealed in a small glass tube, the outer surface of which is made conducting, is insulated by a quartz rod. A simple gold leaf electroscope is attached to the bottom of the glass tube, in order to indicate the presence of a charge. The whole apparatus is enclosed in a glass vessel, which is exhausted to a high vacuum, in order to reduce the loss of charge in consequence of the ionization of the gas by the rays. Using a few milligrams of radium bromide, the gold leaf diverges to its full extent in a few minutes and shows a positive charge. The explanation is simple. A large proportion of the negatively charged particles are projected through the glass tube containing the radium and a positive charge is left behind. By allowing the gold leaf, when extended, to touch a conductor connected to earth, the gradual divergence of the leaves and their collapse becomes automatic and will continue, if not indefinitely, at any rate for as long a time as the radium lasts.

When the radium is exposed under similar conditions, but unshielded in order to allow the α particles to escape, no such charging action is observed. This is not due to the equality between the number of positively and negatively charged particles expelled from the radium, for no effect is observed when the radium is temporarily freed from its power of emitting β rays by driving off the emanation by heat. The writer recently attempted to detect the charge carried by the α rays from radium by allowing them to fall on an insulated

plate in a vacuum, but no appreciable charging was observed. The β rays were temporarily got rid of by heating the radium in order to drive off its emanation. There was found to be a strong ionization set up at the surface from which the rays emerged and the surface on which they impinged. The presence of this ionization causes the upper plate to rapidly lose a charge communicated to it. Although this action would mask to some extent the effect to be looked for, a measurable difference should have been obtained under the experimental conditions, if the α rays were expelled with a positive charge; but not the slightest evidence of a charge was observed. I understand that similar negative results have been obtained by other observers.

This apparent absence of charge carried by the α rays is very remarkable and difficult to account for. There is no doubt that the α particles *behave* as if they carried a positive charge, for several observers have shown that the α rays are deflected by a magnetic field. It is interesting to notice, in this connection, that Villard was unable to detect that the 'canal rays' carried a charge. These rays, discovered by Goldstein, are analogous in many respects to the α rays. They are slightly deflected by a magnetic and electric field and behave like positively charged bodies atomic in size. The value of e/m is not a constant, but depends upon the nature of the gas in the tube through which the discharge is passed. The apparent absence of charge on the α particles may possibly be explained on the supposition that a negatively charged particle (an electron) is always projected at the same time as the positively charged particle. Such electrons, if they are present, should be readily bent back to the surface from which they came by the action of a strong magnetic field. It will be of interest to examine whether the charge carried by the α rays can be detected under such conditions.* Another hypothesis, which has some points in its favor, is that the α particles are uncharged at the moment of their expulsion, but, in consequence of their collision with the molecules of matter, lose a negative electron and consequently acquire a positive charge. This point is at present under examination. The question is in a very unsatisfactory state and requires further investigation.

It is remarkable that positive electricity is always associated with matter atomic in size, for no evidence has been obtained of the existence of a positive electron corresponding to the negative electron. This difference between positive and negative electricity is apparently fundamental, and no explanation of it has as yet been forthcoming.

* Recent experiments have confirmed this point of view. By the use of a strong magnetic field, to remove the slow moving electrons, the charge carried by the α rays has been detected both by J. J. Thomson and the writer.

The evidence that the α particles are atomic in size mainly rests on the deflection of the path of the rays in a strong magnetic and electric field. It has, however, been suggested by H. A. Wilson that the α particle may in reality be a 'positive' electron, whose magnitude is minute compared with that of the negative. The electric mass of an electron for slow speeds is equal to $2e^2/3a$. Since there is every reason to believe that the charge carried by the α particle and the electron are the same, in order that the mass of the positive electron should be about 2,000 times that of the negative, it would be necessary to suppose that the radius of the sphere over which the charge is distributed is only 1/2000 of that of the electron, *i. e.*, about 10^{-16} cms. The magnetic and electric deflection would be equally well explained on this view. This hypothesis, while interesting, is too far reaching in its consequences to be accepted before some definite experimental evidence is forthcoming to support it. The evidence at present obtained strongly supports the view that the α particles are in reality projected matter atomic in size. The probability that the α particle is an atom of helium is discussed later.

Becquerel showed that the α rays of polonium were deflected by a magnetic field to about the same extent as the α rays of radium. On account of the feeble activity of thorium and uranium, compared with radium and polonium, it has not been found possible to examine whether the rays emitted by them are deflectable. There is little doubt, however, that the particles of all the radio-elements are projected matter of the same kind (probably helium atoms). The α rays from the different radioactive products differ in their power of penetrating matter in the proportion of about three to one, being greatest for the α rays from the imparted or 'induced' activity of radium and thorium, and least for uranium. This difference is probably mainly due to a variation of the velocity of projection of the α particles in the various cases. The interpretation of results is rendered difficult by our ignorance of the mechanism of absorption of the α rays by matter. Further experiment* on this point is very much required.

It is of importance to settle whether the α particles of radium and polonium have the same ratio e/m . Becquerel states that the amount of curvature of the α rays from polonium in a field of constant strength was the same as for the α rays from radium. This would show that the product of the mass and velocity is the same for the α particles from the two substances. The α rays of polonium, however, certainly have less penetrating power than those of radium, and

* Bragg and Kleeman (*Phil. Mag.*, Dec., 1904) have recently attacked this question and have offered a very satisfactory explanation of the mechanism of the absorption of the α rays by matter.

presumably a smaller velocity of projection. This result would indicate that e/m is different for the α particles of polonium and radium. It is of importance to determine accurately the ratio of e/m and the velocity for the rays penetrating two substances in order to settle this vital point.

The γ Rays.

In addition to the α and β rays, uranium, thorium and radium all emit very penetrating rays, known as γ rays. These rays are about 100 times as penetrating as the β rays and their presence can be detected after passing through several centimeters of lead. Villard, who originally discovered these rays in radium, stated that they were not deflected in a magnetic field, and this result has been confirmed by other observers. Quite recently, Paschen has described some experiments which led him to believe that the γ rays are corpuscular in character, consisting of negatively charged particles (electrons) projected with a velocity very nearly equal to that of light. This conclusion is based on the following evidence: Some pure radium bromide was completely enclosed in a lead envelope 1 cm. thick—a thickness sufficient to completely absorb the ordinary β rays emitted by radium, but which allows about half of the γ rays to escape. The lead envelope was insulated in an exhausted vessel and was found to gain a positive charge. In another experiment, the rays escaping from the lead envelope fell on an insulated metal ring, surrounding it. When the air was exhausted, this outer ring was found to gain a negative charge. These experiments, at first sight, indicate that the γ rays carry with them a negative charge like the β rays. In order to account for the absence of deflection of the path of the γ rays in very strong magnetic or electric fields, it is necessary to suppose that the particles have a very large apparent mass. Paschen supposes that the γ rays are negative electrons like the β rays, but are projected with a velocity so nearly equal to that of light, that their apparent mass is very great.

Some experiments recently made by Mr. Eve, of McGill University, are of great interest in this connection. He found by the electric method that the γ rays set up secondary rays, in all directions, at the surface from which they emerge and also on the surface on which they impinge. These rays are of much less penetrating power than the primary rays and are readily deflected by a magnetic field. The direction of deflection indicated that these secondary rays consist, for the most part, of negatively charged particles (electrons) projected with sufficient velocity to penetrate through about 1 mm. of lead. In the light of these results, the experiments of Paschen receive a simple explanation without the necessity of assuming that the

γ rays of radium themselves carry a negative charge. The lead envelope in his experiment acquired a positive charge in consequence of the emission of a secondary radiation consisting of negatively charged particles, projected with great velocity from the surface of the lead. The electric charge acquired by the metal ring was due to the absorption of these secondary rays by it, and the diminution of this charge in a magnetic field was due to the ease with which these secondary rays are deflected. It is thus to be expected that the envelope surrounding the radium, whether made of lead or other metal, will always acquire a positive charge, provided the metal is not of sufficient thickness to absorb all the γ rays in their passage through it.

No conclusive evidence has yet been brought forward to show that the γ rays can be deflected either in a magnetic or an electric field. In this, as in other respects, the rays are very analogous to the Röntgen rays.

According to the theory of Stokes, J. J. Thomson and Weichert, Röntgen rays are transverse pulses set up in the ether by the sudden arrest of the motion of the cathode particles on striking an obstacle. The more sudden the stoppage the shorter is the pulse, and the rays, in consequence, have greater power of penetrating matter. In some recent experiments Barkla found that the secondary rays set up by the Röntgen rays, on striking an obstacle, vary in intensity with the orientation of the vacuum tube, showing that the Röntgen rays exhibit the property of one-sidedness or polarization. This is the only evidence so far obtained in direct support of the wave nature of the Röntgen rays.

If Röntgen rays are not set up when the cathode particles are stopped, conversely, it is to be expected that Röntgen rays will be set up when they are suddenly expelled. Now this effect is not observable in an X-ray tube, since the cathode particles acquire most of their velocity, not at the cathode itself, but in passing through the electric field between the cathode and anticathode. It is, however, to be expected theoretically that a type of Röntgen rays should be set up at the sudden expulsion of the β particles from the radio atoms. The rays, too, should be of a very penetrating kind, since not only are the charged particles projected with a speed approaching that of light, but the change of motion must occur in a distance comparable with the diameter of an atom.

On this view the γ rays are a very penetrating type of Röntgen rays, having their origin at the moment of the expulsion of the β particle from the atom. If the β particle is the parent of the γ rays the intensity of the β and γ rays should, under all conditions, be proportional to one another. I have found this to be the case, for the γ rays always accompany the β rays and, in whatever way the β ray

activity varies, the activity measured by the γ rays always varies in the same proportion. Active matter which does not emit β rays does not give rise to γ rays. For example, the radio tellurium of Märcwald, which does not emit β rays, does not give off γ rays.

Certain differences are observed, however, in the ionizing action of γ and X rays. For example, gases and vapors like chlorine, sulphuretted hydrogen, methyl-iodide and chloroform, when exposed to ordinary X rays, show a much greater ionization, compared with air, than is to be expected according to the density law. On the other hand, the relative ionization of these substances by γ rays follows the density law very closely. It seemed likely that this apparent difference between the two types of rays was due mainly to the greater penetrating power of the γ rays. This was confirmed by some recent experiments of Eve, who found that the relative conductivity of gases exposed to very penetrating Röntgen rays from a hard tube approximated in most cases closely to that observed for the γ rays. The vapor of methyl-iodide was an exception, but the difference in this case would probably disappear if X rays could be generated of the same penetrating power as that of the γ rays.

Thus the results so far obtained generally support the view that the γ rays are a type of penetrating X rays. This view is in agreement too with theory, for it is to be expected that very penetrating γ rays will always appear with the β rays.

No evidence of the emission of a type of Röntgen rays is observed from active bodies which emit only α rays. If the α particles are initially projected with a positive charge, such rays are to be expected. Their absence supplies another piece of evidence in support of the view that the α particle is projected without a charge but acquires a positive charge in its passage through matter.*

Emission of Energy by the Radioactive Bodies.

It was early recognized that a very active substance like radium emitted energy at a rapid rate, but the amount of this energy was strikingly shown by the direct measurements of its heating effect made by Curie and Laborde. They found that one gram of radium in radioactive equilibrium emitted about 100 gram calories of heat per hour. A gram of radium would thus emit 876,000 gram calories per year, or over 200 times as much heat as is liberated by the explosion of hydrogen and oxygen to form one gram of water. They showed that the rate of heat emission was the same in solution as in the solid state, and remained constant when once the radium had reached a stage of radioactive equilibrium. Curie and Dewar showed that the

* Recent experiments indicate, however, that the α particles are charged at the moment of this expulsion.

rate of evolution of heat from radium was unaltered by plunging the radium into liquid air or liquid hydrogen.

It seemed probable that the evolution of heat by radium was directly connected with its radioactivity and the experiments of Rutherford and Barnes proved this to be the case. The heating effect of a quantity of radium bromide was first determined. The emanation was then completely driven off by heating the radium, and condensed in a small glass tube by means of liquid air. After removal of the emanation, the heat evolution of the radium in the course of about three hours fell to a minimum corresponding to one quarter of its original value, and then slowly increased again, reaching its original value after an interval of about one month. The heat emission from the emanation tube at first increased with the time, rising to a maximum value about three hours after its introduction. It then slowly decreased according to an exponential law with the time, falling to half value in about four days.

The curve expressing the recovery from its minimum of the heating effect of radium is complementary to the curve expressing the diminution of the heating effect of the emanation tube with time. The curves of decay and recovery agree within the limit of experimental error with the corresponding curves of decay and recovery of the activity of radium when measured by the α rays. Since the minimum activity of radium, measured by the α rays, after the emanation has been removed is only one quarter of the maximum activity, these results indicate that the heating effect of radium is proportional to its activity measured by the α rays. It is not proportional to the activity measured by the β or γ rays, since the β or γ ray activity of radium almost completely disappears some hours after removal of the emanation.

These results have been confirmed by further observations of the distribution of the heat emission between the emanation and the successive products which arise from it. If the emanation is left for several hours in a closed tube, its activity measured by the electric method increases to about twice its initial value. This is due to the 'excited activity' or in other words to the radiations from the active matter deposited on the walls of the tube by the emanation. The activity of this deposit has been very carefully analyzed, and the results show that the matter deposited by the emanation breaks up in three successive and well marked stages. For convenience, these successive products of the emanation will be termed radium A, radium B and radium C. The time T taken for each of these products to be half transformed and the radiations from each product are shown in the following table:

Product.	T	Radiations.
Radium,		α rays.
Emanation,	4 days,	α rays.
Radium A,	3 mins.,	α rays.
Radium B,	21 mins.,	no rays.
Radium C,	28 mins.,	α , β and γ rays.

When the emanation has been left in a closed vessel for several hours, the emanation and its successive products reach a stage of approximate radioactive equilibrium, and the heating effect is then a maximum. If the emanation is suddenly removed from the tube by a current of air, the heating effect is then due to radium A, B and C together. On account, however, of the rapidity of the change of radium A (half value in three minutes) it is experimentally very difficult to distinguish between the heating effect of the emanation and that of radium A. The curve of variation with time of the heating effect of the tube after removal of the emanation is very nearly the same as the corresponding curve for the activity measured by the α rays. These results show that each of the products of radium supplies an amount of heat roughly proportional to its α ray activity. Each product loses its heating effect at the same rate as it loses its activity, showing that the mission of heat is directly connected with the radioactive changes. The results indicated that the product, radium B, which does not emit rays, does not supply an amount of heat comparable with the other products. This point is important and requires more direct verification.

Since the heat emission is in all cases nearly proportional to the number of α particles expelled, the question arises whether the bombardment of these particles is sufficient to account for the heating effects observed. The kinetic energy of the α particle can be at once determined, since e/m and v are known.

The following table shows the kinetic energy of the α particle deduced from the measurements of Rutherford and Des Coudres. The third column shows the number of α particles expelled from 1 gram of radium per second on the assumption that the heating effect of radium (100 gram calories per gram per hour) is entirely due to the energy given out by the expelled α particles.

Observer.	Kinetic.	Number of Particles expelled per Second from 1 Gram of Radium.
Rutherford	5.9×10^{-6} ergs	2×10^{11}
Des Coudres	2.5×10^{-6} ergs	5×10^{11}

This hypothesis that the heating effect of radium is due to bombardment of the α particle can be indirectly put to the test in the following way. It seems probable that each atom of radium in breaking up emits one α particle. On the disintegration theory, the residue

of the atom, after the α particle is expelled, is the atom of the emanation, so that each atom of radium gives rise to one atom of the emanation. Let q be the number of atoms in each gram of radium breaking up per second. When a state of radioactive equilibrium is reached the number N of emanation particles present is given by $N = q/\lambda$ where λ is the constant of change of the emanation. Now Ramsay and Soddy deduced from experiment that the volume of the emanation released from 1 gram of radium was about one cubic millimeter at atmospheric pressure and temperature. It has been experimentally deduced that there are 3.6×10^{19} molecules in one cubic centimeter of gas at ordinary pressure and temperature. The emanation obeys Boyle's law and behaves, in all respects, like a heavy gas, and we may in consequence deduce, since $N = 3.6 \times 10^{19}$ and $\lambda = 2.0 \times 10^{-6}$, the value $q = 7.2 \times 10^{10}$. Now the particles expelled from radium in a state of radioactive equilibrium are about equally divided between four substances, viz., the radium itself, the emanation, radium A and radium C. We may thus conclude that the number of α particles expelled per second from 1 gram of radium in radioactive equilibrium is 2.9×10^{11} . The value deduced by this method is intermediate between the values previously obtained (see previous table), on the assumption that the heating effect is entirely due to the α particles.

I think we may conclude from the agreement of these two methods of calculation that the greater portion of the heating effect of radium is a direct result of the bombardment of the expelled α particles, and that, in all probability, about 5×10^{10} atoms of radium break up per second.*

The energy carried off in the form of β and γ rays is small compared with that emitted in the form of α rays. By calculation it can be shown that the average kinetic energy of the β particle is small in comparison with that of the α particle. This is confirmed by comparative measurements of the total ionization produced by the α and β rays, when the energy of the rays is all used up in ionizing the gas, for the total ionization produced by the β rays is small compared with that due to the γ rays. The total ionization produced by the γ rays is about the same as that produced by the β rays, showing that, in all probability, the energy emitted in the form of these two types of radiation is about the same. From the point of view of the energy radiated and of the changes which occur in the radioactive bodies, the α rays thus play a far more important rôle in radioactivity than the β or γ rays. Most of the products which arise from radium and thorium emit only α rays, while the β and γ rays appear only in the last of the series of rapid changes which take place in these bodies.

* By measuring the charge carried by the α rays, the writer (*Nature*, March 2, 1905) has recently deduced that 6.4×10^{10} atoms of radium break up per second.

Since most of the heating effect of radium is due to the α rays, it is to be expected that all radioactive substances which emit them will also emit heat at a rate proportional to their α ray activity. On this view, both uranium and thorium should emit heat at about one millionth the rate of radium. It is of importance to determine directly the heating effect for these substances and also for actinium and radio-tellurium.

According to the disintegration theory, the α particle is expelled as a result of the disintegration of the atom of radioactive matter. While it is to be expected that a greater portion of the energy emitted will be carried off in the form of kinetic energy by the expelled particles, it is also to be expected that some energy will be radiated in consequence of the rearrangement of the components of the system after the violent ejection of one of its parts. No direct measurements have yet been made of the heating effect of the α particles independently of the substance in which they are produced. Experiments of this character would be difficult, but they would throw light on the important question of the division of the radiated energy between the expelled α ray particle and the system from which it arises.

The enormous emission of energy by the radioactive substances is very well illustrated by the case of the radium emanation. The emanation released from 1 gram of radium in radioactive equilibrium emits during its changes an amount of energy corresponding to about 10,000 gram calories. Now Ramsay and Soddy have shown that the volume of this emanation is about 1 cubic millimeter at standard pressure and temperature. One cubic millimeter of the emanation and its product thus emits about 10^7 gram calories. Since 1 c.c. of hydrogen, in uniting with the proportion of oxygen required to form water, emits 3.1 gram calories, it is seen that the emanation emits about three million times as much energy as an equal volume of hydrogen.

It can readily be calculated on the assumption that the atom of the emanation has a mass 100 times that of hydrogen, that 1 pound of the emanation some time after removal could emit energy at the rate of about 8,000 horse-power. This would fall off in a geometrical progression with the time, but, on an average, the amount of energy emitted during its life corresponds to 50,000 horse-power days. Since the radium is being continuously transformed into emanation, and three-quarters of the total heat emission is due to the emanation and its products, a simple calculation shows that 1 gram of radium must emit during its life about 10^9 gram calories. As we have seen, the heat emission of radium is about equally divided between the radium itself and the three other α ray products which come from it. The heat emitted from each of the other radioactive substances, while their

activity lasts, should be of the same order of magnitude, but in the case of uranium and thorium the present rate of heat emission will probably continue, on an average, for a period of about 1000 million years.

Source of the Energy emitted by the Radioactive Bodies.

There has been considerable difference of opinion in regard to the fundamental question of the origin of the energy spontaneously emitted from the radioactive bodies. Some have considered that the atoms of the radio-elements act as transformers of borrowed energy. The atoms are supposed, in some way, to abstract energy from the surrounding medium and to emit it again in the form of the characteristic radiations. Another theory which has found favor with a number of physicists supposes that the energy is derived from the radio-atoms themselves and is released in consequence of their disintegration. The latter theory involves the conception that the atoms of the radio-elements contain a great store of latent energy, which only manifests itself when the atom breaks up. There is no direct evidence in support of the view that the energy of the radio-elements is derived from external sources, while there is much indirect evidence against it. Some of this evidence will now be considered. There is now no doubt that the α and β rays consist of particles projected with great speed. In order that the α particle may acquire the velocity with which it is expelled, it can be calculated that it would be necessary for it to move freely between two points differing in potential by about five million volts. It is very difficult to imagine any mechanism, which could suddenly impress such an enormous velocity on one of the parts of an atom. It seems much more reasonable to suppose that the α and β particles were originally in rapid motion in the atom and, for some reason, escaped from the atomic system with the velocity they possessed at the instant of their release. There is now undeniable evidence that radioactivity is always accompanied by the production of new kinds of active matter. Some sort of chemical theory is thus required to explain the facts whether the view is taken that the energy is derived from the atom itself or from external sources. The 'external' theory of the origin of the energy was initially advanced to explain only the heat emission of radium. We have seen that this is undoubtedly connected with the expulsion of α particles from the different disintegration products of radium, and that the radium itself only supplies one quarter of the total heat emission, the rest being derived from the emanation and its further products. On such a theory it is necessary to suppose that in radium there are a number of different active substances, whose power of absorbing external energy dies away with the time, at different but definite rates. This still leaves the fundamental difficulty of the origin of these radioactive

products unexplained. Unless there is some unknown source of energy in the medium which the radioactive bodies are capable of absorbing, it is difficult to imagine whence the energy demanded by the external theory can be derived. It certainly can not be from the air itself, for radium gives out heat inside an ice calorimeter. It can not be any type of rays such as the radioactive bodies emit, for the radioactivity of radium, and consequently its heating effect is unaltered by hermetically sealing it in a vessel of lead several inches thick. The evidence, as a whole, is strongly against the theory that the energy is borrowed from external sources and, unless a number of improbable assumptions are made, such a theory is quite inadequate to explain the experimental facts. On the other hand, the disintegration theory, advanced by Rutherford and Soddy, not only offers a satisfactory explanation of the origin of the energy emitted by the radio-elements, but also accounts for the succession of radioactive bodies. On this theory, a definite, small proportion of the atoms of radioactive matter every second become unstable and break up with explosive violence. In most cases, the explosion is accompanied by the expulsion of an α particle; in a few cases by only a β particle, and in others by α and β particles together. On this view, there is at any time present in a radioactive body a proportion of the original matter which is unchanged and the products of the part which has undergone change. In the case of a slowly changing substance like radium, this point of view is in agreement with the observed fact that the spectrum of radium remains unchanged with its age.

The expulsion of an α or β particle, or both, from the atom leaves behind an atom which is lighter than before and which has different chemical and physical properties. This atom in turn becomes unstable and breaks up, and the process, once started, proceeds from stage to stage with a definite and measurable velocity in each case.

The energy radiated is, on this view, derived at the expense of the internal energy of the radio-atoms themselves. It does not contradict the principle of the conservation of energy, for the internal energy of the products of the changes, when the process of change has come to an end, is supposed to be diminished by the amount of energy emitted during the changes. This theory supposes that there is a great store of internal energy in the radio-atoms themselves. This is not in disagreement with the modern views of the electronic constitution of matter, which have been so ably developed by J. J. Thomson, Larmor and Lorentz. A simple calculation shows that the mere concentration of the electric charges, which on the electronic theory are supposed to be contained in an atom, implies a store of energy in the atom so enormous that, in comparison, the large evolution of energy from the radio-element is quite insignificant.

Since the energy emitted from the radio-elements is for the most part kinetic in form, it is necessary to suppose that the α and β particles were originally in rapid motion in the atoms from which they are projected. The disintegration theory supposes that it is the atoms and not the molecules which break up. Such a view is necessary to explain the independence of the rate of disintegration of radioactive matter, of wide variations of temperature, and of the action of chemical and physical agents at our command. This must be conceded if the term atom is used in the ordinary chemical sense. It is, however, probable that the atoms of the radio-elements are in reality complex aggregates of known or unknown kinds of matter, which break up spontaneously. This aggregate behaves like an atom and can not be resolved into simpler forms by external chemical or physical agencies. It breaks up, however, spontaneously with an evolution of energy enormous compared with that released in ordinary chemical changes. This question will be considered later.

The disintegration theory assumes that a small fraction of the atoms break up in unit time, but no definite explanation is, as yet, forthcoming of the causes which lead to this explosive disruption of the atom. The experimental results are equally in agreement with the view that each atom contains within itself the potentiality of its final disruption, or with the view that the disintegration is precipitated by the action of some external cause, that may lead to the disintegration of the atom, in the same way that a detonator is necessary to start certain explosions. The energy set free is, however, not derived from the detonator, but from the substance on which it acts. There is another general view which may possibly lead to an explanation of atomic disruption. If the atom is supposed to consist of electrons or charged bodies in rapid motion, it tends to radiate energy in the form of electromagnetic waves. If an atom is to be permanently stable, the parts of the atom must be so arranged that there is no loss of energy by electromagnetic radiation. J. J. Thomson has investigated certain possible arrangements of electrons in an atom which radiate energy extremely slowly, but which ultimately must break up in consequence of the loss of internal energy. According to present views, it is not such a matter of surprise that atoms do break up as that atoms are so stable as they appear to be. This question of the causes of disintegration is fundamental and no adequate explanation has yet been put forward.

Radioactive Products.

Rutherford and Soddy showed that the radioactivity was always accompanied by the appearance of new types of active matter which possessed physical and chemical properties distinct from the parent

radio-element. The radioactivity of these products is not permanent, but decays according to an exponential law with the time. The activity I_t at any time t is given by $I_t = I_0 e^{-\lambda t}$, where I_0 is the initial activity and λ a constant. Each radioactive product has a definite change constant which distinguishes it from all other products. These products do not arise simultaneously, but in consequence of a succession of changes in the radio-elements; for example, thorium in breaking up gives rise to Th X, which behaves as a solid substance soluble in ammonia. This in turn breaks up and gives rise to a gaseous product, the thorium emanation. The emanation is again unstable and gives rise to another type of matter which behaves as a solid and is deposited on the surface of the vessel containing the emanation. It was found that the results would be quantitatively explained on the assumption that the activity of any product at any time is the measure of the rate of production of the next product. This is to be expected since the activity of any substance is proportional to the number of atoms which break up per second, and, since each atom in breaking up gives rise to one atom of the next product together with α or β particles, or both, the activity of the parent is a measure of the rate of production of the succeeding product.

Of these radioactive products, the radium emanation has been very closely studied on account of its existence in the gaseous state. It has been shown to be produced by radium at a constant rate. The amount of emanation stored up in a given mass of radium reaches a maximum value when the rate of supply of fresh emanation balances the rate of change of the emanation present.

If q be the number of atoms of emanation produced per second by the radium, and N the maximum number present when radioactive equilibrium is reached, then $N = q/\lambda$, where λ is the constant of change of the emanation. This relation has been verified experimentally. The emanation is found to diffuse through air like gas of heavy molecular weight. It is unattacked by chemical reagents and in that respect resembles the inert gases of the argon family. It condenses at a definite temperature -150° C. Its constant of change is unaffected between the limits of temperature of 450° C and -180° C. Since the emanation changes into a non-volatile type of matter which is deposited on the surface of vessels, it was to be expected that the volume of the emanation would decrease according to the same law as it lost its activity. These deductions based on the theory have been confirmed in a striking manner by the experiments of Ramsay and Soddy. The radium emanation was chemically isolated and found to be a gas which obeys Boyle's law. The volume of the emanation observed was of the same order as had been predicted before its separation. The volume was found to decrease with the time according to

the same law as the emanation lost its activity. Ramsay and Collie found that the emanation had a new and definite spectrum similar in some respects to that of the argon group of gases.

There can thus be no doubt that the emanation is a transition substance with remarkable properties. Chemically it behaves like an inert gas and has a definite spectrum and is condensed by cold. But, on the other hand, the gas is not permanent, but disappears, and is changed into other types of matter. It emits during its changes about one million times as much energy as is emitted during any known chemical change.

From the similarity of the behavior of the emanation of thorium and actinium to that of radium, we may safely conclude that these also are new gases which have only a limited life and change into other substances.

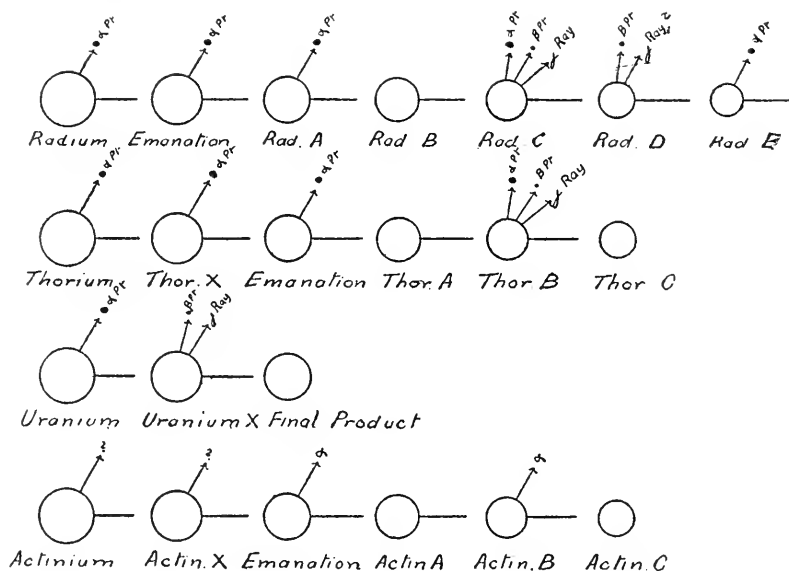


FIG. 1.

The non-volatile products of the radioactive bodies can be dissolved in strong acids and show definite chemical behavior in solution. They can be partially separated by electrolysis and by suitable chemical methods. They can be volatilized by the action of high temperature and their differences in this respect can be utilized to effect in many cases a partial separation of successive products. There can be little doubt that each of these radioactive products is a transition substance possessing, while it lasts, some definite chemical and physical properties which serve to distinguish it from other products and from the parent element.

The radioactive products derived from each radio-element together with the type of radiation emitted during their disintegration, are shown graphically in Fig. 1.

The radiations from actinium have not been so far examined sufficiently closely to determine the character of the radiation emitted by each product. There is some evidence that a product, actinium X, exists in actinium corresponding to Th X in thorium.* It has not, however, been very closely examined.

The question of nomenclature for the successive products is important. The names Ur X, Th X have been retained and also the term emanation. The emanation from the three radio-elements in each case gives rise to a non-volatile type of matter which is deposited on the surface of the bodies. The matter initially deposited from the radium emanation is called radium A. Radium A changes into B and B into C, and so on. A similar nomenclature is applied to the further products of the emanation of thorium and actinium. This notation is simple and elastic and is very useful in mathematical discussion of the theory of successive changes. In the following table a list of the products is given, together with the nature of the radiation and the most marked chemical and physical properties of each product. The time T for each of the products to be half transformed is also added.

The changes which occur in the active deposits from the emanation of radium, thorium and actinium have been difficult to determine on account of their complexity. For example, in the case of radium, the active deposit obtained as a result of a long exposure to the emanation contains quantities of radium A, B and C. The changes occurring in the active deposit of radium have been determined by P. Curie, Danne and the writer. The value of T for the three successive changes is 3, 21 and 28 minutes, respectively. Radium A gives only α rays, B gives out no rays at all, while C gives out α , β and γ rays. These results have been deduced by the comparison of the change of activity with time, with the mathematical theory of successive changes. The variation of the activity with time depends upon whether the activity is measured by the α , β or γ rays. The complicated curves are very completely explained on the hypothesis of three successive changes of the character already mentioned.

The activity of a vessel in which the radium emanation has been stored for some time rapidly falls to a very small fraction after the emanation is withdrawn. However, there always remains a slight residual activity. The writer has recently examined the activity in

* Godlewski (*Nature*, Jan. 19. 1905) has recently separated actinium X. It is similar in chemical properties to thorium X and loses half of its activity in about 10 days.

Radioactive Products.	<i>T.</i>	Rays.	Some Chemical and Physical Properties.
URANIUM. ↓ Uranium X. ↓ Final product.	5 x 10 ⁸ years. 22 days.	α β, γ	Soluble in excess of ammonium carbonate. Insoluble in excess of ammonium carbonate.
THORIUM. ↓ Thorium X. ↓ Emanation. ↓ Thorium A. ↓ Thorium B. ↓ Final product.	10 ⁹ years. 4 days. 1 minute. 11 hours. 55 minutes.	α α α no rays. α, β, γ	Insoluble in ammonia. Soluble in ammonia. Inert gas condenses about -120° C. Attaches itself to negative electrode, soluble in strong acids. Separable from A by electrolysis.
ACTINIUM. ↓ Actinium X? ↓ Emanation. ↓ Actinium A. ↓ Actinium B. ↓ Final product.	3.9 seconds. 41 minutes. 1.5 minutes.	α no rays. α	Gaseous product. Attaches itself to negative electrode, soluble in strong acids. Separable from A by electrolysis.
RADIUM. ↓ Emanation. ↓ Radium A. ↓ Radium B. ↓ Radium C. ↓ Radium D. ↓ Radium E. ↓	1,000 years. 4 days. 3 minutes. 21 minutes. 28 minutes. About 40 years. about 1 year.	α α α no rays. α, β, γ β, γ α	Inert gas, condenses -150° C. Attaches itself to negative electrode, soluble in strong acids. Volatile at 500° C. Volatile at about $1,100^{\circ}$ C. Soluble in sulphuric acid. Attaches itself to bismuth plate in solution, volatilizes at $1,000^{\circ}$ C.

detail. The residual activity at first mainly consists of β rays, and the activity measured by them does not change appreciably during the period of one year. The α ray activity is at first small, but increases uniformly with the time for the first few months that the activity has been examined. These results receive an explanation on the hypothesis that radium C changes into a product D which emits only β rays. D changes into a product E which emits only α rays. This view has been confirmed by separating the α ray product by dipping bismuth-plate into the solution containing radium D and E. The probable period of these changes can be deduced from observations of

the magnitude of the α and β ray activity at any time. It has been deduced that radium D is probably half transformed in 40 years and radium E is half transformed in about 1 year. The evidence at present obtained points to the conclusion that radium E is the active constituent present in Marekwald's radio-tellurium and probably also in the polonium of Mme. Curie.*

The changes in the active deposit of thorium have been analyzed by the writer, and the corresponding changes in actinium by Miss Brooks.

The occurrence of a 'rayless change' in the active deposits from the emanation of radium, thorium and actinium is of great interest and importance. As these products do not emit either α , β or γ rays, their presence can only be detected by their effect on the amount of the succeeding products. The action of the rayless change is most clearly brought out in the examination of the variation of activity with time of a body exposed for a very short interval in the presence of the emanations of thorium and actinium. Let us consider, for simplicity, the variation of activity with time for thorium. The activity (measured by the α rays) observed at first is very small, but gradually increases with the time, passes through a maximum and finally decays according to an exponential law with the time falling to half value in eleven hours. The shape of this curve can be completely explained on the assumption of the two successive changes, the second of which alone gives out rays. The matter deposited on the body during the short exposure consists almost entirely of thorium A. Thorium A changes into B and the breaking up of B gives rise to the activity measured.

If thorium A does not give out rays, the activity of the body at any time t after removal can be easily shown to be proportional to $e^{-\lambda_2 t} - e^{-\lambda_1 t}$, where λ_1, λ_2 are the constants of change of thorium A and B, respectively. Now the experimental curves of variation of activity are found to be accurately expressed by an equation of this form. A very interesting point arises in settling the values of λ_1, λ_2 corresponding to the two changes. It is seen that the equation is symmetrical in λ_1 and λ_2 and in consequence is unaltered if the values of λ_1 and λ_2 are interchanged. Now the constant of the change is determined by the observation that the activity finally decays to half value in 11 hours. The theoretical and experimental curves are found to coincide if one of the two products is half transformed in 11 hours and the other in 55 minutes. The comparison of the theoretical and experimental curves does not, however, allow us to settle whether

* The writer has recently found that radium E and radio-tellurium have identical rates of decay. Both lose half of their activity in 150 days. This result shows that the active substance in radio-tellurium is a transformation product of radium.

the period of change of thorium A is 55 minutes or 11 hours. In order to settle the point, it is necessary to find some means of separating the products thorium A and B from each other. In the case of thorium, this is done by electrolyzing a solution of thorium. Pegram obtained an active product which decayed according to an exponential law with the time falling to half value in a little less than one hour. This result shows that the radiating product thorium B has the shorter period. In a similar way, by recourse to electrolysis, it has been found that the change actinium B has a period of 1.5 minutes. In the case of radium, P. Curie and Danne utilized the difference in volatility of radium B and C in order to fix the period of the changes.

It is very remarkable that the third successive product of radium, thorium and actinium should not give out rays. It seems probable that these rayless changes are not of so violent a character as the other changes, and consist either of a rearrangement of the components of the atom or of an expulsion of an α or β particle with so slow a velocity that it fails to ionize the gas. The appearance of such changes in radioactive matter suggests the possibility that ordinary matter may also be undergoing slow 'rayless changes,' for such changes can not be detected in the radio-elements unless the succeeding products emit rays.

It is seen that the changes occurring in radium, thorium and actinium are of a very analogous character and indicate that each of these bodies has a very similar atomic constitution.

While there can be no doubt that numerous kinds of radioactive matter with distinct chemical and physical properties are produced in the radio-elements, it is very difficult to obtain direct evidence in some cases that the products are successive and not simultaneous. This is the case for products which have either a very slow or very rapid rate of change compared with the other product. For example, it is difficult to show directly that radium B is the product of radium A and not the direct product of the emanation. In the same way, there is no direct evidence that radium C is the parent of radium D. At the same time, the successive nature of these products is indicated by indirect evidence.

There can be little doubt that each of the radioactive products is a distinct chemical substance and possesses some distinguishing physical or chemical properties. There still remains a large amount of chemical work to be done in comparing and arranging the chemical properties of these products and in determining whether the successive products follow any definite law of variation. The electrolytic method can in many cases be used to find the position of the product in the electrochemical series. The products which change most rapidly are

present in the least quantity in radium and pitchblende. Only the slower changing products like the radium emanation and radium D and E exist in sufficient quantities to be examined by the balance. It is possible that the products radium A, B and C may be obtained in sufficient quantity to obtain their spectrum.

Connection between the α Particles and Helium.

The discovery of Ramsay and Soddy that helium was produced by the radium emanation was one of the greatest interest and importance, and confirmed in a striking manner the disintegration theory of radioactivity, for the possible production of helium from radioactive matter had been predicted on this theory before the experimental evidence was forthcoming. Ramsay and Soddy found that the presence of helium could not be detected in a tube immediately after the introduction of the emanation, but was observed some time afterwards, showing that the helium arose in consequence of a slow change in the emanation itself or in its further products.

The question of the origin of the helium produced by the radium emanation and its connection with the radioactive changes occurring in the emanation is one of the greatest importance. The experimental evidence so far obtained does not suffice to give a definite answer to this question, but suggests the probable explanation. There has been a tendency to assume that helium is the final disintegration product of the radium emanation, *i. e.*, it is the inactive substance which remains when the succession of radioactive changes in the emanation has come to an end. There is no evidence in support of such a conclusion, while there is much indirect evidence against it. It has been shown that the emanation which breaks up undergoes three fairly rapid transformations; but after these changes have occurred, the residual matter—radium D—is still radioactive and breaks up slowly, being half transformed in probably about 40 years. There then occurs a still further change. Taking into account the minute quantity of the radium emanation initially present in the emanation tube, the amount of the final inactive product would be insignificant after the lapse of a few days or even months. Thus it does not seem probable that the helium can be the final product of the radioactive changes. In addition, it has been shown that the α particle behaves like a body of about the same mass as the helium atom. The expulsion of a few α particles from each of the heavy atoms of radium would not diminish the atomic weight of the residue very greatly. The atomic weight of the atoms of radium D and E is in all probability of the order of 200, since the evidence supports the conclusion that each atom expels one α particle at each transformation.

In order to explain the presence of helium, it is necessary to look

to the other inactive products produced during the radioactive changes. The α particles expelled from the radioactive product are themselves non-radioactive. The measurement of the ratio e/m shows that they have an apparent mass intermediate between that of the hydrogen and helium atoms. If the α particles consist of any known kind of matter they must be atoms either of hydrogen or of helium. The actual value of e/m has not yet been determined with an accuracy sufficient to give a definite answer to the question. On account of the very slight curvature of the path of the α particles in a strong magnetic or electric field, accurate determination of e/m is beset with great difficulties. The experimental problem is still further complicated by the fact that the α particles escaping from a mass of radium have not all the same velocity and in consequence it is difficult to draw a definite conclusion from the observed deviation of the complex pencil of rays.

The results so far obtained are not inconsistent with the view that the α particles are helium atoms, and indeed it is difficult to escape from such a conclusion. On such a view, the helium, which is gradually produced in the emanation tube, is due to the collection of α particles expelled during the disintegration of the emanation and its further products. This conclusion is supported by evidence of another character. It is known that thorium minerals like monazite sand contain a large quantity of helium. In this respect they do not differ from uranium minerals which are rich in radium. The only common product of the different radioactive substances is the α particle and the occurrence of helium in all radioactive minerals is most simply explained on the supposition that the α particle is a projected helium atom. This conclusion could be indirectly tested by examining whether helium is produced in other substances besides radium, for example, in actinium and polonium.

The experimental determination of the origin of helium is beset with great difficulty on all sides. If the α particle is a helium atom, the total volume of helium produced in an emanation tube should be three times the initial volume of the emanation present, since the emanation in its rapid changes gives rise to three products each of which emits α particles. This is based on the assumption, which seems to be fulfilled by the experiments, that each atom of each product in breaking up expels one α particle. This at first sight offers a simple experimental means of settling the question, but a difficulty arises in accurately determining the volume of helium produced by a known quantity of the radium emanation. It would be expected that, if the emanation were isolated in a tube and left to stand, the volume of gas in the tube should increase with time in consequence of the liberation of helium. In one case, however, Ramsay and Soddy

observed an exactly opposite result. The volume diminished with time to a small fraction of its original value. This diminution of volume was due to the decomposition of the emanation into a non-gaseous type of matter deposited on the walls of the tube, and followed the law of decrease to be expected in such a case, namely, the volume decreased according to an exponential law with the time falling to half value in four days. The helium produced by the emanation must have been absorbed by the walls of the tube. Such a result is to be expected if the particle is a helium atom, for the α particle is projected with a velocity sufficient to bury itself in the glass to a depth of about 1/100 mm. This buried helium would probably be in part released by the heating of the tube, such as occurs with the strong electric discharge employed in the spectroscopic detection of helium. Ramsay and Soddy have examined the glass tubes in which the emanation had been confined for some time to see if the buried helium was released by heat. In some cases traces of helium were observed.

Accurate measurements of the value of e/m for the α particle and also an accurate determination of the relative volume of the emanation and the helium produced by it would probably definitely settle this fundamental question.

Certain very important consequences follow on the assumption that the α particle is, in all cases, an atom of helium. It has already been shown that the radio-elements are transformed into a succession of new substances, most of which in breaking up emit an α particle. On such a view, the atom of radium, thorium, uranium and actinium must be supposed to be built up in part of helium atoms. In radium, at least five products of the change emit particles, so that the radium atom must contain at least five atoms of helium. In a similar way, the atoms of actinium and thorium (or, if thorium itself be not radioactive, the atom of the active substance present in it) must be compounds of helium. These compounds of helium are not stable, but spontaneously break up into a succession of substances, with an evolution of helium, the disintegration taking place at a definite but different rate at each stage. Such compounds are sharply distinguished in their behavior from the molecular compounds known to chemistry. In the first place, the radioactive compounds disintegrate spontaneously and at a rate that is independent of the physical or chemical forces at our control. Changes of temperature, which exert such a marked influence in altering the rate of molecular reactions, are here almost entirely without influence. But the most striking feature of the disintegration is the expulsion, in most cases, of a product of the change with very great velocity—a result never observed in ordinary chemical reactions. This entails an enormous liberation of energy during the change, the amount, in most cases, being about one million times as great as that observed in any known chemical reac-

tion. In order to account for the expulsion of an α and a β particle with the observed velocities, it is necessary to suppose that the particles are in a state of rapid motion in the system from which they escape. Variation of temperature, in most cases, does not seem to affect the stability of the system.

It is well established that the property of radioactivity is inherent in the radio-atoms, since the activity of any radioactive compound depends only on the amount of the element present and is not affected by chemical treatment. As far as observation has gone, both uranium and radium behave as elements in the usually accepted chemical sense. They spontaneously break up but the rate of their disintegration seems to be, in most cases, quite independent of chemical control. In this respect, the radioactive bodies occupy a unique position. It seems reasonable to suppose that while the radioactive substances behave chemically as elements, they are, in reality, compounds of simpler kinds of matter, held together by much stronger forces than those which exist between the components of ordinary molecular compounds. Apart from the property of radioactivity, the radio-elements do not show any chemical properties to distinguish them from the non-radioactive elements except their very high atomic weight. The above considerations evidently suggest that the heavier inactive elements may also prove to be composite.

Origin of the Radio-elements.

We have seen that the radio-elements are continuously breaking up and giving rise to a succession of new substances. In the case of uranium and thorium, the disintegration proceeds at such a slow rate that in all probability a period of about 1,000 million years would be required before half the matter present is transformed. In the case of radium, however, where the process of disintegration proceeds at over one million times the rate in uranium and thorium, it is to be expected that a measurable proportion of the radium will be transformed in a single year. A quantity of radium left to itself must gradually disappear as such in consequence of its gradual transformation into other substances. This conclusion necessarily follows from the known experimental facts. The radium is being transformed continuously into the emanation which in turn is changed into other types of matter. Since there is no evidence that the process is reversible, all the radium present must, in the course of time, be transformed into emanation. The rate at which radium is being transformed can be approximately calculated either from the number of α particles expelled per second or from the observed volume of the emanation produced per second. Both methods of calculation agree in showing that in a gram of radium about half a milligram is transformed per year. From analogy with other radioactive changes, it is

to be expected that the rate of change of radium will be always proportional to the amount present. The amount of radium would thus decrease exponentially with the time falling to half value in about 1,000 years. On this view, radium behaves in a similar way to the other known products, the only difference being that its rate of change is slower. We have already seen that, in all probability, the product radium D is half transformed in about 40 years and radium E in about one year. In regard to their rate of change, the two substances radium D and E, which are half transformed in about 40 years and one year respectively occupy an intermediate position between the rapidly changing substances like radium A, B and C and the slowly changing parent substance radium.

If the earth were supposed to have been initially composed of pure radium, the activity 20,000 years later would not be greater than the activity observed in pitchblende to-day. Since there is no doubt that the earth is much older than this, in order to account for the existence of radium at all in the earth, it is necessary to suppose that radium is continuously produced from some other substance or substances. On this view, the present supply of radium represents a condition of approximate equilibrium where the rate of production of fresh radium balances the rate of transformation of the radium already present. In looking for a possible source of radium, it is natural to look to the substances which are always found associated with radium in pitchblende. Uranium and thorium both fulfill the conditions necessary to be a source of radium, for both are found associated with radium and both have a rate of change slow compared with radium. At the present time, uranium seems the most probable source of radium. The activity observed in a good specimen of pitchblende is about what is to be expected if uranium breaks up into radium. If uranium is the parent of radium, it is to be expected that the amount of radium present in different varieties of pitchblende obtained from different sources will always be proportional to the amount of uranium contained in the minerals. The recent experiments of Boltwood, Strutt and McKoy indicate that this is very approximately the case. It is not to be expected that the relation will always be very exact, since it is not improbable, in some cases, that a portion of the active material may be removed from the mineral by the action of percolating water or other chemical agencies. The results so far obtained strongly support the view that radium is a product of the disintegration of uranium. It should be possible to obtain direct evidence on this question by examining whether radium appears in uranium compounds which have been initially freed from radium. On account of the delicacy of the electric test of radium by means of its emanation, the question can be very readily put to experimental trial. This has been done for uranium by Soddy, and for thorium by

the writer, but the results, so far obtained, are negative in character, although if radium were produced at the rate to be expected from theory, it should very readily have been detected.* Such experiments, however, taken over a period of a few months are not decisive, for it is by no means improbable that the parent element may pass through several slow changes, possibly of a 'rayless' character, before it is transformed into radium. In such a case, if these intermediate products are removed by the same chemical process from the parent element, there may be a long period of apparent retardation before the radium appears. The considerations advanced to account for radium apply equally well to actinium, which, in all probability, when isolated will prove to be an element of the same order of activity as radium. The most important problem at present in the study of radioactive minerals is not the attempt to discover and isolate new radioactive substances, but to correlate these already discovered. Some progress has already been made in reducing the number of different radioactive substances and in indicating the origin of some of them. For example, there is no doubt that the 'emanating substance' of Giesel contains the same radioactive substance as the actinium of Debierne. In a similar way, there is very strong evidence that the active constituent in the polonium of Mme. Curie is identical with that in the radio-tellurium of Marekwald. The writer has recently shown that the active constituent in radio-tellurium or polonium is, in all probability, a disintegration product of radium (radium E). The same considerations apply to the radio-lead of Hofmann, which is probably identical with the product radium D. It still remains to be shown whether or not there is any direct family connection between the radioactive substances uranium, thorium, radium and actinium. It seems probable that some at least of these substances will prove to be lineal descendants of a single parent element, in the same way that the radium products are lineal descendants of radium. The subject is capable of direct attack by a combination of physical and chemical methods, and there is every probability that a fairly definite answer will soon be forthcoming.

Radioactivity of the Earth and Atmosphere.

It is now well established, notably by the work of Elster and Geitel, that radioactive matter is widely distributed both in the earth's crust and atmosphere. There is undoubtedly evidence of the presence of the radium emanation in the atmosphere, in spring water, and in air sucked up through the soil. It still remains to be settled whether the observed radioactivity of the earth's crust is due entirely

* In a recent letter to *Nature*, Soddy states that he has found that there is a slow growth of radium in a uranium solution. A similar result has been noted by Whetham.

to slight traces of the known radioactive elements or to new kinds of radioactive matter. It is not improbable that a close examination of the radioactivity of the different soils may lead to the discovery of radioactive substances which are not found in pitchblende or other radioactive minerals. The extraordinary delicacy of the electroscopic test of radioactivity renders it not only possible to detect the presence in inactive matter of extremely minute traces of a radioactive substance, but also in many cases to settle rapidly whether the radioactivity is due to one of the known radio-elements.

The observations of Elster and Geitel render it probable that the radioactivity observed in the atmosphere is due to the presence of radioactive emanations or gases, which are carried to the surface by the escape of underground water. Indeed it is difficult to avoid such a conclusion, since there is no evidence that any of the known constituents of the atmosphere are radioactive. Concurrently with observations of the radioactivity of the atmosphere, experiments have been made on the amount of ionization in the atmosphere itself. It is important to settle what part of this ionization is due to the presence of radioactive matter in the atmosphere. Comparisons of the relative amount of active matter and of the ionization in the atmosphere over land and sea will probably throw light on this important problem.

The wide distribution of radioactive matter in the soils which have so far been examined has raised the question whether the presence of radium and other radioactive matter in the earth, may not, in part at least, be responsible for the internal heat of the earth. It can readily be calculated that the presence of radium (or equivalent amounts of other kinds of radioactive matter) to the extent of about five parts in one hundred million million by mass would supply as much heat to the earth as is lost at present by conduction to its surface. It is certainly significant that, as far as observation has gone, the amount of radioactive matter present in the soil is of this order of magnitude.

The production of helium from radium indirectly suggests a means of calculating the age of the deposits of radioactive minerals. It seems reasonable to suppose that the helium always found associated with radioactive minerals is a product of the decomposition of the radioactive matter present. In the mineral fergusonite, for example, about half of the helium is removed by heating the mineral and the other half by solution. Thus it does not seem likely that much of the helium formed in the mineral escapes from it, so that the amount present represents the quantity produced since its formation. If the rate of the production of helium by radium (or other radioactive substance) is known, the age of the mineral can at once be estimated from the observed volume of helium stored in the mineral and the amount of radium present. All these

factors have, however, not yet been determined with sufficient accuracy to make at present more than a rough estimate of the age of any particular mineral. An estimate of the rate of production of helium by radium has been made by Ramsay and Soddy by an indirect method. It can be deduced from their result that 1 gram of radium produces per year a volume of helium of about 25 cubic mms. at standard pressure and temperature. They, however, consider this to be an under estimate. On the other hand, if the particle is a helium atom, it can be calculated that 1 gram of radium produces per year about 200 cubic mms. of helium.

Let us consider, for example, the mineral fergusonite. Ramsay and Travers have shown that it yields about 1.8 c.c. of helium and contains about 7 per cent. of uranium. It can be deduced from known data that each gram of the mineral contains about one four-millionth of a gram of radium. Supposing that one gram of radium produces $\frac{1}{5}$ c.c. of helium per year, the age of the mineral is readily seen to be about 40 million years. If the above rate of production of helium is an overestimate, the time will be correspondingly longer. I think there is little doubt that, when the data required are known with accuracy, this method can be applied with considerable confidence to determine the age of the radioactive minerals.

Radioactivity of Ordinary Matter.

The property of radioactivity is exhibited to the most marked extent by the radioactive substances found in pitchblende, but it is natural to ask the question whether ordinary matter possesses this property to an appreciable degree. The experiments that have so far been made show conclusively that ordinary matter, if it possesses this property at all, does so to a minute extent compared with uranium. It has been found that all the matter that has so far been examined shows undoubted traces of radioactivity, but it is very difficult to show that the radioactivity observed is not due to a minute trace of known radioactive matter. Even with our extraordinarily delicate methods for the detection of radioactivity, the effects observed are so minute that a definite settlement of the question is experimentally very difficult. J. J. Thomson has recently given an account at the British Association meeting of the work done on this subject in the Cavendish Laboratory, and has brought forward experimental evidence that strongly supports the view that ordinary matter does show specific radioactivity. Different substances were found to give out radiations that differed in quality as well as in quantity. A promising beginning has already been made but a great deal of work still remains to be done before such an important conclusion can be considered to have been definitely established.

THE HARVARD MEDICAL SCHOOL.

BY FRANK WALDO, Ph.D.,

CAMBRIDGE, MASS.

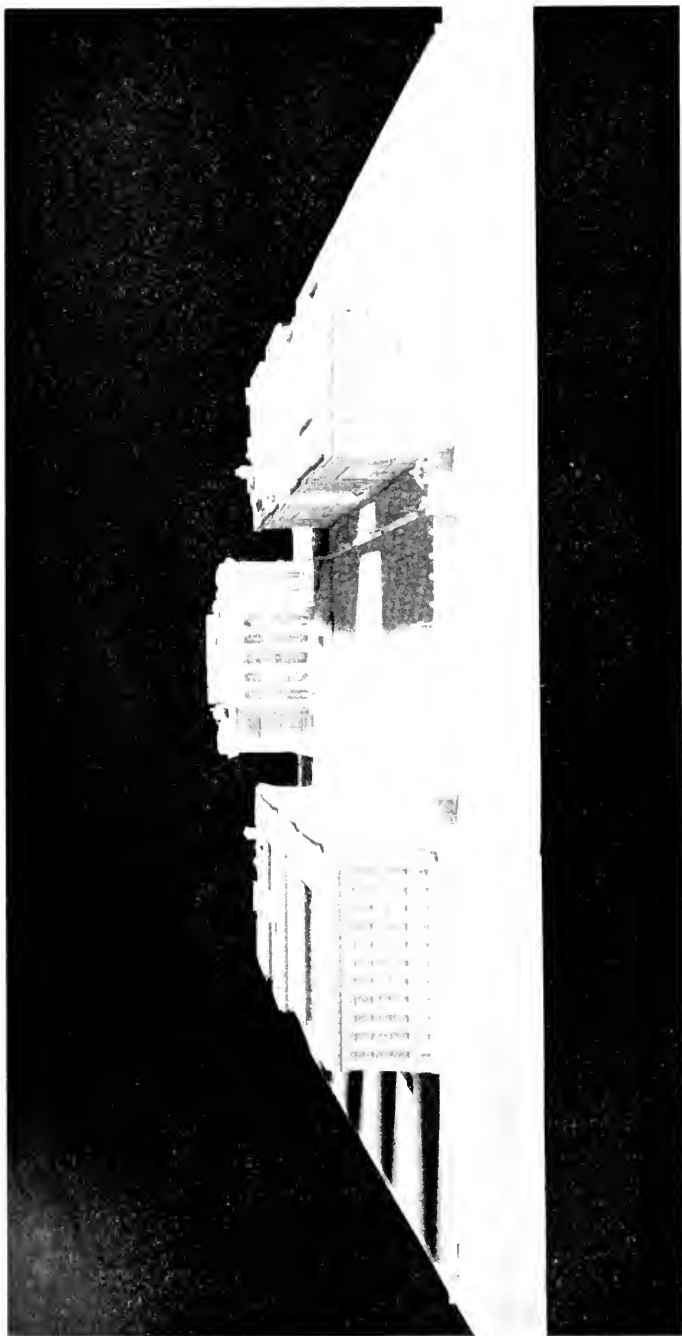
WHILE the new building plant of the Harvard Medical School is approaching completion it seems a fitting time to give a brief account of the work of the school and its equipment. Harvard was the second of the American colleges to establish a school of medicine. The study of medicine in Harvard dates from the close of the war of the American Revolution, when in the years 1782 and 1783 three professorships of medicine were founded; and the first degree, that of M.B. (bachelor of medicine), was conferred in 1788. It was not until 1811 that the degree of M.D. began to be given. Up to 1810 the instruction was given in Cambridge, at which date the school was transferred to Boston, where in 1815 the first medical school building was erected. The second building that was occupied was completed in 1883.

The theory of medicine has of course been taught from the beginning of the Harvard Medical School and eminent men have lectured to its students, but outside hospital and clinic facilities had to be sought. In the first Harvard Medical School building there was no laboratory at all.

With the removal in 1883 to the buildings at present occupied by the school, limited laboratory facilities were provided, in which very important investigations have been conducted. The hospital and clinical service is still, however, so dependent on outside cooperation that this work has been much hampered.

For entrance into the school a college degree is required, or in exceptional cases its equivalent, and since 1892 a four years' course has had to be pursued in order to obtain the degree of doctor of medicine.

The present policy of the school is to so arrange the studies that the student can give his time fixedly for lengthy periods to one subject or group of subjects. Thus anatomy and histology are given the first half of the first year, and physiology and physiological and pathological chemistry during the second half. In the second year pathology and bacteriology are studied during the first half year. It has been the rule to lay down a rigidly required course, throughout, in the study of medicine, but beginning in the fall of the present year the fourth year work will be elected in order to give the student an opportunity to specialize in the department of medicine that he proposes to adopt for his practise.



MODEL OF THE HARVARD MEDICAL SCHOOL.

The Harvard Medical School has numbered among its faculty from the first some of the most eminent physicians of our country. The professors have not been practitioners only, but men of high scientific attainments who have made notable contributions to the science of medicine. Among the most important things accomplished in the recent studies by the Harvard medical faculty may be mentioned discoveries concerning congenital dislocation, cancer, acetonemia, blood pressure, small-pox and scarlet fever.

The contributive activity of various departments of the Harvard Medical School is indicated by the list of publications made during the year from October 1, 1903, to October 1, 1904. Anatomy, 7; physiology, 9; histology and embryology, 3; bacteriology, 7; pharmacology and therapeutics, 2; pathology, 22; comparative pathology, 4; surgery, 14; hygiene, 8. Probably nearly as many more investigations were being carried on but were not published within the period mentioned.

The school is about to enter upon a new and distinct period in its history as the possessor of the finest equipment for medical study of any medical school in the world. In its new location the Harvard Medical School will be enabled to carry on in the most satisfactory manner the study of medicine in theory, practise and laboratory investigation. It, of course, remains to be seen how thoroughly the conditions will be utilized by the faculty and students in furthering the advance of medical knowledge and medical study, but the excellent work done with limited facilities bespeaks a great future activity.

The provisions made in the new buildings for the study of medicine are those that are demanded by the medical knowledge and the advanced methods of the times. Apropos of this it has been well said that the advance in medicine during the past thirty years has been greater than in all preceding time.

The distribution of the buildings, which are being erected at an expenditure of about \$2,000,000, and their general style of architecture is shown in the accompanying illustration, from a photograph of a model that was exhibited at the St. Louis Fair, in which the administration building appears in the center at the head of the court, while on the right (facing the picture) the front building is to be devoted to the subjects of hygiene and pharmacology, and the second one to physiology and physiological chemistry. The front building on the left is to be occupied by the departments of surgery, bacteriology and pathology; and the one behind it to anatomy, histology and embryology.

Work upon these new buildings was begun in September, 1903, but it is not expected that they will be completed until towards the close of 1905, which will preclude their being occupied until the fall term of 1906.

The design of the buildings, which are of marble, is distinctly Grecian, and when completed they will form a noteworthy group merely from the architectural point of view. The work of construction is being pushed forward as rapidly as possible. At the time of present writing, the building to be devoted to hygiene and pharmacology is farthest advanced towards completion; the walls are up on the one for surgery, bacteriology and pathology; the iron framework and the walls are in position for the one for physiology and physiological chemistry, and the building for histology and embryology is nearly as far advanced. Only the foundation and a little of the upper portion of the administration building have been erected.

It is of interest to note that much of the funds that have been so generously contributed to enable the Harvard Medical School to make this forward leap is New York money. Mr. J. P. Morgan gave the three buildings at the back of the group, and Mrs. Collis P. Huntington and Mr. David Sears gave the buildings in the foreground. According to the treasurer's report and other accounts, Mr. Morgan gave \$1,135,000; Mrs. Huntington, \$250,000; Mr. Sears, \$250,000, and to these sums must be added a million from Mr. John D. Rockefeller, nearly \$371,000 from Henry L. Pierce (1898) and about a half million dollars from other sources.

In the erection of such an extended plant for the medical school all possible precautions have been taken to make it suit its purpose in all respects, and to allow for the expansion of the school and for increased demands on the part of medical instruction.

The four main laboratory buildings have each two wings; and not only have the assignments of location for each department been carefully considered as regards the school as a whole, but the allied or supplementary subjects are placed in the wings that are united through a common center. Connecting these wings is an amphitheater over which are placed the special libraries pertaining to the departments occupying the wings. The arrangement of these departments is such as to place in the same building those that are most intimately connected. The actual arrangement adopted has already been outlined in the mention of the various buildings at the beginning of this article. It must be remarked in addition that the study of surgery is provided for in various departments. The arrangement of the wings is such that they may be extended as the school grows so as to ultimately have three-fold the working capacity at present provided for. In the construction of the various buildings and their adaptation to their special purposes, the questions of light, heat and ventilation have been carefully considered; especial use of the principle of lighting by high windows has been made since this insures a good light at the rear of the rooms.

In general, each laboratory wing is divided longitudinally by a broad corridor, and the rooms on each side, which are in most instances of convenient size (23 feet by 30 feet), have adjustable terra cotta walls whereby the rooms may be enlarged or reduced in size according to needs in individual cases. But in the case of the physiological-chemistry building there is no medial corridor, and the laboratories are placed across the wing. Also in the building devoted to pathology and bacteriology one wing contains two large teaching laboratories, while the other wing is divided up into smaller rooms for research work.

In the administration building there are the school offices, a general reading room, an alumni room, four lecture rooms and the Warren Museum occupies the third floor.

The general public associates the names of Pasteur and Koch with single discoveries, but fails to realize that those men have introduced



new methods of work and study, and that the things that their names are especially associated with are but incidents in broad systems; and it is the encouragement of such studies and their practical application that the Harvard Medical School has especially in mind in the arrangement of its new laboratory equipment.

We wonder that the great improvements and discoveries in medicine are not more widely applied. How can they be when the great majority of practitioners have not had the scientific training necessary

to enable them to understand and apply what is being done by the most advanced workers and discoverers? The training that the medical student must undergo in order to enable him to comprehend and apply with intelligence the new methods and discoveries in medicine can not be obtained in a poorly equipped institution nor by poorly equipped minds. It is for this reason that Harvard has hailed with such joy the incoming of the means to equip her medical school properly, and has so raised its standard of admission that the equivalent of a college degree is demanded of those permitted to enter the school.

The study of medicine, broadly considered, has reached such a stage that its present day aspect can be taught only in a great university and by university methods. The old-fashioned medical school served its purpose; but it has had its day, and it can no longer prepare its students to meet the demands of modern medical science.

The new equipment of the medical school will greatly strengthen the connection between it and the college at Cambridge. Hitherto it has been a school apart from the main university, and many a man has graduated from Harvard College without being made practically aware that there is such a thing as the Harvard Medical School. It will be possible under the new conditions to greatly enlarge the scope of the electives that bear on a medical education that may be taken by members of the college or other departments of the university. The departments of psychology and physics in the university can now be properly correlated with the Medical School both in pedagogy and in original investigations.

Hitherto the lack of space facilities and apparatus has made the lecture room and the clinic the main features of student contact with the professors of the school, and this has of necessity kept the feeling of a technical school alive in the student body. The new equipment will incite and foster the growth of the broader university spirit in both study and research. The medical school will now be able to do what it could not do before, that is, to offer facilities to students and investigators of other departments of the university for special study and research under medical school auspices.

One of the most important features of the improved systems of medical study is the learning how to use medical literature and the acquirement of the *habit* of using it. It is only a small proportion of the physicians of the country who can come directly in contact with the special fields of investigation in medicine, and so the chief available channel for keeping up with current progress is through medical literature. The Harvard Medical School possesses unusual facilities for the training of its students in the proper use of the literature of the science. In the first place there are the great general libraries of Boston and Harvard College forming conjointly one of the best col-

lections of books in the world. Next, there is the Boston Medical Library, which is freely open to the Harvard medical students and which possesses one of the most complete collections of medical books in existence, besides containing an unrivaled display of medical journals, which number between seven and eight hundred and embrace the publications of all important countries.

In the various departments of the Harvard Medical School collections of books have been made that serve as technical working libraries; and in the plans for the new buildings this very important feature has been duly provided for. Thus in connection with each laboratory there will be such books, pamphlets, reports and journals as, in the opinion of the person in charge, are the most necessary reference books for students pursuing that specialty. A medical student so trained in the use of medical literature can hardly be content to depend upon antiquated text-book knowledge in his practise in after years.

In that most important matter of applied medicine—hospital service and clinics—the new conditions of the Harvard Medical School promise to be as nearly ideal as the forethought of man can plan. When the grounds for the new site were purchased, enough land was secured to permit the erection of a number of hospital buildings adjacent to the medical school group. Appreciating the advantages of a close connection with the Harvard Medical School, the trustees of several of the new local hospital movements have availed themselves of the opportunity offered and have secured building sites convenient to the school. Moreover, they have signified the intention of joining forces as completely as possible in the carrying on of their humane work. There is first of all the new Brigham Hospital with its foundation of about five millions.

The trustees of the Brigham Hospital fund have signified their intention, after some legal complications have become settled, of purchasing ten acres of the Harvard Medical School grounds as a site for their proposed buildings; but without restriction or accompanying agreement of alliance. Cooperation will mean much to the Harvard Medical School, and quite as much to the hospital. The new Children's Hospital has a location on the west of the medical school buildings, and the Thomas Morgan Rotch Infant's Hospital will build on the school grounds. Near by is the new building of the Samaritan Hospital which was commenced last May; and within easy reach by cars is the Free Hospital for Women. The affiliation of the Harvard Medical School with these institutions will give it the best hospital connections of any medical school in America.



Alpheus Spring Packard

ALPHEUS SPRING PACKARD.

BY PROFESSOR A. D. MEAD,
BROWN UNIVERSITY.

ANOTHER American naturalist of the generation and the type to which belonged Leidy, Cope, Baird, Goode and Hyatt has passed away, Alpheus Spring Packard, professor of zoology and geology at Brown University.

His lineage of sturdy, scholarly men, his academic heritage from great naturalists and the freshness of natural history in America at the time he commenced his career are all perceptible in the sterling quality and the wide range of his life work. The grandfather of the naturalist, the Rev. Dr. Hezekiah Packard, was a revolutionary soldier and fought at Bunker Hill. He received from Harvard College the degrees of A.B., A.M. and D.D. and was an eminent preacher, teacher and writer. The Rev. Dr. Jesse Appleton, one of the early presidents of Bowdoin College, was Professor Packard's maternal grandfather. His father, Alpheus Spring Packard, was a member of the Bowdoin faculty for sixty-five years and served the college successively as tutor, professor of ancient languages and classic literature, of rhetoric and oratory, of natural and revealed religion; as librarian and as acting president. He was an author and a revered teacher; it was of him that Longfellow wrote in his *Morituri Salutamus* delivered at the celebration of the fiftieth anniversary of the poet's class,

"they all are gone
Into the land of Shadows,—all save one.
Honor and reverence, and the good repute
That follows faithful service as its fruit,
Be unto him, whom living we salute."

Professor Packard was born at Brunswick, Maine, February 19, 1839, and died at his home in Providence, February 14, 1905, after an illness of about six weeks. He entered Bowdoin College at the age of eighteen. In his senior year he commenced the serious pursuit of investigations in natural history and continued it with unremitting zeal until the very week of his death, when he insisted upon correcting the proof of his last memoir, published by the National Academy, of which he had long been a distinguished member. While an undergraduate student he enjoyed the friendship and the inspiring instruction of Dr. Paul A. Chadbourne, who was afterwards president of Williams College. It was through him that Packard joined the

Williams College Expedition to Greenland and Labrador in 1860, and to him, many years later, he dedicated his book 'The Labrador Coast,' with grateful acknowledgment of the encouragement and many kindnesses he had received from him in early student days. Three years of graduate study (1861-64) with Louis Agassiz at Cambridge not only brought Packard under the influence of this great naturalist and scientific missionary to America, but brought him naturally into close touch with that older generation of 'lawgivers' who had passed away, but with whom Agassiz had worked; Oken, Humboldt, Cuvier, Lamarck and St. Hilaire. The momentum gathered through the labors of these men in what we should call now general natural science was passed on through Agassiz to his many pupils who have rendered such splendid service to natural science in this country, Alexander Agassiz, Hyatt, Packard, Putnam, Morse, Wilder, Brooks, Verrill, Allen, Scudder, Whitman and Jordan.

To these young men American geology and the American fauna, living and extinct, offered extensive and rich choice in fields of research. Packard chose them all and has left his mark upon them all: geology; paleontology; systematic, structural and economic zoology; embryology, and even anthropology. At Cambridge while he was studying with Agassiz he was also pursuing a course in medicine—as Agassiz himself had done in Munich more than thirty years before—and received his S.B. from Harvard and his M.D. from Bowdoin (the Maine Medical School) in the same year, 1864. With respect to theoretical biology Agassiz's laboratory was an interesting place during this period following the publication of Darwin's 'Origin of Species.' Uncritical acceptance of the doctrine of organic evolution would have been impossible in view of Agassiz's attitude toward this 'notion . . . ever returning upon us with hydra-headed tenacity of life, and presenting itself under a new form as soon as the preceding one has been exploded and set aside . . .' The theoretical phase of biology appealed strongly to Packard and to it he devoted much time and study, especially after the year 1870. He was an ardent admirer of Lamarck, adopted many of his ideas and applied them to new material; and with Cope and Hyatt founded the school of evolutionary thought for which he proposed the name Neo-Lamarckian. To all these subjects, except medicine, Packard contributed papers, memoirs, general books or text-books, and upon them all, except medicine, he lectured to his classes in Brown University.

His geological researches began with his student trip to Labrador in 1860. From these and later studies in Labrador (1864) several articles resulted; among them were the 'Glacial Phenomena of Maine and Labrador' (1866) and the book already referred to, 'The Labrador Coast' (1891). While assistant on the Maine Geological Survey

1861-62, he made discoveries of fossils in the Fish River Region which determined the age of these rocks. About five years later, 1867, he discovered the glacial striæ radiating from Mt. Washington. In 1867 he published a 'Revision of the Fossorial Hymenoptera of North America' and in 1882 the text-book 'First Lessons in Geology.' Many other geological papers have come from his pen.

His zoological articles, especially those on insects, far outnumbered those upon other subjects. Professor Samuel Henshaw in 'The Entomological writings of Alpheus Spring Packard' enumerates three hundred and thirty-nine papers, books and notes published up to 1887; among them the 'Monograph of the Geometrid Moths' 1876, the text-books, 'A Guide to the Study of Insects' 1869, which ran through eight editions in the next fifteen years, 'Insects of the West' 1877, 'Our Common Insects' 1876, 'Half Hours with Insects' 1877. Many important works upon insects have come from his pen since that date. These include the well-known monograph on the Bombycine Moths, 1895, and the text-books 'Entomology for Beginners' 1888, 'Forest and Shade Tree Insects' 1888, and the 'Text-Book of Entomology' 1898. During the last year three insect articles were completed. One of these, his last paper, is a large 'Monograph of the Bombycine Moths of America, including their Transformations and Origin of the Larval Markings and Armature' which will appear as a Memoir of the National Academy of Sciences.

Professor Packard was known through many articles and books on zoological subjects outside the field of entomology. 'The Development and Anatomy of *Limulus Polyphemus*' 1871, 'The Monograph of North American Phyllopod Crustacea' 1883, the 'Life History of Animals, including Man, or Outlines of Comparative Embryology' 1876, the 'Zoology for Students and General Readers' 1879, 'The Cave Fauna of North America' 1888, are some of the books which brought to naturalists and students new data or new arrangements and treatment of subjects which were highly appreciated. To-day, amid the profusion of newer text-books, it is not easy to accord to these older works their full merit or to realize their true value. Regarding the 'Life History of Animals,' Kingsley says it 'was the first attempt since the day of Agassiz's Lowell Institute Lectures to summarize the facts of Embryology'; and of the 'Zoology' he says, it 'was the first attempt to give American students a truly scientific text-book in which morphology and classification were given equal prominence.'

Anthropological and ethnological investigations he followed with keen interest, and contributed to these subjects several miscellaneous notes and papers.

Of his general books that on 'Lamarck, the Founder of Evolution, His Life and Work,' 1901, is especially noteworthy. The work was

the result of years of study, interpretation and defense of Lamarek's writing, and of a journey to France for the purpose of looking up the records of Lamarek's private and professional life. In this portrayal of Lamarek there may be perceived something of the personal loyalty, esteem and almost affectionate regard which Professor Packard unconsciously but inevitably showed in conversing about the 'founder of evolution.' These conversations about Lamarek and other naturalists of the past were one of the many things which revealed to Packard's friends his own unconscious genuineness. The absolute absorption of his interests by natural science made the persons, events and facts connected with it as real and natural as each day's life.

The quiet reticence which characterized Packard did not grow out of a life of contemplation without action and contact with things and men. From his student days he had actively participated in expeditions, commissions, surveys, foreign and domestic travel and in the founding of scientific institutions. At the end of his junior year in college, he went with Chadbourne on the Greenland and Labrador Expedition. In his senior year he went with a class on a trip to the Bay of Fundy. Immediately after his graduation, in 1861-62, he explored the wilderness of northern Maine as assistant on the Geological Survey of that state. He enlisted as assistant surgeon in the First Maine Veteran Volunteers which joined the Army of the Potomac in 1864. He joined a party organized by a Mr. William Bradford in the summer of 1864 and paid a second visit to Labrador. In 1867 he was examining the glacial traces in the White Mountains. The animals of the Florida reefs and of the Beaufort, N. C., flats engaged his attention in 1869-70, and the next year we find him studying the development of crustacea and collecting fossil mollusca in Charleston, S. C. In 1871 he was appointed Massachusetts state entomologist, a position which he held three years. Meanwhile he visited Europe and spent much time in the study of insects at the British Museum. The summer of 1873 found him working again with Agassiz, as a teacher in the Anderson School of Natural History at Penikese. He returned the next year to the school and for a time was the dean of its faculty. He held an appointment from 1875 to 1877 as one of the zoologists on the United States Geological Survey under Ferdinand V. Hayden, and from 1877 to 1882 was a member of the United States Entomological Commission. In the latter capacity he made extensive trips in the western part of the United States, investigating the breeding grounds and distribution of the Rocky Mountain locust. In 1874 he was appointed on the Kentucky Geological Survey, and with Putnam made explorations of the great caves and observations upon the cave fauna which laid the foundations of his later works upon these subjects. He visited Mexico in 1885, Cuba in

1886, and in 1889 traveled in Morocco, Algeria, Egypt and Europe, arriving in Paris to attend the meetings of the International Zoological Congress of which he was elected an honorary president.

In the course of his long and active career he was associated with many American institutions and took a prominent part in the founding of some of them. After his service in the army he became librarian and acting custodian of the Boston Society of Natural History 1865-66. Then with his friends, Hyatt, Morse, Putnam and Cooke, he accepted a position in the Essex Institute in Salem which was at that time a thriving and important scientific institution. When the Peabody Academy of Science in Salem was founded in 1868 and absorbed the Essex Institute, Packard became its curator of Invertebrates and later, in 1876, was elected director of the academy. It was this group of fellow students, Packard, Hyatt, Morse and Putnam, who in 1868 founded the *American Naturalist*, and Packard remained its editor-in-chief for twenty years. While curator at the Peabody Institute, he lectured on entomology in the Massachusetts State College, 1869-77, in the Maine Agricultural College, 1871, and on natural history in Bowdoin College, 1871-74.

Packard was also prominently connected with a novel undertaking which has proved to be of inestimable value in the development of biological science in America. The Anderson School of Natural History at Penikese Island was inaugurated by Louis Agassiz in 1873; here Packard taught for two years and then, when this school was given up on account of Agassiz's death, Packard perpetuated the idea by establishing a summer school of biology at Salem under the auspices of the Peabody Academy. He directed this laboratory until 1878, when he left Salem to accept the professorship of zoology and geology at Brown University. The cherished idea of the seaside laboratory of natural history then took form in the Annisquam laboratory established through the efforts of Packard's colleague Professor Hyatt, under the auspices of the Woman's Education Society of Boston, and this experiment in turn led the way to the establishment of the Marine Biological Laboratory at Woods Hole. This institution, directed for so many years by a Penikese student, Dr. C. O. Whitman, and the United States Fish Commission laboratory at Woods Hole, established by Professor Spencer F. Baird, a teacher at the Penikese school, have not only afforded inspiration and opportunity for research to hundreds of biologists, but have given birth to scores of similar laboratories on the Atlantic and Pacific coasts.

From the colleges in which he was a student Packard received the degrees of A.B., Bowdoin, 1861; A.M., Bowdoin, 1862; M.D., Bowdoin, 1864; S.B., Harvard, 1864; Ph.D., Bowdoin, 1879; LL.D., Bowdoin, 1891.

The value of Packard's work can not be best estimated and, perhaps, is not fully appreciated by the younger generation of morphologists and physiologists, whose energies are absorbed in the amazing elaboration of cell studies; it must be left to 'the judgment of his confrères.' From these men of many countries have come unequivocal tokens of approval. The American Academy of Sciences elected him to membership in 1872, the Société Royale des Sciences de Liège, Belgium, in 1875; the Society of Friends of Natural Science in Moscow, in 1891. In 1901 he was elected a foreign member of the Linnean Society of London. In this distinction he once more renewed the comradeship of his fellow students and collaborators at Penikese, Alexander Agassiz and C. O. Whitman, who were the only other American zoological members. He was elected to membership in the entomological societies of London, Paris, St. Petersburg, Stockholm and Brussels; was one of the honorary presidents of the International Zoological Congress at Paris, and honorary president of the Zoological Section of the French Association for the Advancement of Science, and in 1898 was vice-president of the Zoological Section of the American Association for the Advancement of Science.

In the latter years of his teaching, his colleagues and the students of the university where for twenty-six years he had held a professorship awarded him tokens of esteem rarely bestowed upon their colleagues and teachers. The members of the faculty constrained him to attend a banquet held in his honor, at which the address of his lifelong friend, Professor Hyatt, completed his modest confusion. A loving cup recently presented to him by his class in zoology was valued by the distinguished, genial teacher above the diplomas of many learned societies.

Professor Packard was not quite sixty-six years of age, but his active scientific career extended over a period of forty-five years, and during that time he published upwards of four hundred books and papers. He married, in 1867, Elizabeth Debby, daughter of the late Samuel B. Walcott, of Salem, who, with two daughters and a son, survives him.

ORGANIZATION IN SCIENTIFIC RESEARCH.

BY PROFESSOR WM. E. RITTER,
UNIVERSITY OF CALIFORNIA.

PROGRESS in science leads to ever greater, more multifarious minutiae of knowledge, and at the same time to ever clearer revelation of the close and vital interdependence among the different sciences. This characteristic of progress tends inevitably, for the individual investigator, toward an unyielding paradox. On the one hand, he is confronted by an ever increasing mass of detail, which necessitates ever narrower specialization, while, on the other hand, he is required to fit himself ever more thoroughly in an increasing number of sciences. See how it is faring with the zoologist, for example, since his case happens to be one of painful concreteness to the present writer. To enter this field by any of its numerous gateways with fair prospects of being able to achieve much, one needs to be armed to the teeth with weapons obtained in several other fields. In the first place, he ought to be a physiologist among physiologists, with all that implies of physics and chemistry. It is not enough that he be a zoologist with 'pretty fair training in physiology.' In the second place, he ought to handle the mathematician's weapons just as the mathematician himself handles them. Further, he can hardly get on without being geologist, oceanographer, meteorologist, one or another, depending on what aspect of zoology may be his chief interest. For the strict individualist in research it looks as though some of the sciences are in a way to progress themselves to a standstill before long.

What is to be done about it?

It is becoming more and more obvious that in some of the sciences continued progress, particularly in certain directions, calls for the helping hand of workmen whose training and interests are not primarily in the science directly concerned, but in neighboring sciences. It is no longer possible for an investigator engaged upon some of the problems of science, however broad and thorough be his training in sciences other than his own, to use the tools borrowed from other fields with real effectiveness in his own field. It is a question not merely of preliminary training, but as well of *point of view*, to be reached only by continuous and long continued living in a particular realm of knowledge until a certain habit of mind peculiar to that realm has been acquired. This is the sort of help that every science, probably, certainly most sciences, must have from its neighbors. There

are aspects of certain biological problems, for instance, that admit of no other than mathematical treatment; and this treatment ought to be, indeed to be thoroughly sound must be, at the hand not of a botanist or zoologist with some incidental mathematical training, but of a mathematician. The astrophysicist is really a physicist using his tools in astronomy. The biochemist is primarily a chemist applying his cunning in the domain of living things. The paleontologist, whatever else he may be, must be a zoologist, and so on. So important is this matter that at the risk of seeming verbosity, I venture to illustrate it yet further.

Take anthropology, and to make the case more concrete, consider the question of the native peoples of western North America, for in a remote, amateurish sort of way I have an interest in some phases of this question. The broadest, fullest knowledge possible about these tribes is, of course, the ultimate aim. The investigations must then comprehend their somatology, their language, their psychology, their culture and their archeology, which runs into paleontology and so into geology. Now who but one soaked in linguistics is really competent to handle the language end of the problem? But where, think you, is the man thus prepared who is equally soaked in comparative anatomy and thus made equally fit for the somatological end of the problem? He simply does not exist, nor can he.

Or again, take the field of marine biology, about which I speak with some of the confidence that experience is capable of begetting. And first let the distinction be sharply made, as it surely must be, between *marine biology* and *general biology advanced by researches on marine organisms*. The former has for its aim, in the large, the getting of as comprehensive an understanding as possible of the life of the sea. It, of course, presents itself under a great variety of secondary, tertiary, etc., questions; but the sum total of the phenomena of *marine* plants and animals will never be lost sight of as its real aim. The latter makes use of animals and plants that live in the sea in general biological researches. That these organisms happen to be marine is an incident merely. The investigator turns away from his sea organisms without hesitation when others, from whatever source, come to hand that suit his purpose better. Further, the user of marine organisms in such general investigations is quite indifferent to every thing concerning them that does not bear upon his particular problem. He puts aside the marine animal after it has served his purpose without having even noticed, perhaps, the major part of its traits and qualities, and questions about it.

Now marine biology as here comprehended must have the correlated efforts of highly trained investigators in several widely separated fields of science. In the first place, there must be, of course, for the

biological investigations proper, a considerable number of specialists in botany and zoology. Then, in addition, there must be at least the physicist or physical chemist for the physico-chemical study of the water; the geologist for bottom and shore topography and bottom deposits; and the hydrographer must be called in for currents, tides, up-welling water and meteorological conditions.

It is obvious, then, that increased coordination of effort would be distinctly advantageous in many fields of science; and that in some, at least, it is a *sine qua non* to considerable progress in the future. How is this to be brought about? How are these diversities of talent and training to be brought together and held together to the end that they may accomplish that which in no other way can be accomplished? Cooperation among individual workers, entered into on their own initiative and held together by their own cohesiveness, has done something, and probably in future will do more. In some districts of nature, and in some sorts of problems, this may fill the bill. To other districts and other kinds of problems, however, among which are undoubtedly some of the largest and potentially richest, I believe this kind of coordination can not extend in great effectiveness.

Organization around single large problems, or groups of closely related problems, with the two binding elements of talent for organizing and directing, and money for sustaining, I believe to be the direction in which we must look in the future more than we have been looking hitherto.

Something of the value and possibilities of organization in research are usefully illustrated by certain of the science departments of our national government. Particularly to be mentioned is the Geological Survey; and some of the divisions of the Department of Agriculture are likewise notable. But astronomy is giving us object lessons most to the point in this matter. The astronomical observatory with its permanent staff of investigators, each of whose work has a definite bearing upon a common purpose of the observatory, all under the coordinating hand of the director, shows us in principle how much of the scientific work of time to come must be done. It would appear that these splendid instrumentalities of research are getting right at the kernel of the question of means; and it seems as though other sciences ought to be profiting more than they are by the example.

It is likely to be replied that the observatories are made possible solely by the great sums of money given them, and that astronomy is doing no more in the way of equipping herself and organizing her forces than other sciences would do were they equally fortunate in getting money. True, astronomy is, or thus far has been, the favored sister in the family of sciences with those who have riches and a disposition to use them for the promotion of knowledge; and it is said

sometimes that she is thus favored because she is more beautiful, more winsome, than her sisters. Well, possibly this is true; it may be or it may not be. We need not stop to discuss relative merits in this particular, since it is quite aside from the question. If other sciences must do what astronomy is doing in order to get on, and if money in more abundance is essential for this, then more money must be secured by those needing it. If astronomy, by reason of greater winsomeness, is able to get it more easily, that is her good fortune. So far as the essential matter is concerned, it can be only a question of overcoming greater difficulties by greater effort. But the real things are *merit* and *need*. When these *both* are, first, strongly felt, and, second, strongly presented, they are pretty sure to have a relaxing effect upon purse strings somewhere sooner or later, particularly in our country where wealth is so abundant and the general spirit of giving for the promotion of learning so much abroad.

Some of the practical bearings that a wider application of the principle of organization in research would have may now be briefly noticed.

In the first place, as touching the status of research in the universities, there can be no doubt that were research a primary rather than an incidental matter with the scientific departments of the universities, the principle could be applied, without specially greater expenditure of money, to an extent quite impossible under the present order. Supposing, for example, the department of botany of University X were to be organized and equipped primarily with reference to a comprehensive botanical survey of the particularly interesting botanical region in which it may happen to be located; how vastly greater would be its efficiency in forwarding botanical science than if its composition were determined by some other consideration, say the needs of instruction, and the botanical survey were to take its chance. Or again, suppose the department of geology of University Y, situated in a region especially favorable for investigations in dynamic geology, were to be organized primarily with reference to such investigation. A department thus constituted would promote this aspect of geology with a degree of certainty and efficiency quite out of question under prevailing conditions. A point of importance should here be noted relative to what the organizing of a university department on such lines as indicated could mean. Such a department of geology, for example, need not consist merely of the geologists that would constitute the ordinary teaching department of geology, but it would contain for the special needs of the investigations, and hence selected and compensated with reference to this end, persons belonging primarily to other fields of science, and hence presumably to other university departments; and there would be no reason why these should not be members of other

universities at the same time. For example, the department of geology would have need for, let us say, a chemist, and a paleontologist, and these might be employed for the special service, while they could still belong primarily to their respective departments, either of the same or of another university.

The inquiry what effect such a system widely in vogue would have on the individuality of workers in science is quite to the point. Some, I fancy, would be apprehensive lest it should prove harmful to this quality, of right so highly prized among men of science. I am persuaded, however, that a little reflection will show that while individuality might now and then suffer, it would be the gainer in far larger measure. On the whole, instead of being a heavy hand on independent, individual effort, it would furnish opportunity and incentive to it. For observe, it would be a system not of forcing investigators into work, for which they should have neither taste nor fitness, but rather of *selecting* them for tasks for which they would have both, and then of *giving* them facilities and opportunities for following their bent that they could not generally secure through their individual, unaided efforts.

How familiar a thing it is to all university men of science to see a young man receive his doctor's degree as the reward of some research carried to results with real zeal and talent; but then, under stress of the necessity of earning a livelihood, carried off into some position that affords little or none of either time, facility or incentive for further prosecution of his central interest in science.

There can be no doubt that science, in this country particularly, has been and is a heavy loser from diversion and misapplication of its forces, through the regimen under which research has to be prosecuted. This loss is partly direct and absolute, and partly indirect, through the detached and fragmentary character of what is done under the prevalent highly individualistic order. Of course, it would be idle to contend that this order is wholly bad, or that all that is bad about it could be corrected by such a system. That, however, coordination and concentration through organization would be of even more advantage in several sciences where now practically nothing of the sort exists, there can be no doubt. Such a system largely in operation would undoubtedly work radical change in the means and methods of research in numerous directions, but these need not be discussed here. One further matter only do I mention. That is the question of the effect it would have on instruction in science in the universities and colleges. It is easy to see how to some extent instruction might suffer. It is still easier to see how, on the other hand, it would be a very great gainer; and there can be hardly a question that the gain would far outweigh the loss.

THE ORIGIN OF SPECIES THROUGH SELECTION CONTRASTED WITH THEIR ORIGIN THROUGH THE APPEARANCE OF DEFINITE VARIATIONS.

BY PROFESSOR T. H. MORGAN,
COLUMBIA UNIVERSITY.

IT is a point of some interest that at the present time those zoologists and botanists, who seem willing to transfer their allegiance from Darwin's theory of natural selection to the theory of the survival of mutations, often insist that the two points of view differ, after all, only in degree and that selection is still the key note to the situation. It seems to me, on the contrary, that there is a fundamental difference between these two views, and in the hope of making this clearer I have attempted in the following pages to contrast in certain respects the applications that have been made of Darwin's theory with the implications of the newer theory of the survival of definite variations.

Attention has seldom, I believe, been called to the fact that only those theories that have been advanced to account for the evolution of animals and plants, have received wide recognition, that pretend to explain how the adaptation of the organism to its surroundings has been acquired. No such requirement is made in the case of theories of evolution of the inorganic world. On what does this difference depend? Why do we make certain demands in the case of organic evolution that we do not make for the evolution of inorganic nature? The answer in part is, that a living thing is unstable, it is easily destroyed, and it must, if it is to maintain its integrity, be able to respond to changes in the outer world in such a way as to keep the balance that makes its existence possible.

It is true that certain chemical substances are also highly unstable, but we find in them no adjustments, no regulations, for maintaining themselves, such as animals and plants exhibit. No theory, as I have said, that pretends to account for the evolution of new organisms, has been regarded as satisfactory unless it explained how the new forms acquire those adjustments that make their life possible. How perfect these adjustments must be is a question that has never been sufficiently considered, partly because of the difficulties surrounding such an examination, and partly because of the widespread belief that living things are as perfectly adapted to their environment as we can imagine possible by the adjustment of their individual parts to the surroundings

in which they live. As an illustration of how such adjustments are supposed to occur I shall take a single example, from Weismann's writings, although it would be an easy matter to give endless examples, similar to this one, from the writings of other Darwinians, who, as a rule, have been only too prone to make use of the same argument in accounting for the origin of the adaptations of animals and plants.

Length of Life as an Adaptation.

Weismann has written a most interesting essay on 'The Duration of Life,' in which he attempts to show that the length of life of the individuals of a species has been regulated by natural selection of individual variations. While it may be granted that in many respects Weismann has out-Darwined Darwin, yet his method in this instance is the same as that which the Darwinians have always employed whenever an occasion occurred.

It has often been pointed out that the life of larger animals is longer than that of smaller ones, and this seems not unreasonable, since in many cases it takes a longer time for a larger animal to reach maturity; yet this relation is by no means universal, as Weismann points out, for, while it is true that an elephant may live two hundred years and a horse not more than forty, yet a man lives longer than a horse, and a cat and a toad may also live forty years. A pig may live no longer than a crayfish. Flourens tried to show that the length of life of an animal is about five times its growing period, but this does not generally hold, since a horse may live ten times as long as it takes to reach maturity.

Complexity of structure can not explain the result, because some very simple forms live to a great age. Weismann also concludes that the length of life is not determined by the 'constitution' of the animal, for, while a queen bee may live for several years, the male lives for only a few weeks. Therefore, Weismann concludes, it is 'proved that physiological considerations alone can not determine the duration of life.'

Thus by an apparent process of exclusion Weismann reaches the conclusion, 'that duration of life is really dependent upon adaptation to external conditions, that its length, whether longer or shorter, is governed by the needs of the species.' In support of this view he points out that 'life does not greatly outlast the period of reproduction except in those species that tend, their young, and as a matter of fact we find that this is the case.' How then has this regulation been brought about? Weismann's answer is that the duration depends first on the time required to reach maturity, and since the longer this time the more the chance for destruction, the number of descendants produced must be greater in proportion as the duration of the reproductive period

becomes longer. This statement is obviously of no value, for a sea urchin that may grow up in a year, produces millions of eggs, while an elephant that takes thirty years to mature produces only about six young in the whole course of its life. Equally valueless, it appears to me, is Weismann's statement 'that nature does not tend to secure the longest possible life to the adult individual, but, on the contrary, tends to shorten the period of reproduction as far as possible, and with this the duration of life.'

Coming now to the main question as to how natural selection may be supposed to increase the length of life, Weismann states, that "Duration of life like every other characteristic of the organism is subject to individual fluctuation. From our experience with the human species we know that long life is hereditary. As soon as the long lived individuals of a species obtain some advantage in the struggle for existence they will probably become dominant, and those with the shortest lives will be exterminated."

Without attempting to offer an elaborate refutation of Weismann's view, I should like briefly to present the following considerations:

I. It is, of course, almost self-evident that the existence of a species is closely bound up with its powers of reproduction, but it does not follow from this that the length of life has been adjusted to come to an end when the animal can no longer reproduce itself, *because* it can not reproduce itself any longer.

2. On the contrary it is more probable that the same causes that have led to the cessation of the powers of reproduction may be closely associated with those that bring about a decline in the general vitality; so that while death may follow at a variable period after the power of reproduction is lost, the two processes have not been adjusted to each other by some external need, but are part of the same physiological decline.

3. In the higher animals especially, there may be thousands of immature eggs when the animal ceases to reproduce, as in the case of the human species. It would seem to be greatly to the advantage of a species to have the individual that has surmounted the dangers of youth bring all of its eggs to maturity before it dies; yet such is not the case. The eggs fail to mature not because it is to the advantage or disadvantage of the species to perish after it has set free a part of its eggs, but because the general decline of the organism brings to an end the power to ripen its eggs.

4. The natural duration of life of each species determines when its reproductive powers begin to decline, and the relation is, therefore, exactly the reverse of that which Weismann assumes; for the cessation of the reproductive power is determined by the decline of vitality and this decline is not regulated by the cessation of the power to reproduce.

5. That the process of selection of individual fluctuations can, at best, only keep the species up to an artificial standard that will be lost as soon as a rigorous process of selection ceases, has been shown by de Vries and others. The permanent inheritance of each species can not have been acquired in this way. Unless, for example, those individuals whose life is somewhat longer or shorter were being constantly destroyed *in every generation* the little would soon be lost that had been so laboriously gained. It is needless to point out that no such process is taking place on a scale sufficient to regulate the evolutionary process.

6. The length of life of a species is something that is as characteristic of the species as any of its structural or physiological properties. To state that the duration of life can not be supposed to be the result of physiological processes is not simply paradoxical but absurd. The paradox and also the absurdity disappear as soon as we recognize the fact that the length of life is a characteristic of each new species and is a purely physiological process. Those new elementary species whose physiological processes fulfill the conditions of a certain environment survive, those that do not perish; and there is no subsequent lengthening of one character and shortening of another, as on a sliding scale, to fit the new form in all details to its new environment. The length of life is predetermined with the advent of the new form, and is not subsequently regulated for the benefit of that particular species. From this point of view we get a simple and clear analysis of the problem, while that which Weismann maintains leads only to an unmeaning 'paradox.'

It seems to me that the method of the Darwinian school of looking upon each particular function, or structure, of the individual as capable of indefinite control through selection is fundamentally wrong. For instance, in regard to the number of eggs characteristic of each species, it is assumed that the output is also regulated by means of selection. On the contrary it appears to me that the power to produce a certain number of eggs is one of the fixed characteristics of each species that appears, and is not increased or diminished by external needs. The number of individuals that reach maturity will stand, therefore, as a measure of how far a new species is from the beginning adapted to the old environment, or to the new one in which it establishes itself. There may be a wide range of perfection in this respect, for there are some species that produce few eggs, but succeed in bringing a large number of them to maturity, and there are other species which, despite the countless number of eggs that they produce, only succeed in barely holding on to existence. Since the great majority of lower animals and plants produce large numbers of eggs we may infer that the arrangement for propagation, while it suffices to keep the species in

existence, is extremely wasteful, and far from being as perfect as we can easily imagine it might become if the process could be regulated by individual selection.

An Adaptation may be More Perfect than Survival requires.

Are organisms ever more perfectly adapted in certain characters to their environment than the demands of survival require? A positive answer to this question might release us in part from the modern test of utilitarianism.

It is a well-known fact that through use many, perhaps all, parts of the body are capable of doing more than they are called upon to do during the ordinary life of the individual. The muscles through practise not only become larger and stronger, but can even be educated to do more rapid work, as seen in the fingers of the skilled pianist. The sensation of touch can be made more perfect through practise. The skin thickens wherever continued pressure is brought to bear on it. The bones will change their form, and even make new sockets under suitable conditions. The walls of the blood vessels become thicker if more blood is thrown into the blood channels. These are typical examples of what the body is capable of doing, and the responses in each case are obviously to the advantage of the individual. What is the meaning of this power to do more than the ordinary requirements of life demand?

It has been suggested that the survival of the individual is sometimes determined by its capacity to rise to extreme occasions. For example, the deer that is capable of putting on a little more speed than its fellows, is the one that escapes. But this assumption fails to meet fully the case, for, in the first place, it assumes as already present a certain amount of the very quality to be explained. In the second place a similar capacity is also present in other organs, in which it is highly improbable that the power to improve somewhat could be of sufficient importance to be decisive in a life and death struggle. It could be of little advantage for instance to have the power of improving the musical sense beyond a very low average, and no one will suppose that this has been decisive in the evolution of the race.

In other directions also we find an apparently superfluous perfection of development. It is improbable that the extraordinary adjustments of which the eye is capable have all been acquired little by little through a life and death struggle. The eye is, however, such an important organ for the welfare of the individual, that it is hard to demonstrate positively that each stage was not of great use, but for the ear it seems improbable that its perfection in certain respects could have been of vital importance for the maintenance of the race.

The symmetry of animals and of plants is also in many cases

more perfect than the requirements demand. The almost exact resemblance between the right and left sides of the body, while advantageous up to a certain point, is often far more perfect than competition requires. In fact we find the Darwinians often dodging this consideration, and referring the results to 'the laws of growth,' etc. But if these 'laws of growth' exist why may they not have also carried the perfection of any organ far beyond the point at which the test of survival stops?

We meet with a somewhat similar case in the distribution of color over the bodies of animals. Granting that in some cases the presence of colors, after they have appeared, may be of some use to the animal or plant, yet the wonderful symmetry of distribution, and the gradual shading of the colors is often far more regular than appears to be required. This result also will no doubt be ascribed to 'the laws of growth,' but if we once admit such a principle at work, why bring in any other outside law to explain the perfection of those characters that are useful to the organism? If when a new species appears its colors happen to be so distributed that the individual gains some advantage, so much the better! If the color does not count one way or the other, then it does not enter into the problem of survival; but if it exposes an animal to a greater risk than it can surmount, that species will fail to hold its own. The same regularity and graduation of color exists also in animals that are microscopic, and no one thinks of accounting for these conditions through selection. Why then do we need a special explanation when the animals are so large that they attract our attention?

A number of writers, of whom Eimer is perhaps the most prominent, have insisted that evolution progresses along certain definite lines that are quite independent of selection of individual variations. The process has been called orthogenesis. Certain aspects of this view are in full accord with the theory of the survival of definite variations; for, we find, in fact, one of the most characteristic features in the appearance of definite variations to be that the same forms appear over and over again, showing a definite tendency to vary in certain definite directions. A striking case of this sort is that of the jappanned peacocks described by Darwin, and of the mutations of the evening primrose described by de Vries. If future work can show that a change in a given direction is likely to be followed by others in the same direction, amongst some at least of the offspring, the process will have much in common with the process of orthogenesis. If this process should be in the direction of making some particular organ more perfect than the conditions demand, the new type may persist along with the parent form also, which it need not replace. If, on the contrary, the new acquirement unfits the new species for its environment the new species

will never become established. Cases of this sort, in which a species continually gives off mutations, that can not survive, and yet continue to appear, are known.

In most cases the survival of a species is not determined by one particular character, but by the sum total of all. Therefore since the characters mutate independently, we might expect to find occasionally in a new species some characters more perfect than the actual requirements demand; other characters less perfect than is necessary to maintain the species if survival depended on these alone, and many characters that suffice for the demands of survival. Thus in man, to take but a single example, the ear and the eye may be more perfectly developed in some respects than the demands of survival require, while the appendix vermiformis is actually injurious to the welfare of the race. The majority of the peculiarities lie somewhere between these extremes. A new race of men can not be produced by selection of those individuals that show fluctuating variations in these different directions, but must arise by the sudden appearance of a new type or types, which, finding a foothold, may establish themselves along side of the present races.* It may be that definite variations are even at present occurring, but are not of sufficient importance or difference to attract attention. Permanent improvement must be looked for in this direction, and not from the picking out of those individuals that fluctuate in an advantageous direction.

How Adaptation may arise through the Appearance of Definite Variations.

If we take the position that the creation of new forms is not the outcome of a long continued process of remodeling of each species, but that new forms appear 'spontaneously,' how can we account for the adaptation of new species to their environment? Are we to believe that all new forms that appear from 'inner causes' will be already adapted to some external set of conditions? A very slight familiarity with living things will give, I believe, a negative answer to this question. Nevertheless let us not conclude too quickly that none of the new forms will be adapted to some environment, even if some of them are not.

Darwin defined natural selection as follows: 'This preservation of favorable individual differences and variations, and the destruction of those which are injurious, I have called natural selection, or the sur-

*I do not, of course, mean to imply that any one of the present races of mankind could not be greatly improved artificially by encouraging the individuals best suited to civilized conditions to propagate, and by discouraging propagation by the criminal, indolent and unhealthy individuals. Until this is done we can not hope for even an artificial improvement in the standard of the race.

vival of the fittest.' He constantly compares the action of natural selection to that of artificial selection, in which he supposes that the breeder picks out those individual differences of the kind known as 'fluctuating variations.'

Modern zoologists who claim that the Darwinian theory is sufficiently broad to include the idea of the survival of definite variations seem inclined to forget that Darwin examined this possibility and rejected it. The grounds for this rejection seemed valid at the time, but a wider knowledge of the facts has shown that the problem is simpler than Darwin was aware of.

While Darwin uses the term 'struggle for existence' in a very loose, and often in a metaphorical sense, as he himself points out; and while it is true that he speaks of varieties and even species struggling with each other, yet the central idea is that natural selection adapts the organism to its environment by picking out and accumulating slight, individual differences. It is, indeed, only in this way that natural selection appears in the rôle of a creative factor in evolution, and it is this power to build up new adapted types that appears to give the theory its high value.

Numerous cases of discontinuous variation have been known for a long time, so that it is no mere assumption that such occur in nature. Darwin himself has collected many instances of this sort, and amongst domesticated animals and plants sudden variations have been frequently recorded. In fact there can be no doubt, especially in the case of plants, that such variations have often been utilized by the breeder, even unconsciously at times. A few cases of this sort have been described even for domesticated pigeons, and it is not improbable that the great variety of domesticated breeds may, in part, have arisen in this way, and not as the result of the selection of the individual fluctuations of the wild rock-pigeon. Darwin argued that sudden variations can not have been the source of new species, because, as a rule, when they are crossed with the parent form the offspring are not intermediate, but are exactly like one or the other parent, and it is a well known fact that when wild species are crossed the hybrid is midway in character between its parents. Therefore, Darwin believed, wild species could not have arisen as discontinuous variations.

Our knowledge on these points has greatly increased since Darwin's time, especially in recent years, mainly as the result of de Vries's work on the evening primrose. It appears that there are several different kinds of definite variations. The simplest cases are those in which some one character suddenly becomes lost, as when an albino mouse arises from a gray mouse. If such an albino is crossed with the parent gray form the offspring in the first generation are all like the gray mouse, but if these offspring are then inbred, they will produce some

pure white which breed pure white, and some pure gray mice which breed pure gray, besides some impure forms like those of the first generation, which breed both colors. In other cases the new form if bred to the parent stock gives rise to offspring which even in the first generation are like the new form. Thus it appears that when the ancon ram was bred to an ordinary ewe the offspring were like the father. Similar cases are recorded for the merino sheep, for the japped peacock, and for other new types. It appears here that the new type dominates in some or in all of the offspring. Darwin had in mind cases like these when he rejected the view that discontinuous variations have furnished the material for natural selection.*

There are, however, still other kinds of sudden and definite variations, and these, not the former, are the kind which are mainly responsible for new species. New elementary species arise not through a loss of some character of the old form (although new species may have amongst their new characters some that are due to loss), but by the appearance of a new character or characters which follow a different law of inheritance. When such elementary species are crossed with the parent type, a new type may arise, which is usually intermediate in character between the parents, but in some cases may be more like one than the other. Similar results follow when the new elementary species are crossed with each other. Thus the results are comparable to those that occur when Linnaean species are crossed, although in the case when forms belonging to two widely different Linnaean species are combined the results may be so complicated that it is beyond our power to give a satisfactory analysis of the results at present.†

The term mutation has been used for the sudden appearance of new variations belonging to any one of the preceding cases. Whether it may not prove necessary to use different terms for the different kinds of discontinuous variations in so far as they follow different laws of inheritance remains for the future to decide. We might, perhaps, use the term *mutation* (and mutant) only where new elementary species are formed; *retrogression* where a character is lost (elementary varieties being formed, which follow the Mendelian law of inheritance, as

* It is not clear from the records whether this class follows the Mendelian rule of inheritance, with the new form as the dominant in the first generation. From the statements that are ordinarily made, it might appear that even in the first generation some of the offspring are like one parent and some like the other, which, if true, would make these cases different from the first class given that follow Mendel's law of inheritance.

† In my book on 'Evolution and Adaptation,' I pointed out that while a single step or mutation could not be halved, yet if a number of steps were taken in the same direction the number might then be halved. This may be true but is unnecessarily hypothetical, and, as pointed out here in the text, the apparent difficulty that Darwin met with can now be explained in other ways.

in the case of albinos, etc.) ; *atavism* when a latent character becomes active, as when a lost character reappears; and *saltation* where a new combination of characters is produced and where the new form being crossed with the parent-stock does not give the Mendelian ratio, as in the case of the ancon ram, the japanned peacock, etc., *if*, in fact, these cases do not really follow the same rule of inheritance as do the elementary varieties.

De Vries has pointed out that each step, each mutation, may not have been any greater than the difference between the extremes of fluctuating variations, and if this is the case we see that evolution may have been a very *gradual* process, although not necessarily a very *slow* one. Darwin's idea that the process of evolution was very gradual is in full harmony with the mutation theory, but on the latter view we can better understand how evolution may at times have been relatively rapid, and that no such enormous periods are required for the process, as the Darwinian school is inclined to assume.

The time has come, I think, when we are beginning to see the process of evolution in a new light. Nature makes new species outright. Amongst these new species there will be some that manage to find a place where they may continue to exist. How well they are suited to such places will be shown, in one respect, by the number of individuals that they can bring to maturity. Some of the new forms may be well adapted to certain localities, and will flourish there; others may eke out a precarious existence, because they do not find a place to which they are well suited, and can not better adapt themselves to the conditions under which they live; and there will be others that can find no place at all in which they can develop, and will not even be able to make a start. From this point of view the process of evolution appears in a more kindly light than when we imagine that success is only attained through the destruction of all rivals. The process appears not so much the result of the destruction of vast numbers of individuals, for the poorly adapted will not be able to make even a beginning. Evolution is not a war of all against all, but it is largely a creation of new types for the unoccupied, or poorly occupied places in nature.

Conclusions.

In the preceding pages I have tried to bring into contrast the point of view of the Darwinian school and the newer conception of the survival of elementary species. I have tried to show what selection has meant to the selectionist. They have never hesitated to take each particular character of an animal or plant, and dress it up in more perfect garments, while the body of the species, if I may so speak, has been left as it was before. There has been a continual tampering with the characters of the organism with the laudable intention of doing

with them that which nature herself seems unable to do, namely, to dissociate them from the rest of the organization and perfect them in this way or in that. It is this meddling with the fluctuating characters of the species that has been the characteristic procedure of the Darwinians, in their attempt to show how new species have been created. In contrast to this method, the theory of the survival of species assumes that a form once made does not have its individual parts later disassociated and adjusted to better fit the external needs of the species. Such a new form can change only by becoming again a new species with a new combination of characters; some of which may be more developed in one direction than before, others less; etc.

New forms on the Darwinian theory are supposed to be created by a process of picking out of individual differences. If, in addition to this, Darwin supposed that at times varieties and species crowd each other out nothing new is thereby created.* On the other hand the theory of the survival of definite variations refers the creation of new forms to another process, namely, to a sudden change in the character of the germ. The creating has already taken place before the question of the survival of the new form comes up. After the new form has appeared the question of its persistence will depend on whether it can get a foothold. The result is now the same as when species crowd each other out. This distinction appears to me to be not a matter of secondary interest, but one of fundamental importance, for it involves the whole question of the 'origin of species.' So far as a phrase may sum up the difference, it appears that new species are *born*; they are not *made* by Darwinian methods, and the theory of natural selection has

*If the survival of certain species determines, in a metaphorical sense, the kinds of future mutations that occur, the course of evolution may appear to be guided by selection or survival; but however true it may be that selection acts by lopping off certain branches, and limits to this extent the kinds of possible future mutations, the *origin* of the new forms remains still a different question from the question of the survival of certain species. This negative action of selection is not the process that most Darwinians have had in mind as the source of the origin of new species. It is true that Weismann believes that selection of individual differences determines the origin of new species, and that the creation of these new species determines the future course of variations in the same direction, but his argument that fluctuating variations can go on indefinitely varying in the direction of selection is refuted by what has been actually found to be the case when the process of selection of fluctuating variations is carried out. Most of the individuals of a species may be brought in this way to show the particular character selected in its highest degree as a fluctuating variation, but it appears not possible to transgress this limit; and rigorous selection in every generation is necessary to hold the individuals to the highest point reached. Only by the appearance of new definite variations can a given character be permanently fixed, or a new species created that will show fluctuating variations around the new standard.

nothing to do with the *origin* of species, but with the survival of already formed species. Not selection of the fittest individuals, but the survival of the *sufficiently* fit species.

There is a fundamental difference between the idea that fluctuating variations become specific characters through accumulation by selection, and the idea that new species arise as definite variations, which, with their appearance, characterize the new form as a new species. According to the Darwinian theory, natural selection performs a double duty, first, to build up new species, and, second, to maintain them in competition with other species. According to the other view, species are not formed by any kind of selection, and the question of survival only concerns the maintenance of species, already formed. The primary problem is the problem of the 'origin of species.' The central idea is not what species survive, but how species originate; no matter whether they are going to become victorious or not.

After a species has appeared it will surely be admitted by every one, that forms that can survive will survive! If Darwin's theory meant only this to those who adopted it, is it not surprising that such a truism should have been hailed as a great discovery? Was not the theory heralded because it seemed to explain how new species arose? What shall we say then when we find a situation like that existing at the present time, when we are told that after all the only difference between Darwin's theory of natural selection and the theory of the survival of definite variations is that in the one case fluctuating variations are selected, and in the other mutations, and that in both cases natural selection is the key to the evolutionary process! Is not the 'origin of species' still the real point at issue?

I yield to no one in admiration for what Darwin has done in behalf of the biological sciences, for he succeeded, where the great French zoologists failed, in establishing the principle of evolution. Furthermore no other hypothesis, that has as yet been proposed, accounts so well for the widespread *occurrence* of adaptation of organisms to the environment as does the principle of natural selection. But appreciation of Darwin's claims in these directions need not blind us to the insufficiency of the theory of natural selection to account for the *origin of species*; nor to the fact that his followers have been especially concerned in propounding and making application of this side of the theory. They have shown little interest in selection as the great conserving factor of evolution, and the reason for this is not far to seek, because of the much greater importance that they have attributed to natural selection as a creative factor in building up individual differences into specific characters.

GALILEO.

BY EDWARD S. HOLDEN, Sc.D., LL.D.,
U. S. MILITARY ACADEMY.

III.*

AN extant annotation dated February 26, 1616, which is undoubtedly genuine, declares that upon this day Galileo was summoned before Cardinal Bellarmine and in the presence of witnesses was warned of the error of the Copernican opinion taught by him, and was admonished henceforth not to hold, teach or defend it in any way whatsoever, verbally or in writing . . . which injunction the said Galileo promised to obey. The exact wording should be noticed. Upon it the subsequent fate of Galileo hangs. The document is genuine. Does it represent the facts of his examination of 1616 exactly as they occurred?

The proceedings against Galileo in 1632-3 show that the Pope and the Holy Office acted precisely as if the statements of the annotation were exact. The publication of his *Dialogues* (1631) was a *flagrant* violation of the command not to teach, etc. In the case of a personage so celebrated as Galileo nothing less than a flagrant violation would be noticed. The Roman Curia could not afford to harass him about trifles. With his defense of 1633 he submitted the following certificate:

We, Roberto Cardinal Bellarmine, having heard that it is calumniously reported that Signor Galileo Galilei has in our hand abjured and has also been punished with salutary penance, and being requested to state the truth as to this, declare: that the said Signor Galileo has not abjured . . . any opinion or doctrine held by him,† neither has any salutary penance been imposed upon him; but only the declaration made by the Holy Father and published by the Sacred Congregation of the Index has been intimated to him, wherein it is set forth that the doctrine attributed to Copernicus, . . . is contrary to the Holy Scriptures and therefore can not be defended or held.‡ In witness whereof we have written and subscribed these presents with our hand this 26th day of May, 1616. Roberto Card. Bellarmino.

Galileo's enemies had spread the calumnious reports mentioned. He wished to have a proof that they were false. Cardinal Bellarmine

* Continued from the POPULAR SCIENCE MONTHLY for February, 1905.

† According to the terms of this certificate Galileo never had 'held' the Copernican opinion—or at least he had never 'abjured' it. The annotation of February 26, 1616, commands him to 'relinquish' it.

‡ The words respecting *teaching* are not here given, it is to be remarked.

was his friend and admirer and at his request gave this certificate. Bellarmine died in 1621 and could not be called as a witness in 1632. When Galileo was called upon to defend himself for teaching the Copernican doctrine in his *Dialogues*, which had given great offense, he produced this certificate and called attention to its wording, which differs materially from that of the protocol of February 26, being much less stringent in form. In essence it is the same; to teach a doctrine as true is to 'defend' it. Cardinal Bellarmine did not have the protocol before him in writing the informal certificate. The prohibition of the latter is, however, precise and absolute; the doctrine 'can not be defended,' that is, taught in any way as if it were true. It can not even be 'held,' silently. It represented the attitude of the cardinal's mind precisely; the church would not suffer if its terms were obeyed. In reading Galileo's defense of 1632-3, we shall see the use he made of the discrepancy between these two documents, one formal and of record (February 26), the other friendly and informal (May 26).

It is the theory of Gebler in his careful history, 'Galileo Galilei and the Roman Curia,' that the genuine document of February 26 is not a true record of the facts. He admits that it was written in its proper place by the notary. He finds an 'obvious contradiction' between a formal command 'not in any way to hold or defend,' which are the words of the process of 1633, and the prohibition of Bellarmine's certificate 'not to defend or hold.' After an examination of all the documents it is impossible, I think, to take Gebler's view. It is necessary to admit the words of the genuine documents to mean precisely what they say.

Gebler lays down three facts as indisputable: '(I.) Galileo did not receive any prohibition except the cardinal's admonition not to defend or hold the Copernican doctrine; (II.) Entire silence on the subject was therefore not enjoined upon him; (III.) The second part of the note in the Vatican MS. of February 26, 1616, is therefore untrue.' My own conclusions are entirely different as to all three prohibitions. The Cardinal's admonitions are, in effect, absolutely the same as those of the formal prohibition; silence was enjoined, and more than this Galileo was forbidden to hold certain opinions even mentally and silently. If not, what does Bellarmine mean by the word 'hold'? Is it, I ask, credible that an authority that forbids a man to hold an opinion, even silently, would permit him to teach it? To ask the question is to answer it. When Galileo taught the opinion he disobeyed the orders of a Church whose authority he fully admitted during the whole of his life.

Within the assigned limits of this paper the matter can not be discussed at length. Two points may be touched upon however.

Galileo's letters to Florence in 1616 do not mention the prohibition to himself for two good reasons, *first*, to divulge the proceedings of the Holy Office would have been a serious matter; *second*, Galileo had every reason for convincing his friends that the Holy Office had only come to decisions 'purely public' regarding the Copernican doctrine, and 'not affecting my [his] personal interests' (letter of March 6, 1616).

Again, the protocol of February 25 gives the orders of the Pope that certain things should be done 'in case of his refusal to obey.' It does not explicitly enjoin or prohibit the same action after his promise of obedience. Cardinal Bellarmine had full power in such a matter. If Galileo had refused to obey he would have been imprisoned. When he had promised to abandon the opinion of Copernicus the obvious step for Cardinal Bellarmine was to bind him to effective silence by a formal promise before witnesses. The protocol of February 26 recites that this was done. The words mean, I am obliged to conclude, precisely what they say. It must not be forgotten that Galileo, like every other good Catholic, had been forbidden to hold the Copernican opinion by the general prohibition of March 5, 1616.

The reigning Pope was Paul V., who hated 'science and polite scholars.' He was very civil to Galileo, however, received him graciously (March 11, 1616) and promised him safety from his enemies. Galileo was a celebrity; by his submission to authority he had averted a great scandal in the church; accordingly the Pope was gracious. For the next seven years (1616-23) Galileo's conduct precisely agrees with the supposition that he recognized that he must not teach the Copernican doctrines. He published nothing during this period. The authorities at Rome were engaged in 'correcting' the work of Copernicus. Galileo eagerly waited for the corrections, for they would be authoritative and would exhibit the limits within which it would be permitted to 'teach.'

In May, 1618, he sent a MS. copy of his treatise on the tides to Archduke Leopold of Austria, who was friendly to him. It implicitly assumes the truth of the Copernican doctrine "which I then (1616) held to be true * until it pleased those gentlemen to prohibit the work and to declare that opinion (of Copernicus) to be false and contrary to Scripture. Now, knowing as I do, that it behoves us to obey the decisions of the authorities, and to believe them, since they are guided by a higher insight than any to which my humble mind can attain, I consider this treatise which I send you merely to be a poetical conceit, or a dream, and desire that your Highness may take it as such" The words are ironical. They will have less effect

* In this letter Galileo declares that he 'held' the opinion till 1616. He then 'relinquished' it (February 26), but never 'abjured' it (May 26).

upon us when we remember that the science of this treatise of Galileo's is quite erroneous. It denies that the moon controls the tides. The treatise was not published. It was shown in MS. to a few trusted friends, but the ideas here set forth were developed in Galileo's *Dialogues* published in 1632.

In 1618 three comets appeared in the sky. Galileo communicated his views of their nature to a few friends. He considered them to be merely atmospheric appearances which rise far beyond the moon, to be sure, and not heavenly bodies. The conclusion was erroneous, of course. In 1619 the Jesuit Father Grassi delivered a lecture in Rome maintaining that the comets were heavenly bodies (as they are). Galileo induced one of his pupils to reply to Grassi, and himself corrected the MS. work so that its severe criticisms of the Jesuit (who was, after all, defending a true thesis) are Galileo's own. A reply was written by Grassi in which Galileo is personally attacked and the Copernican system assailed. Galileo's answer is the famous *Il Saggiatore* (the assayer) which was printed October, 1623. It was brilliantly, but very carefully written, and before it was published it passed from hand to hand among Galileo's friends, who purged it of every phrase likely to be dangerous. The *imprimatur* was given on a report of Father Riccardi,* a former pupil of Galileo's, of whom we shall hear more.

In July Pope Gregory XV. died and was succeeded by Urban VIII. who, as Cardinal Maffeo Barberini, had for many years been one of Galileo's strongest supporters. A new era seemed to open with his accession. His many letters to Galileo had always been friendly, often cordial. In thanking Galileo for his letters on solar spots (1613) the cardinal had written: "I shall not fail to read them with pleasure, again and again, which they deserve. . . . I thank you very much for your remembrance of me, and beg you not to forget the high opinion that I entertain for a mind so extraordinarily gifted as yours." In 1620 the cardinal composed a poem in Galileo's honor and sent it to him as a 'proof of great affection.'

During the progress of Galileo's affair with the Holy Office in 1615 and 1616, the cardinal stood his friend and believed that it was chiefly to his own efforts that an issue so satisfactory to the astronomer personally was brought about. He was a friend to Galileo; he was not a believer in the Copernican doctrine; he made no efforts to prevent its condemnation. He proved to be inexorable where the interests of the papacy were, or seemed to be, involved. His accession was hailed by Galileo's friends, and *Il Saggiatore* was dedicated to him, and he accepted the dedication. The book is considered a model of

* Riccardi had been convinced that the Ptolemaic theory was false and had accepted in its place not the theory of Copernicus, but that of Tycho Brahe.

dialectic skill and a literary masterpiece. The original controversy about the comets is almost lost sight of. The errors of Grassi are shown up mercilessly. The Copernican system, which Galileo 'as a pious Catholic considers entirely erroneous and completely denies' is covertly defended. It is shown to agree with the revelations of the telescope; and these are proved to be inexplicable on any other system. As the Copernican opinion is, however, condemned by the church, as Ptolemy's is untenable, and Tycho's inadequate, Galileo concludes that some other system must be sought for.

In this brilliant essay—which was withheld until Galileo's powerful friend was seated in the pontifical chair—Galileo held, taught and defended the Copernican doctrine. It was supposed to be, at least, safe for him to do so in a covert way. The book was read by the Pope, who enjoyed it highly—so Galileo heard. It was examined by the Inquisition and no action was taken. By these and other signs Galileo judged that an attempt to remove the condemnation of the Copernican system might now, at least, succeed. Its weightiest opponent, Cardinal Bellarmine, an earnest, sincere and learned man, had died in 1621. Galileo proposed to go to Rome to congratulate the new Pope on his accession. The proposal was well received. Friends wrote to him: "I swear to you that nothing pleased his holiness so much as the mention of your name . . . the Pope replied that it would give him great pleasure, . . . if the journey would not be injurious to your health; for great men like you must spare themselves that they may live as long as possible."

Galileo arrived in Rome towards the end of April, 1624. He was received with the greatest honor. Every one knew the Pope to be his friend and that he had many supporters among notabilities. In the space of six weeks he was granted six long audiences with the pontiff. The Copernican system was discussed. Galileo argued warmly in its favor. He met with no success, while the Pope replied with arguments of his own against it. The new doctrine was not to be tolerated. Certain of the cardinals, at Galileo's request, engaged in the matter. The Pope was inexorable. No one can decide now what the Pope's arguments were. From the whole course of events, it seems probable that he was not satisfied that the Copernican theory was true; and it is evident that his mind was made up to allow no scandal to arise from its teaching. Galileo returned home loaded with favors. A pension was promised to his son. The Pope gave him a splendid picture, and two medals, and furthermore addressed a letter to the Grand Duke of Tuscany (June 7, 1624) in which he declares that Galileo's great discoveries 'will shine on earth so long as Jupiter and his satellites shine in heaven.' 'That you may fully understand to what extent he is dear to us, we wish to give this brilliant testimony

to his virtues and piety.' 'We have observed in him not only literary distinction, but also the love of religion and all the good qualities worthy of the papal favor.'

Galileo was again at the very summit of prosperity. He thought it safe, on his return to Florence, to write a reply to an Italian advocate, Ingoli, in which he defends the Copernican theory. In the first place he shows that he formerly defended it because of its inherent probability. He proves that he had not defended an idea improbable or unreasonable in itself. Again he desires to show the Protestant Copernicans in Germany that the heliocentric doctrine had not been rejected in Italy from ignorance of its great probability, but from reverence for Holy Scripture, zeal for religion and our holy faith.

Il Saggiatore had been well received. Why might he not go further under the favor of the Pope? All reports from Rome were favorable. And indeed he had heard (December, 1625) that the Pope had listened to several passages from this last pamphlet and had highly approved them. If he had gone so far, why then might he not go still farther? On the surface of affairs there was no apparent reason. Up to this time Galileo had preserved the forms fully. He professed not to hold Copernican doctrines. Not holding them, how could his writings be taken as teaching or defending them? The Pope, his friend, had not disapproved his previous writings. Galileo misinterpreted this as a sign of his toleration of the doctrines. It is now apparent that the Pope's whole course was consistent. He desired to give Galileo every liberty, but was sternly set against any teachings that would diminish the authority of the Church. From first to last he was unconvinced of the scientific truth of the Copernican opinion. He had personally befriended and honored Galileo. He looked for a grateful acknowledgment in return. Galileo had been denounced by his enemies, but they were overawed, and would certainly take up no quarrel in which he was not flagrantly disobedient to the prohibition of 1616. *Il Saggiatore* had been a brilliant success. He now set about arranging another work—the *Dialogues on the two principal systems of the World*—parts of which had been in hand for some years.

This is the place to record Galileo's share in the invention of the microscope. While he was in Rome (1624) a complicated microscope was shown to him that had been invented by Drebbel, a Dutchman. Galileo simplified and greatly improved it. His relation to the invention of the telescope and of the microscope is the same. The first ideas came from others; Galileo put them into practical forms. The real inventor of the microscope is not Drebbel, but Zacharias Jansen, a spectacle maker of Middleburg who made the first instruments in the last years of the sixteenth century, before the telescope was invented, therefore.

Galileo's dialogues on the system of the world (1632) have, at the head, a Greek epigraph:

In Every Judgment beware of Your Prejudices!

They are dedicated to the Grand Duke of Tuscany. The personages of the *Dialogues* are Salviati (Galileo himself) who maintains the Copernican doctrines; Sangredo, a man-of-the-world, intelligent, but not a savant; and Simplicius, a convinced Aristotelian, a dull fellow, always worsted in the argument. Galileo's enemies convinced the Pope that Simplicius stood for the Pontiff himself. The subjects discussed are the fall of bodies, the flight of projectiles, the principles of mechanics, the rotation and revolution of the earth and of the planets, the system of Ptolemy—and here Sangredo remarks that he knows many disciples of Ptolemy who have become Copernicans, but not one Copernican converted to the ancient system. The new star of 1572 is shown to have been far more distant than the moon, by long calculations (and it is noteworthy that logarithms are not employed to shorten the work). The preface recites that, some years previously a 'salutary edict' had been promulgated at Rome which, to prevent scandals, forbade the teaching of the Pythagorean opinion of the earth's motion,* that some hardy spirits had, nevertheless, dared to declare that this edict had been issued without comprehension of the matter and that it was the result of passion, and not of judicial examination. It had been said that advisers entirely ignorant of astronomy ought not to have thus clipped the wings of philosophers.

My zeal, says Galileo, can not support these rash complaints. Well understanding this prudent decree, I wish to do justice to the truth. I was then at Rome; the most distinguished prelates heard and applauded me; the decree would not have been issued without giving me some knowledge of it. I, therefore, wish to show to foreign nations that in Italy, and even at Rome, all that could be advanced in favor of Copernicus was known, before that censure was published. I declared myself the advocate of Copernicus. Proceeding according to a mathematical hypothesis, I endeavored to prove it to be preferable to that which declares the earth at rest, not in an absolute manner preferable, but in the sense in which it is attacked by pretended Aristotelians, who in their philosophizing neglect observations. He will show, he says, certain advantages of the heliocentric system. If Italians have not assented to the mathematical opinion of the motion of the earth, it is not because all of them have been ignorant of the reasons others allege in its support, but because they have other reasons

* This general edict, of course, included Galileo, whether there was any special command laid upon him or no.

based on piety, religion, on a knowledge of divine omnipotence and the weakness of the human understanding. It is the opinion of good authorities that the foregoing introduction was first written by Galileo, then revised by the censor at Rome—perhaps by the Pope himself—and finally returned to the author with permission to make such verbal changes as would not alter the sense of the Roman revision.

In the *Dialogues* the three interlocutors proceed to construct a scheme of the universe, step by step. The construction is made by Simplicius, and the system proposed by Copernicus and demonstrated by Galileo emerges triumphant. All the glory is for Copernicus and his advocate, Galileo. No credit is assigned to Kepler for his discoveries which had done away with the whole apparatus of epicycles retained by Copernicus. Kepler is not mentioned here or elsewhere with praise. Simplicius objects to some mathematical reasoning because Aristotle recommended his disciples to abstain from geometry. Salviati thinks Aristotle wise; for geometry is the art by which his errors and deceits are discovered. As to the empty spaces beyond Saturn: who are we to judge of the greatness of the universe? Can we say that these spaces are useless because we see no planet there? May they not be peopled with invisible planets? Who suspected the existence of the moons of Jupiter? Who tells us that all the heavenly bodies were created for *us*? Certain authors—Kepler, for one—assert that tides are caused by the moon. Galileo will not waste his time in refuting such assertions. Nothing is so astonishing to Galileo as that Kepler, a free and penetrating spirit, should have assented to such ‘ineptitudes.’ Simplicius on his part declares that the tides are miracles. In all the book there is no discussion of Scriptural texts.

It is not necessary to carry the analysis of these famous dialogues further. The arguments employed are so familiar to us that we forget they were once fresh and novel. They were accepted by Galileo’s contemporaries as witty and brilliant, and even now Italians admire their style, though most English readers find them, as a whole, prolix, not to say dull. The Copernican doctrine is enforced in every possible way. Every argument for the Aristotelian theory is brought forward, in turn, by Simplicius only to be utterly refuted. Sarcasm is unsparingly employed. Simplicius is not only wrong, but ludicrously so. After each unusually convincing passage Salviati is careful to add that, after all, the Copernican doctrine is a ‘fantasy’ or a ‘vain chimera.’ At the termination of the dialogues, which extend over four days, no general summing-up is made. The reader is left to draw his own conclusions. Salviati apologizes to Simplicius for the ardor of his language and assures him that he had no intention to offend him, but wished rather to stimulate him to communicate his ‘sublime’ ideas—ideas which have been utterly refuted in the course

of the book. 'Your reasons,' says Simplicius, 'are most ingenious; but I do not believe them to be either true or conclusive.' Then Simplicius recalls a wise reflection, made formerly, in his presence, by an eminent personage before whom all must bow, as follows: 'We observe,' he says, 'nothing but appearances; by what right do you presume to limit the power of God by fixing the ways in which it has pleased Him to produce them?' These are the very words spoken by Pope Urban to Galileo in 1624. They were considered conclusive by the Pope. In the mouth of Simplicius they ring hollow.

It must not be forgotten that Galileo's theory of the tides upon which the *Dialogues* turn is, in itself, entirely erroneous. The tides are not due to the moon, he says, but to certain motions of the earth, which are then discussed. The first motion is its rotation round an axis, the second its motion of revolution about the sun, and there is a third motion by virtue of which its axis of rotation is constrained to pass always through the same stars. The third motion (invented by Copernicus) is superfluous. The axis of the earth is always parallel to itself as it moves round the sun. Two motions are sufficient to account for all the phenomena; the third does not exist. It was, however, upon this third motion that Galileo founded his theory of the tides, which is, therefore, baseless. Many of his arguments for the Copernican doctrine are irresistible. Those founded on the tides are, necessarily, erroneous.

To obtain the authority to print the *Dialogues* Galileo went to Rome (May, 1630), where his friend and former pupil, Father Riccardi, was censor (master of the Sacred Palace). Without the *imprimatur* nothing could be printed. When the *imprimatur* of the censor was once given to any book its author was *prima facie* relieved from responsibility. In the subsequent proceedings against Galileo it was charged that he obtained the *imprimatur* by a 'ruse.' The history, as understood at Rome, was briefly as follows: In May, 1630, Galileo took the MS. to Rome, submitted it to the master of the Sacred Palace (Riccardi) and asked permission to print. Riccardi wished, for greater security, to review the book himself. To save time, it was agreed that the book should be printed at once and that the sheets, leaf by leaf, should be sent to Riccardi. To carry out this plan the *imprimatur* was given for Rome. Galileo soon went to Florence and from thence asked the censor for permission to print at Florence. This permission was refused. Riccardi insisted that the sheets should be submitted to him according to the original agreement. The plague was then raging throughout Italy and it was impossible to transmit parcels from Florence to Rome on account of the quarantine.

It was finally arranged through the Tuscan ambassador, Niccolini, that the printing should be done at Florence under the condition of

the submission of the whole work to a competent theologian of the Benedictine order, and that the introduction and conclusion should be sent, before issue, to the censor at Rome. The whole matter was then transferred to the inquisitor at Florence and the book was printed with the entire approval of Father Stephani, who had been charged with its supervision. The introduction and conclusion were duly sent to Rome, but the Roman censor kept them for months without giving his approval or, in fact, without communicating with Galileo. It was clear that Riccardi was doubtful. Through the Tuscan ambassador at Rome renewed efforts were made by Galileo to obtain Riccardi's approval, and, in the meantime, without waiting for it (March 1631) the printing was proceeded with at Florence. Riccardi (April 28, 1631) at last answered Galileo's request, refusing the *imprimatur* until new conditions had been fulfilled. The censor, in this letter, recalled the fact that this original *imprimatur* was only given conditionally.

"Father Stephani," says the censor, "has no doubt subjected the book to a conscientious revision; but as he was not acquainted with the Pope's views he had no power to give any approval, etc." A desire to delay the whole matter is evident. Riccardi fears for himself; he knows the Pope's views; he is a firm friend of Galileo's also. After further negotiations (May, 1631) the whole matter was referred to the inquisitor at Florence with full powers. Riccardi conveyed to the inquisitor the 'views' that must govern his decision: The Copernican system must be treated only as a mathematical hypothesis; there must be no reference to Scripture; the introduction and the conclusion of the book the censor will send from Rome. Accordingly, they were sent with permission to Galileo to change the rhetorical style but not the matter. It is the opinion of certain good authorities that the Pope himself revised the introduction. The book was finally printed (February, 1632) with the *imprimatur* of Rome and also of Florence. The authorities at Rome had not seen the text of the *Dialogues*. It appears that throughout the long and vexatious delays Galileo obeyed all explicit instructions given by the censors. There were good reasons for removing the printing of the work to Florence. It is, however, certain that it would never have been authorized in Rome in its final shape.

(To be continued.)

THE CULTIVATION OF TOBACCO IN THE PHILIPPINES.

BY A. M. SANCHEZ.

BUREAU OF AGRICULTURE, MANILA, P. I.

TOBACCO was introduced into the Philippines soon after the Spaniards took possession, seed being brought from Mexico by Spanish missionaries. For many years little or no effort was made to restrict or encourage its cultivation, until 1781, when the cultivation and sale of tobacco was declared a state monopoly. In the tobacco-growing districts of Luzon, each family was compelled to grow a certain number of plants and deliver the entire product to the agents of the government; no tobacco could be reserved for the use of the planter. Houses were searched for concealed tobacco and fines imposed for infractions of the law. These harsh provisions occasioned many riots and disturbances, and the monopoly was finally abolished in 1882. Since then, the cultivation and manufacture of tobacco have been in the hands of private individuals and companies.

At present tobacco-growing is one of the principal agricultural industries in the Philippines. The greater part of the tobacco is grown in the Island of Luzon, principally in the provinces of Isabela, Cagayan, Union, Ilocos Norte, Ilocos Sur and Batangas. Small quantities of tobacco are grown in the Visayan and southern islands, the greater quantities probably being produced in Masbate, Tablas, Panay, Bohol, Leyte, Siquijor, Negros and Mindanao.

The best quality of tobacco is grown on the light alluvial soils of the Cagayan River, in the provinces of Isabela and Cagayan. Isabela tobacco burns smoothly and freely, with a pleasant taste. The leaves are smooth, small in vein, thin in texture, stretch and cover well, and have an agreeable aroma.

Philippine tobacco is highly esteemed in the Orient. Its agreeable aroma and flavor have won for it a high place among cigar tobaccos. When we consider the desirable qualities of Philippine tobacco, with the primitive methods of cultivation in use, the imperfect curing and fermentation it receives, and the modern methods of treating the crop in America and other countries, it becomes quite clear that with modern scientific treatment, Philippine tobacco would be greatly improved, if not raised to rank among the best tobaccos of the world.

Soils and Fertilizers.

In the Cagayan Valley, where the best tobacco is grown, the general character of the soil is a sandy loam, three feet or more in depth,

easily cultivated and in good physical condition. Small areas of loam or heavier soil are found in several places; but these are usually low depressions, where flood waters accumulate and stand long, thus allowing the fine particles of clay carried in suspension to settle on the surface of the ground. The lands cultivated to tobacco are the bottoms or lands subject to floods from the high waters of the Cagayan River. Once or twice during the rainy season these lowlands are flooded to the depth of several feet by water carrying in suspension considerable quantities of fine sediment rich in fertilizing matter which, on standing, is deposited on the surface of the soil. No artificial fertilizer is used on the tobacco lands, and plants are entirely dependent on the fertilizing action of floods to supply the necessary amounts of the elements of fertility.

While the amount of fertilizing matter annually furnished these soils by the overflows of the Cagayan River is considerable, there is no doubt that with the aid of fertilizers much better results would be obtained.

Growing Tobacco under Shade.

In the province of Isabela one hectare of land was devoted this year (1903-1904) by one of the tobacco companies to an experiment in growing tobacco under shade. The construction of the shade was the same in all essential particulars as that commonly used in the Connecticut Valley and in Florida for growing fine-grade Sumatra tobacco, except that bamboo and bejuco (rattan) were substituted for hard-wood posts and nails. Owing to unavoidable delays, the field was planted too late in the season to obtain a representative result this year. It was observed, however, that the plants under shade were not attacked by insects and had broader, finer and darker-colored leaves than the plants outside. The superintendent in charge of the work expressed himself as convinced of the practicability of this method for producing a fine grade of tobacco for wrapping purposes. The Insular Bureau of Agriculture will conduct an experiment the coming season in growing Sumatra tobacco under shade.

Methods of Cultivation in Use.

The first operation in growing tobacco is the preparation of the seed-bed. This the native usually makes near his house, or preferably, in some cleared piece of ground in the woods near by. New or virgin soil is preferred, so that the young plants can have a vigorous growth and be in suitable condition for transplanting. Any brush and stumps that may be on the land are gathered and burned until entirely reduced to ashes. The ground is then stirred with the native plow or with an iron bar having a flattened end with a sharp edge.

After breaking up all large clods and leveling the land, the seed is scattered broadcast on the surface and by means of planks pressed into the soil. Usually a shade is placed over the bed to protect the young plants from the direct rays of the sun. Forty to sixty days after planting, the plants are ready for transplanting. This begins about the last of December and is continued until the middle of February. Experience has shown that transplanting later than March does not give satisfactory results. The preparation of the field to which the young plants are to be transferred consists of plowing and harrowing, in which operations the corresponding native implements are used.

The ground being stirred, the native provides himself with a string of the same length as the width of the field. Each end of the string is securely attached to a stick for the purpose of laying out the rows. Sometimes the string itself is divided into spaces of two and one half feet by securely tying red ribbons at these intervals. These show where the plants are to go in the rows. After stretching the string across the field, the holes are made with a stick or bolo, about three inches deep and three inches wide. The holes are watered immediately after the plants are put in. The planting is done in the evening or very early in the morning, when the rays of the sun are not strong. After six or seven weeks from the transplanting the plants are usually ready for topping.

Topping.—When the flower buds begin to appear topping is begun. Usually from fifteen to twenty leaves are left on each plant.

Worming.—The battle with the worms begins in the seed-bed and does not end until the crop is harvested. No poisons are used, but the worms are caught by hand and killed. This is usually done in the mornings or late in the evenings.

Harvesting and Curing.—As a general rule the tobacco is primed; that is, the leaves of the plant are removed as they mature. It is customary to make five gatherings at intervals of about a week. The native collects the leaves and places them in large baskets which, when filled, are carried to the drying-shed in rough sleds or carts. If the soil is rich, a second profitable crop is produced from the suckers. As soon as the original crop is topped, suckers will sprout from each leaf. These, of course, are broken off as soon as they appear, otherwise they would hinder the growth of the leaves. When all the leaves have been primed from the original stalk, except three or four at the top, two suckers are allowed to grow from the bottom of the stalk. When the remaining leaves are removed, the stalk is cut just above where the suckers sprout and the field is immediately cultivated. It is claimed that when the season is favorable very good filler-tobacco is produced from the suckers.

In the drying-shed the leaves are sorted, usually into five classes,

according to the size, color and condition of the leaf. The sorted leaves are put on sticks about one meter in length, the classes being kept separately. One hundred tobacco leaves are put on every stick and this is hung on the drying-shed to dry. The drying-shed most generally found in this country is made in the shape of the native house with roof, but with uncovered sides. The sticks with the tobacco leaves are hung on supports, usually set at the following distances: The first about five feet from the ground, the next two feet higher, while the succeeding ones usually have a distance between them of from three to four feet. It is seldom that the native takes the trouble to cover the sides of his shed and thus protect his tobacco from the intense sunlight, strong winds and rains. I have seen large quantities of tobacco hung on rafters to dry in the open fields, without any covering whatever to protect the leaves from the searching rays of the sun, and from the rains and dews. Again, the practise is very common of hanging the tobacco on poles horizontally suspended from the floors of the native shacks. More attention should be given to the proper construction of drying-sheds if the best results from the curing are to be obtained.

When dried, the tobacco is taken to some company's curing-house, where the first fermentation is done. The tobacco during this fermentation is still on the sticks used for hanging. The piles are kept at a temperature of between 35° and 40° C., the object being to give the tobacco a little color for guidance in classification and in further curing. After the first fermentation is complete, the tobacco is divided into five classes according to length and quality of the leaves. In the second fermentation, which is made with the tobacco in fardos, the temperature is kept at about 55° C. The piles are frequently turned over to secure the proper heat and regulate the fermentation. The success of the operation depends principally on the experience and skill of the manipulator, as there are so many vital points that enter into consideration.

The curing-houses owned by the several tobacco companies are not constructed so as to get the best results from the fermentation. Usually ventilation is lacking, and it is very difficult to control the fermentation the way that it should be done in order to obtain the shades of color in the tobacco which the market demands.

Yields of Tobacco.

The yields vary greatly with the seasons and also with the character of the soil. An average for several years from one acre is 610 lbs. In favorable seasons 3,000 lbs. of dry tobacco have been obtained from one acre of land.

LIFE IN A SEASIDE SUMMER SCHOOL.

BY PROFESSOR CHARLES E. BESSEY,
THE UNIVERSITY OF NEBRASKA.

LATE one night in August I boarded the staunch little steamer 'Queen City,' at Victoria, and steamed out upon the Strait of Juan de Fuca, and up the western coast of Vancouver Island. This remarkable body of water, fifteen miles wide and seventy miles long, is the common gateway for British and American vessels. The treaty which settled the boundary dispute many years ago (1846) fixed the international line in the middle of the strait, so that each country has a broad and deep water passage to the Pacific Ocean. As we proceed northwesterly up the coast on the British side of the strait, the rugged and rock-bound coast of Vancouver Island rises on our right, while across the water is the Olympic coast of Washington. Of both shores little more is known than the mere coast line and a narrow strip near the water. Back of the shore line are foothills running back to the mountains still beyond them and covered all the way with dense and almost impenetrable forests of cedar (*Thuja plicata*) and fir (*Abies amabilis*). We steam along slowly, for this is a dangerous coast, and there is a heavy swell on the water and enough fog in the air to obscure the details of the shore line.

It is broad daylight when we turn into the deep harbor of Port Renfrew, almost directly opposite Cape Flattery, and come up to the long wharf. Here we find Jackson, the genial little Englishman, who fills the several offices of harbormaster, postmaster, storekeeper and hotelkeeper. When the boat comes in from Victoria, as it does once in a week or ten days, Jackson is a very busy man, but then he has a long time in which to recuperate before the next arrival of the boat. While he is looking after the freight and luggage, and sorting over the mail, we go to the big summer hotel and ask 'Jim,' the Chinaman, to get an early breakfast for two. My companion is a genial geologist, who has been here before, and knows Jim, and how to persuade him into complying without too great delay. While waiting for breakfast we look northward over the harbor to the foothills which surround it, and whose sides are covered with dense forests down to the water's edge. I have rarely looked upon a scene of such natural beauty, and stood long feasting my eyes upon sky and mountain, and forest and water.

Breakfast eaten, and the camp mail secured, my genial geological friend advises me to prepare to take the trail to the camp several miles away, which I do by putting on canvas leggings and stout hob-nailed shoes. We try to dicker with the Indians (familiarly known as the 'Siwashes') to take our heavy luggage to the camp by canoe, but they are lazy and rapacious, and refuse to do so unless we pay several times the usual price, which we in turn refuse to do. So we take what we need most and start out over the trail. And such a trail! It begins fair enough, looking quite like an ordinary trail, but soon it changes into a mere path, and then abruptly drops down the slippery sides of a canyon, crosses a stream, and runs straight up



THE MINNESOTA SEASIDE STATION: LIVING HOUSE IN THE BACKGROUND;
LABORATORIES IN THE FOREGROUND.

the other side. The geologist leads the way, carefully planting his feet in the notches in the canyon side, and I follow, thankful for the big hob-nails in my shoes. He jumps the stream, and so do I, and then he scrambles up the steep wall on the other side, and I follow, puffing and panting. At the next canyon the trail literally takes to the trees, crossing by a fallen tree whose trunk is slippery with damp mosses and lichens. Those blessed hob-nailed shoes do their duty, and I reach the other side safely, only to find my companion far ahead crawling under some fallen trees under which the trail runs.

But all things come to an end, and so does this wonderful trail.



LOOKING ACROSS THE STRAIT OF JUAN DE FUCA TO THE OLYMPIC MOUNTAINS
FROM THE STATION.



A TYPICAL FOREST SCENE NEAR THE STATION. Near the center is a cedar (*Thuja plicata*) with firs (*Abies amabilis*), spruces (*Picea sitchensis*), and hemlock (*Tsuga heterophylla*) near by.

It has been more interesting in other ways than in its crookedness and difficulties. At the port the trees were so tall and large as to attract attention. But as we went deeper into the forest the cedars, spruces, firs, hemlocks and pines became so much larger that we had to stop now and then to admire their giant trunks, and their great masses of green foliage a hundred feet and more above our heads. Huckleberry bushes of two species (*Vaccinium ovalifolium* and *V. parvifolium*) grew by the trail side offering their tempting fruit to us as we passed. There were mosses and lichens everywhere, sometimes hanging from the branches in great masses, a foot in diameter and a yard in length. At our feet, by our side, even on the mossy trunks of the trees, were pretty flowers of many species,



THE GEOLOGIST'S LECTURE IN THE WIND-WORN COVE.

ferns, and even shrubs in profusion. On the ground here and there were gigantic ferns (*Pteris aquilina lanuginosa*) seven to eight feet high, and a yard across, and looking more like shrubs than the modest brakes of the east.

Do you marvel that I call this a wonderful trail, and that in spite of its length and difficulties it was so full of interest that these were soon forgotten, and only its beauties and scientific interest remembered?

The camp, technically known as the Minnesota Seaside Station, consists of a substantially built log living-house and two laboratories, which stand on the shore overlooking the strait of Juan de Fuca and



YOUNG ZOOLOGISTS GETTING SERPULIDS AND STARFISHES.

the Olympic Mountains of Washington. The beach is rocky, and on the rocks and in the water are immense masses of giant seaweeds. Here we are received by the director, a tall, stout man with a twinkle in his eye; the sub-director, a merry little woman, whose speciality is



COLLECTING GIANT KELPS AT LOW TIDE.

the study of the seaweeds, and the chaperon, a cheery old lady, the mother of the sub-director. I look into the big room in the living house and note the great fire-place with a big settee on each side, which promises solid comfort in the cool evenings.

With the director I go to the laboratories, where we find three rooms, in all of which students are hard at work. Here are tables, microscopes, reagents, books and other laboratory apparatus, and the rooms look much like the laboratories in the colleges and universities, except that here the furniture is roughly made by carpenters. We go down to the beach and take a close view of the seaweeds, the hermit crabs, sea anemones and star fishes. We look up and note the gigantic size of the trees which form the forest background. We hear the clangor of a bell, and the director suggests that we hurry back to camp, for that is the noon-day dinner signal. He takes us by the men's 'lavatory,' which is a quiet brook near one of the laboratories. Towels and soap are here in profusion, for every man supplies his own. Here, day by day, the men perform their ablutions and make their toilets. The water is always abundant and the toilet room is never overcrowded!

The dinner served in the big room was quite characteristic of our camp life. On each side of two long tables were long plain benches. Over these we stepped to our assigned places. Potatoes, turnips and bacon, with bread, butter and tea, all in generous quantities, constituted the substantial meal. It was a merry meal, as were all our meals. When twenty-two hungry campers sit down to a 'square meal' there is always much jollity. Dinner over, the noonday lecture was announced to take place in a shady spot two hundred yards from the camp. It was given by the director, who sat on a log, and talked to us on the characteristics of the spruce, hemlock and fir trees of the region, while his audience sat on other logs or on the ground near him. Above us are the trees under discussion, and at our feet are the cones which have fallen from them. So we have a bit of out-door laboratory work while listening to the lecture. When we break up, some go to the laboratories, while others stroll over the rocks hunting for specimens.



A VANCOUVER COAST OCTOPUS.



'JOHN,' THE INDIAN FISHERMAN, BRINGING SALMON; GIANT KELPS (*Nereocystis*) IN THE WATER BEYOND.



INDIAN BASKET-MAKERS; LOW TIDE, EXPOSING ROCKWEEDS (*Fucus*)

Later in the day we take in a quiz given by an instructor to his class in bacteriology. After supper, which is much like dinner, an evening lecture is given by another instructor, who tells us about Agassiz and his work, while we sit about the fireplace, with its crackling fire of driftwood, for the evening is cool, although it is August. A little later I am shown to my berth in the men's compartment on the second floor. The carpenter had built plain wooden berths in tiers of two each, and these have had boughs of cedar laid in them on which I roll in my blankets and sleep soundly. A similar compartment is provided for the women of the party, and here our chaperon gathers her charge. The sounds of the retreating tide as the waves lap upon the rocks lull our senses, and we sink into such a sleep as only those can enjoy who live in camp.



WATCHING THE BLACK-FISH.

The roar of the breakers wakes us early, and I go down to the beach and walk along its rocky ledges for half a mile and watch the swaying kelps (*Nereocystis*) and the nodding sea palms (*Postelsia*) as the waves dash over them. A messenger comes to call me to the breakfast I am forgetting, and we hurry back by a short cut over the neck of a promontory, crossing a canyon on the trunk of a fallen spruce five or six feet in diameter. On its upper side it carries several large trees, and yet its wood is as sound as when it fell a century or so ago. After breakfast the sub-director instructs her class in seaweeds for a couple of hours, when the director takes them and goes

down the beach in search of those giant brown plants of the ocean, called kelps. He leads us a merry scramble, and at last finds what he is looking for (*Dictyon neuron californicum*) and sits on a boulder and gives us an open air lecture upon kelps in general and this one in particular. At its conclusion he announces that we must hurry back in order not to be late to dinner, for promptness in all things is the rule in this school. He who does not appear at meal time doesn't get any meal, that is all. It is a simple rule, and it is very effective.

After the noon meal the geologist takes his class out for their first lecture, finding a rocky, water-worn cove close by the water, where



A JULY NIGHT ON VANCOUVER ISLAND.

we gather while he tells of the agency of water in rock formation and sculpture, with the cove itself as an example. No method of instruction could be more simple, none more effective. After the lecture we wander for hours over the rocks and study the strata in the cliffs above us. When we get tired of rocks we peer into the tide-pools and study the wonderful vegetation, of a kind all unknown to the inland botanist. Then we poke the spiny sea urchins in their snug niches in the pools, and pester the curious sea anemones, which are to be found everywhere. We watch the crabs, who in turn watch us and scuttle away sidewise with a very knowing look in their funny eyes.

And thus the days go. There is always something a-going. One

evening a mysterious play regarding the 'Hodag' is performed in a lantern-lighted dell in the forest, followed by a sober lecture upon the superstitions of mankind and the difficulties met with in attempting to eradicate them. Another evening a scientific comedy is enacted, followed by a lecture on the structure and activities of the cell, which the play illustrated. Near the close of the session an evening is given to athletic sports, and another to a social dance, in which the music is furnished by a squeaking phonograph.

On the last Sunday evening the geologist gave us an address on 'Science and Religion,' and on the night before camp was broken up the writer hereof gave the closing address on 'The Place of Science in Education.' Yes, we were busy, and learned a great deal not only about the plants and animals and rocks, but many other things as well. The director proved himself a genius in his management of the school and camp, and when we broke up we parted from him with the keenest regret.

Who goes to such a summer school you ask? That can be answered best by giving a list of those who were there this season. First there were the officials, director, sub-director, chaperon, geologist, doctor and professor. Then the students were a Chicago school teacher, a St. Paul high school teacher of science, three university instructors, two Minneapolis teachers, an Illinois high school teacher of science, six university students and one high school student. The writer may be included here as the guest, making a party of twenty-two in all. I can not think of a more helpful session of combined study and 'outing,' nor of a more natural and effective method of giving and receiving instruction than that in this seaside summer school on Vancouver Island.

THE PROGRESS OF SCIENCE.

THE NOBEL PRIZES.

As has already been noted here the Nobel prizes in science have this year been awarded to Lord Rayleigh, Sir William Ramsay and Professor Ivan Pavlov. Each of these men of science has that international reputation which is said to be the best forecast of the verdict of posterity. Lord Rayleigh and Sir William Ramsay are famous for their joint discovery of argon, to which the latter has added helium, neon, krypton and zenon; but each has long been known as a leader in his science. Lord Rayleigh's great work is his 'Theory of Sound'; his collected papers, recently published, cover a wide range of subjects in mathematical physics. He was Maxwell's successor in the chair of experimental physics at Cambridge, now held by Professor J. J. Thomson, but has since 1884 carried on his researches in his private laboratory in his country place in Essex. Lord Rayleigh is one of those who have given distinction to science in Great Britain without holding a professional position, a class unfortunately lacking in this country. Like Darwin and others of this class, he also represents a hereditary interest in science, his brother having done scientific work, and his son having this year been nominated for membership in the Royal Society. Sir William Ramsay, who has recently been knighted, is professor of chemistry in University College, London. Apart from his discovery of new elements and their properties, he has done important work on the molecular surface energy of liquids and in other directions, including improvements in the teaching of chemistry. His recent visit to America has left most pleasant

memories. His address on the 'The Present Problems of Inorganic Chemistry,' given at the St. Louis Congress was published in the issue of this journal for November last. Professor J. P. Pavlov is less well known to Americans than Rayleigh and Ramsay, partly because his researches were originally published in a language difficult to read. His important work on digestion with special reference to the control of the nervous system was translated into German in 1898, and by specialists, at least, it is now fully appreciated. He has also made important improvements in technique and discoveries in regard to the formation of urea, the functions of the liver and in other directions. He is professor in the Imperial Institute for Experimental Medicine at St. Petersburg, which is liberally supported by the Russian government.

It will be remembered that Alfred Nobel, who amassed a fortune by the invention of dynamite, bequeathed it to form a trust, which amounts to about \$8,000,000, "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



LORD RAYLEIGH.

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 reduction of standing armies, as well as for the formation and the propaganda of peace conferences."

It appears that the explicit directions of the founder have been violated in at least two ways. Certain local Nobel

institutes have been established at Stockholm, on which about a third of the income is spent, and a prize has in no case been awarded to a man for work done or made known 'in the course of the preceding year.' It would be unfortunate to violate a trust of this kind, even though its provisions were unwise; as a matter of fact the instructions of Nobel were better considered



SIR WILLIAM RAMSAY

than the substitute. Very large prizes, say \$50,000 each, for the best scientific work of the year, given often to young men, would more directly stimulate research and would be more useful to the recipients than prizes given for general eminence.

The prizes in the sciences have been awarded as follows:

	PHYSICS.	CHEMISTRY.	MEDICINE.
1901.	Röntgen.	Van't Hoff.	Behring.
1902.	Lorenz and Zeeman.	Fischer.	Ross.
1903.	Becquerel, M. and Mme. Curie.	Arrhenius.	Finsen.
1904.	Rayleigh.	Ramsay.	Pavlov.

The prizes have gone three times to England and to Germany; twice to Holland (though Van't Hoff is now in

Berlin) : once to France, to Sweden, to Denmark and to Russia.

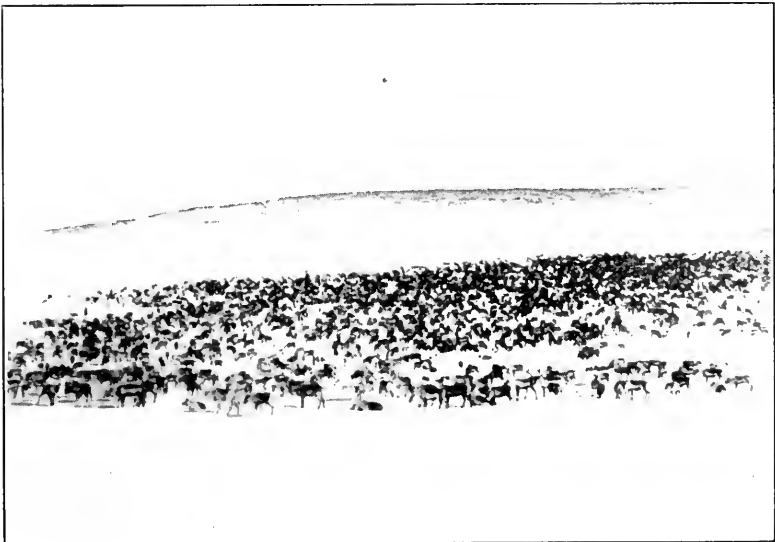
The Independent raises the question as to whether America has been neglected, and asks for a vote for five Americans who deserve the prize next year. It must unfortunately be acknowledged that no American deserves the prizes in science on the lines followed by the administrators of the trust. Nobel himself laid special stress on an invention benefiting mankind, and Dr. Bell and Mr. Edison are here preeminent. In pure science Willard Gibbs deserved the prize, but we have now no physicist, chemist or physiologist as eminent as Europeans who could be named. We stand better in some other sciences, and we may hope in work being carried forward by men who may ultimately attain international eminence.

THE JESUP NORTH PACIFIC EXPEDITION.

MR. MORRIS K. JESUP, president of the American Museum of Natural History, provided in 1897 means for a thorough ethnological exploration of

the northern coast of North America and Asia from British Columbia to the Amur River. The expedition has resulted in valuable accessions to the American Museum and in important ethnological, archeological, linguistic and anthropometric studies, which are now in course of publication in twelve volumes under the editorship of Dr. Franz Boas, of the American Museum and Columbia University. Investigations along the northern coast have been carried out by Messrs. Boas, Faraud, Smith and Teit, and on the Asiatic side by Messrs. Laufer, Fowke, Jochelson and Bogoras.

The memoir last published is an account of the material culture of the Chukchee, the tribes inhabiting the extreme northeastern corner of Siberia, of special interest consequently to those who speculate on the past peopling of the Americas by way of Bering Strait or the future construction of telegraphs and railways through these regions. It also has an adventitious interest just now in view of a possible change in sovereignty. It appears, indeed, that this territory has not been completely



REINDEER HERD.



REINDEER CHUKCHEE YOUNG MAN.



ESKIMO GIRL.



MARITIME CHUKCHEE WOMAN.



REINDEER CHUKCHEE WOMAN.

subdued, the Russians having withdrawn in 1764, leaving the inhabitants to settle their affairs according to their own customs. Commerce has in part accomplished what force failed to do, though the bulk of the territory remains exempt from any trace of Russianization.

The Chukchee number only about 12,000, of whom about one quarter are maritime and three quarters are reindeer people, while there are about 1,200 Eskimo on the coast. It is not settled

as to whether the Chukchee and Eskimo belong to the same stock. Types of Mongolian faces are not uncommon, and at present there is a good deal of admixture. The domestication of reindeer is characteristic of the tribes inhabiting the Asiatic side of Bering Sea, and their economic condition resembles that of the more southerly cattle-breeding tribes. The large size of some of their herds is shown in the illustration. The Chukchee depend on reindeer for clothing and for food; for the

covering of their huts and for transportation. Great numbers of these animals are annually slaughtered, Mr. Bogoras having used as many as fifty in one month as food for his dogs. The price of a reindeer is a package of brick tea and a bundle of tobacco, the value of which is together about a dollar. The maritime Chukehee engage principally in fishing and there is a good deal of exchange between them and the reindeer people.

The houses have a wooden frame covered with skins, sometimes protected as shown in the illustration, by sods or stones. The diameter of the hut or tent is from fifteen to twenty-five feet, and there is an inside room usually about 4 ft. 6 in. in height, 7 ft. in breadth and 12 ft. in length. Fifty or more reindeer skins are used to cover one of the huts, and they require a great deal of care. New skins are used in winter and old skins in summer. Fire is used for cooking, but scarcely heats the house beyond the temperature of the outside air. The inner compartment is lighted by a lamp, but is heated chiefly by the bodies of the inhabitants. As the inner room is used

not only for sleeping, but also for eating and entertaining, every square foot is occupied.

The maritime Chukehee eat chiefly the meat of sea-mammals, while the others depend on the reindeer. They like raw frozen meat, and do not object to its being putrid. They drink tea and smoke tobacco continually, and use as much alcohol, which may be unrectified and undiluted 95 per cent. spirit, as they can get.

Fly-agarie is the only means of intoxication discovered by the natives of northeastern Asia. It is made from mushrooms and appears to produce effects similar to hasheesh. The sense of smell of the natives is said to be very acute; their color nomenclature is defective, which may be due to defective vision or to lack of interest in colors.

SCIENTIFIC ITEMS.

SEÑOR MANUEL GARCIA celebrated his hundredth birthday on March 7 in excellent health. He gave the first performance of Italian opera in New York City in 1825, and was long celebrated as a teacher of singing. His important



CHUKCHEE WINTER HOUSE.

contribution to science was the invention of the laryngoscope fifty years ago. Senhor Garcia was presented with a portrait of himself by Mr. John S. Sargent and received a number of congratulatory addresses with decorations from King Edward, Emperor William and the king of Spain.

THE first John Fritz gold medal will be conferred upon Lord Kelvin. This medal is awarded by a joint committee of the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, The American Society of Civil Engineers and the American Institute of Mining Engineers to the man most representative of, and eminent in, scientific advance in the engineering field.—A medal in commemoration of M. Alfred Cornu will be struck by the French Physical Society.—It is proposed to erect a memorial in Jena to Professor Ernst Abbe in commemoration of his services to optical science and industry.

THE first Herbert Spencer lecture,

established by Pandit Shyamaji Krishnavarma, M.A., of Balliol College, was given at Oxford on March 9, by Mr. Frederic Harrison, M.A., honorary fellow of Wadham College.—Dr. H. A. Lorentz, professor of physics in the University of Leyden, and Professor V. F. Bjerknæs, professor of mathematical physics in the University of Stockholm, will give courses of lectures at Columbia University next year.

DR. LEWELLYS F. BARKER, professor of anatomy at the University of Chicago, has been called to the chair of medicine in Johns Hopkins University, vacant by the removal of Dr. William Osler to Oxford. At the same time Dr. W. S. Thayer, associate professor of medicine, has been advanced to a professorship of clinical medicine.—Dr. Frank Schlesinger, of the Yerkes Observatory, has been elected director of the New Allegheny Observatory in succession to Dr. F. L. O. Wadsworth, who has resigned.

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VON BAER AND THE RISE OF EMBRYOLOGY.

BY PROFESSOR WILLIAM A. LOCY,
NORTHWESTERN UNIVERSITY.

THE process of building an animal's body is one of the most wonderful in all nature. After three weeks' incubation of the hen's egg, for illustration, the young bird steps into the world with heart, lungs, brain, eyes and other organs completely formed, which straightway adjust themselves to the new conditions of life. At the beginning of incubation, this living, breathing organism was merely a single element of structure—a cell, or at most a group of a few cells surrounded by a quantity of nourishment in the form of yolk—potentially an animal, in reality simply an egg.

To arrive at the period of hatching, a succession of changes has taken place whereby the food material has been transformed into the living matter of organic units, and these have become aggregated into the tissues of the body. That such a sweeping change has been wrought in such a short time is a marvel of organic architecture involving much more than mere rearrangement of material.

The history of the development of a single individual becomes endowed with greater interest, when observation teaches us that all animals, in the process of becoming, pass through a similar series of steps. In whatever group of living forms the penetrating insight of the scientific observer has been turned, fortified by the microscope, there is the same remarkable story—complex living forms arising from relative simplicity to great complexity in a short time. Every organism, above the very lowest, no matter how complex, starts its existence in the condition of a single microscopic cell, and between that simple state and the fully formed condition every gradation of structure is exhibited. Each time an animal is developed these constructive changes are repeated in orderly sequence.

But, strangely enough, the course of development in any higher organism is not straightforward, but devious. The bird, as well as all higher animals, acquires gill-clefts and other rudimentary structures not adapted to its condition of life. Most of the rudimentary organs are transitory and bear testimony, as hereditary survivals, to the line of ancestry. They are clues by means of which phases in the evolution of animal life may be deciphered.

Bearing in mind these shifting changes, one begins to see why the adult structures of animals are so difficult to understand. They are not only complex they are also greatly modified. The adult condition of any organ or tissue represents the last step in a series of gradually acquired modifications, and is, therefore, the farthest departure from that which is ancestral and archetypal. But in the process of formation all the simpler conditions are exhibited. If, therefore, we wish to understand an organ or an animal we must follow its development, and see it in simpler conditions, before the great modifications have been added.

The tracing of the stages whereby cells merge into tissues, tissues into organs, and how the organs by combinations build up the body, is embryology. It has become one of the richest and most suggestive of the biological sciences in furnishing clues to the past history of animals and throwing light on their relationships.

It is the purpose of this paper to trace in a summary way the rise of that interesting division of biological science, pointing out its epochs, and telling something about the men who laid its foundations, the discussion being limited to the animal side, with no attempt to represent the rise of plant embryology. That we can 'read all history in the lives of a few great men' is essentially true in reference to the progress of embryology. There are many individual workers, each contributing his share, but the ideas of the science are molded into effective form only in the minds of the leaders. In this group of 'the leaders,' Von Baer stands as a monumental figure, at the parting of the ways between the new and the old—the sane thinker, the great observer.

The story of the rise of embryology can, for convenience, be divided into five periods each marked by an advance in general knowledge. These are: (1) the period of Harvey and Malpighi; (2) the period of Wolff; (3) the period of Von Baer; (4) the period from Von Baer to Balfour; and (5) the period of Balfour with an indication of present tendencies.

The Period of Harvey and Malpighi.

In General.—The conventional way of looking at the rise of embryology has been derived mainly through the channels of German scholarship. But there is reason to depart from the traditional aspect

of the subject, in which Wolff is heralded as its founder, and the one central figure prior to Pander and Von Baer.

The embryological work of Wolff's great predecessors Harvey and Malpighi has been passed over too lightly. Although these men have received ample recognition in closely related fields of investigation, their insight into those mysterious events which culminate in the formation of a new animal has been rarely appreciated. Now and then a few writers, as Brooks and Whitman, have pointed out the great worth of Harvey's work in embryology, but fewer have spoken for Malpighi in this connection. Koelliker, it is true, in his address at the unveiling of the statue of Malpighi, in his native town of Crevalcuore, in 1894, gives him well-merited recognition as the founder of embryology, and Sir Michael Foster has written in a similar vein in his delightful 'Lectures on the History of Physiology.'

However great was Harvey's work in embryology, I venture to say that Malpighi's was greater when considered as a piece of observation. Harvey's work is more philosophical; he discusses the nature of development and shows unusual powers as an accurate reasoner. But that part of his treatise devoted to observation is far less extensive and exact than Malpighi's, and throughout his lengthy discussions he has the flavor of the ancients.

Malpighi's work, on the other hand, flavors more of the moderns. In terse descriptions, and with many sketches, he shows the changes in the hen's egg from the close of the first day of development onwards.

It is a noteworthy fact that, at the period in which he lived, Malpighi could so successfully curb the tendency to indulge in wordy disquisitions, and that he was satisfied to observe carefully, and tell his story in a simple way. This quality of mind can not be too much admired. As Emerson has said: "I am impressed with the fact that the greatest thing a human soul ever does in this world is to see something and tell what it saw in a plain way. Hundreds of people can talk for one who can think, but thousands can think for one who can see. To see clearly is poetry, philosophy and religion all in one." But 'to see' here means to interpret as well as to observe. Harvey was also an original observer, but, in embryology, not in so eminent a degree as Malpighi.* Could we have had the insight of Harvey united to the observing powers of Malpighi, we should have had an almost perfect combination.

Although there were observers in the field of embryology before

* Notwithstanding the deserved praise of Malpighi as an observer, it may be remarked, in passing, that he was not the leader of his period in pure observation and description. Swammerdam showed even greater powers for critical and finished work in this direction. (See 'Malpighi, Swammerdam, and Leeuwenhoek,' *Pop. Sci. Mo.*, April, 1901.)

Harvey, little of substantial value had been produced. The earliest attempts were vague and uncritical, and, naturally, embraced only fragmentary views of the more obvious features of body formation. Nor, indeed, are we to look for much advance in the field of embryology even in Harvey's time. The reason for this will be obvious when we remember that the renewal of independent observation had just been brought about in the preceding century, when, in 1543, the science of anatomy had been reformed by Vesalius.

Harvey himself was one of the pioneers in the intellectual awakening. By his immortal discovery of circulation of the blood (1619-1628) he had established a new physiology. Now, studies on the development of the body are more special, they involve observations on minute structures and recondite processes, and must, therefore, depend upon considerable advances in anatomy and physiology. Naturally the science of embryology came later.

Harvey.—Harvey's was the first attempt to make a critical analysis of the process of development, and that he did not attain more was not due to limitations of his powers of discernment, but to the necessity of building on the general level of the science of his time, and, further, to his lack of instruments of observation and technique. Nevertheless, Harvey may be considered as having made the first independent advance in embryology.

By clearly teaching, on the basis of his own observations, the gradual formation of the body by aggregation of its parts, he anticipated Wolff. This doctrine came to be known under the title of 'epigenesis,' but Harvey's epigenesis* was not, as Wolff's was, directed against a theory of predelineation of the parts of the embryo, but against the ideas of the medical men of the time regarding the metamorphosis of germinal elements. It lacked, therefore, the dramatic setting which surrounded the work of Wolff in the next century. Had the doctrine of preformation been current in Harvey's time, we are quite justified in assuming that he would have assailed it as vigorously as Wolff did.

Harvey's embryological work was published in 1651 under the title 'Exercitationes de Generatione Animalium.' It embraces not only observations on the development of the chick, but also on the deer and some other mammals. He being the court physician of Charles I., that sovereign had many deer killed in the park, at intervals, in order to give Harvey the opportunity to study their development.

As fruits of his observation on the chick, he showed the position † in which the embryo arises within the egg, viz., in the white opaque

* As Whitman has pointed out, Aristotle taught epigenesis as clearly as Harvey and is, therefore, to be regarded as the founder of that conception.

† Fabricius supposed that the chick developed from the twisted cords of the white of the egg.

spot or cicatricula. He also corrected Aristotle, Fabricius and his other predecessors in many particulars.

Harvey's greatest predecessor in this field, Fabricius, was also his teacher. When, in search of the best training in medicine, Harvey wended his way from England to Italy, in Padua, he came under Fabricius as one of his teachers. In 1600, Fabricius published the earliest illustrations on the development of animals, and, again, in 1625, six years after his death, appeared his illustrated treatise on the development of the chick.† Altogether his figures show developmental stages of the cow, sheep, pig, galeus, serpent, rat and chick. The value of his work may be easily overestimated by a casual examination of the plates.

Harvey's own treatise was not illustrated. With that singular independence of mind which he showed in all his work, the vision of the pupil was not hampered by the authority of his teacher, and, trusting only to his own sure observation and reason, he described the stages of development as he saw them in the egg, and placed his own construction on the facts.

One of the earliest things to arrest his attention in the chick was a pulsating point, the heart, and, from this observation, he supposed that the heart and blood were the first formations. He says: "But as soon as the egg, under the influence of the gentle warmth of the incubating hen, or of warmth derived from another source, begins to pullulate, this spot forthwith dilates, and expands like the pupil of the eye, and from thence, as the grand center of the egg, the latent plastic force breaks forth and germinates. This first commencement of the chick, however, so far as I am aware, has not yet been observed by any one."

It is to be understood, however, that his descriptive part is relatively brief (about 40 pages out of 350 in Willis's translation), and that the bulk of the 106 'exercises' into which his work is divided is devoted to comments on the older writers and discussions of the nature of the process of development.

Portraits of Harvey are by no means uncommon. The one in the National Portrait Gallery, in London, is represented in Fig. 1. This is usually regarded as the second-best portrait of Harvey, since the one painted by Jansen, now in possession of the Royal College of Physicians, is believed to be the best one extant. Permission to reproduce the latter is not given.

The picture in the National Gallery shows a countenance of composed intellectual strength, with a suggestion, in the forehead and outline of the face, of some of the portraits of Shakespeare.

The aphorism '*Omne vivum ex ovo*,' though not invented by

† The earliest figures on the development of the chick are probably those of Coiter, 1573.

Harvey, was brought into general use through his works. It is not to be taken in its full modern significance. With Harvey it meant simply that the embryos of all animals, the viviparous as well as the oviparous, originate in eggs, and it was directed against certain contrary medical theories of the time.

The first edition of his 'Generazione Animalium,' London, 1651, is provided with an allegorical title-page embodying this idea. As

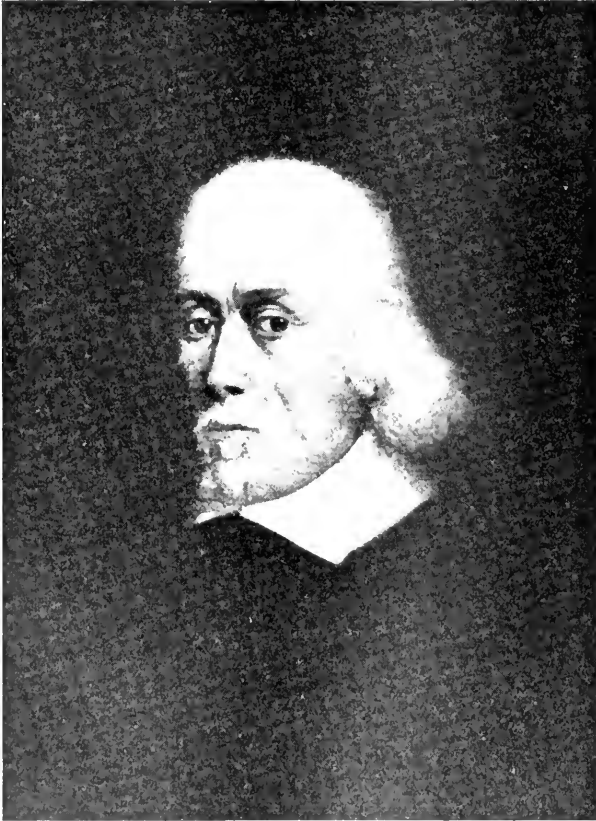


FIG. 1. WILLIAM HARVEY (1578-1657).

shown in Fig. 2, it represents Jove on a pedestal, uncovering a round box—or ovum—bearing the inscription 'ex ovo omnia' and from the box issue all forms of living creatures including also man.

Malpighi.—The observer in embryology who looms into prominence between Harvey and Wolff, is Malpighi. He supplied what was greatly needed at the time—an illustrated account of the actual stages in development of the chick from the end of the first day to hatching, shorn of verbose references and speculations.

His observations on development are in two separate memoirs, both



FIG. 2. TITLE-PAGE TO HARVEY'S *Generazione Animantium* (1651).

sent to the Royal Society in 1672, and published by the society in Latin, under the titles 'De Formatione Pulli in Ovo' and 'De Ovo Incubato.' The two taken together, are illustrated by twelve plates containing eighty-six figures, and the twenty-two quarto pages of text are nearly all devoted to descriptions.

His pictures, although not correct in all particulars, represent what he was able to see, and are very remarkable for the age in which they were made, and considering the instruments of observation at his

command. They show successive stages from the time the embryo is first outlined, and, taken in their entirety, they cover a wide range of stages.

His observations on the development of the heart, comprising twenty figures, are the most complete. He clearly illustrates the aortic arches,—those transitory structures of such great interest as showing a phase in ancestral history.

He was also the first to show by pictures the formation of the head-fold and neural groove as well as the brain vesicles and eye



FIG. 3. MARCELLUS MALPIGHI (1628-1694.)

pockets. His delineation of heart, brain and eye vesicles are far ahead of those illustrating Wolff's 'Theoria Generationis' made nearly a hundred years later. But Wolff rose to a higher level in his later work on the development of the intestine, and produced some figures better than any of Malpighi's.

The original drawings for 'De Ovo Incubato,' still in possession of the Royal Society, are made in pencil and red chalk. They far surpass the reproductions in finish and accuracy. In looking them over in 1902, I noticed four aortic arches represented in one figure where the engraver has shown only three.

The portrait of Malpighi shown in Fig. 3 is taken from his Life

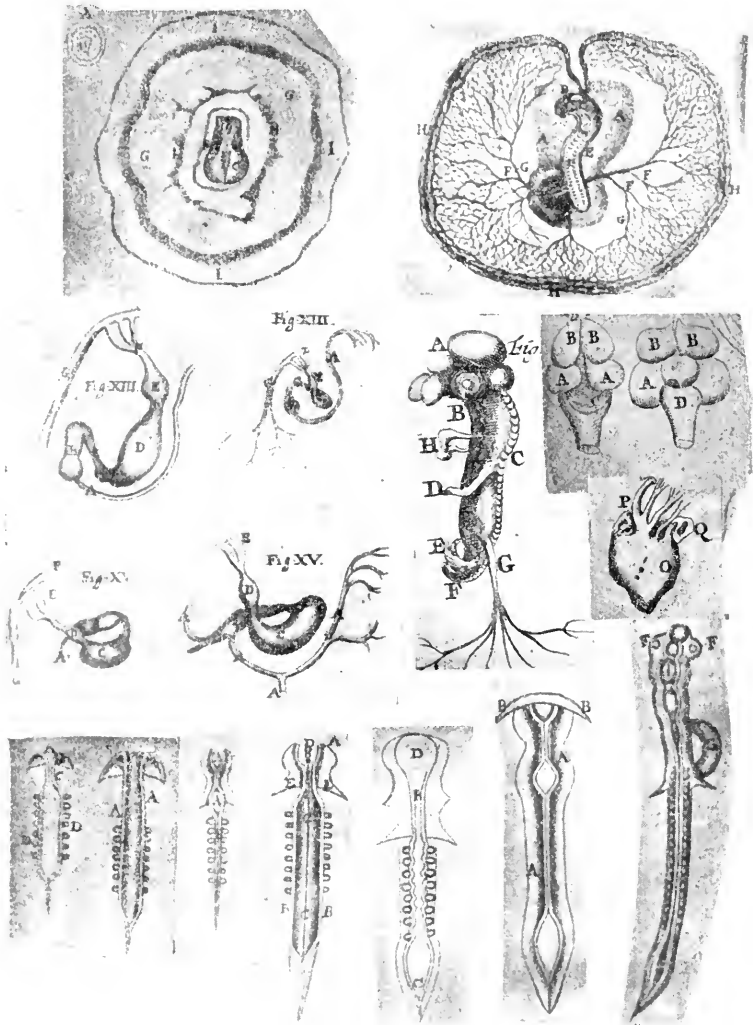


FIG. 4. SELECTED SKETCHES FROM MALPIGHI'S WORKS SHOWING STAGES IN THE DEVELOPMENT OF THE CHICK (1672).

by Atti. From descriptions of his personal appearance, it is probably a better likeness than the handsome idealized portrait painted by Tabor, and presented by Malpighi to the Royal Society of London.*

Fig. 4 shows a few selected figures from the various plates of his embryological treatises, to compare with those of Wolff.

While Harvey taught the gradual formation of parts, Malpighi, from his own observations, supposed the rudiments of the embryo to

* For a reproduction of that portrait see Pop. Sci. Mo., Vol. LVIII., 1901, p. 563.

preexist in the egg. He thought that, possibly, the blood vessels were in the form of tubes, closely wrapped together, which by becoming filled with blood were distended. Nevertheless, in the treatises mentioned above he is very temperate in his expressions on the whole matter, and evidently believed in the new formation of many parts. In the work published after his death he appears to have been less circumspect.

Malpighi's work, with that of some of his contemporaries, marks the beginning of the theory of preformation.*

On the whole, Malpighi should rank above Harvey as an embryologist, on account of his discoveries and fuller representation, by drawings and descriptions, of the process of development. As Sir Michael Foster has said: "The first adequate description of the long series of changes, by which, as they melt the one into the other, like dissolving views, the little white opaque spot in the egg is transformed into the feathered, living, active bird, was given by Malpighi. And where he left it, so for the most part the matter remained until even the present century. For this reason we may speak of him as the founder of embryology."

The Period of Wolff.

Between Harvey and Wolff, embryology had become dominated by the theory that the embryo exists already preformed within the egg, and, as a result of the rise of this new doctrine, the publications of Wolff had a different setting from that of any of his predecessors. It is only fair to say that to this circumstance is owing, in large part, the prominence of his name in connection with the theory of epigenesis. As we have already seen, Harvey, more than a century before the publications of Wolff, had clearly taught that development was a process of gradual becoming. Nevertheless, Wolff's work as opposed to the new theory was very important.

While the facts fail to support the contention that he was the founder of epigenesis, it is to be remembered that he has claims in other directions to rank as the foremost student of embryology prior to Von Baer.

As a preliminary to discussing Wolff's position we should bring under consideration the doctrine of preformation and encasement.

Rise of the Theory of Predelineation.—The idea of preformation in its first form is easily set forth. Just as when we examine a seed, we find within an embryo plantlet, so it was supposed that the various forms of animal life existed in miniature within the egg. The process of development was supposed to consist of the expansion or unfolding of this preformed embryo. The process was commonly illustrated by reference to flower buds. "Just as already in a small bud all the

* See further under the period of Wolff.

parts of the flower, such as stamens and colored petals, are enveloped by the green and still undeveloped sepals,—just as the parts grow in concealment and then suddenly expand into a blossom, so also in the development of animals it was thought that the already present small but transparent parts grow, gradually expand, and become discernible.”* From the feature of unfolding this was called in the eighteenth century the theory of *evolution*, giving to that term quite a different meaning from that accepted at the present time.

This theory, strange as it may seem to us now, was founded on a basis of actual observation—not entirely on speculation. Although it was a product of the seventeenth century, from several printed accounts one is likely to gather the impression that it arose in the eighteenth century and that Bonnet, Haller and Leibnitz were among its founders. This implication is in part fostered by the circumstance that Swammerdam’s ‘*Biblia Naturæ*,’ which contains the germ of the theory, was not published until 1737—more than a half century after his death—although the observations for it were completed before Malpighi’s first paper on embryology was published in 1672. While it is well to bear in mind that date of publication, rather than date of observation, is accepted as establishing the period of emergence of ideas, there were other men, such as Malpighi and Leeuwenhoek, contemporaries of Swammerdam, who published in the seventeenth century the basis for this theory.

Malpighi supposed (1672) the rudiment of the embryo to pre-exist within the hen’s egg, because he observed evidences of organization in the unincubated egg. This was in the heat of the Italian summer (in July and August, as he himself records), and Daresté suggests that the developmental changes had gone forward to a considerable degree before Malpighi opened the eggs. Be this as it may, the imperfection of his instruments and technique would have made it very difficult to have seen anything definitely in stages under twenty-four hours.

In reference to his observations he says that, in the unincubated egg, he saw a small embryo enclosed in a sac which he subjected to the rays of the sun. “Frequently I opened the sac with the point of a needle so that the animals contained within might be brought to the light, nevertheless to no purpose: for the individuals were so jelly-like and so very small that they were lacerated by a light stroke. Therefore it is right to confess that the beginnings of the chick pre-exist in the egg and have reached a higher development in no other way than in the eggs of plants.” (“*Quare pulli stamina in ovo præexistere, altiorémque originem nacta esse fateri convenit, haud dispari ritu, ac in Plantarum ovis.*”)

* O. Hertwig.

Swammerdam (1637–1680) supplied a somewhat better basis. He observed that the parts of the butterfly, and other insects as well, are discernible in the chrysalis stage. Also, on observing caterpillars just before going into the pupa condition, he saw in outline the organs of the future stage, and very naturally concluded that development consists of an expansion of already formed parts.

A new feature was introduced through the discovery, by Leeuwenhoek about 1677,* of the fertilizing filaments of eggs. Soon after, controversies began to arise as to whether the embryo preexisted in the sperm or in the egg. By Leeuwenhoek, Hartsoeker and others the egg was looked upon as simply a *nidus* within which the sperm developed, and they asserted that the future animal existed in miniature in the sperm. These controversies gave rise to the schools of the Animalculists, who believed the sperm to be the animal germ, and of the Ovists, who contended for the ovum in that rôle.

One of the curiosities of this period is shown in Fig. 5, taken from an old Dutch edition of Leeuwenhoek's works, in which he undertakes to represent pre-delineation of both sexes within the sperm.

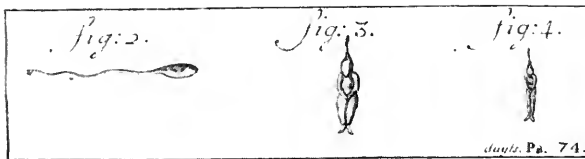


FIG. 5. SKETCHES ILLUSTRATING PRE-DELINATION OF THE EMBRYO WITHIN THE SPERM. FROM AN OLD EDITION OF LEEUWENHOEK'S WORKS.

It is interesting to follow the metaphysical speculations which led to another aspect of the doctrine of preformation. There were those, notably Swammerdam, Leibnitz and Bonnet, who did not hesitate to follow the idea to the logical consequence, that, if the animal germ exists preformed, one generation after another must be encased within it. This gave rise to the fanciful idea of encasement or *emboîtement* which was so greatly elaborated by Bonnet and, by Leibnitz, applied to the development of the soul. Even Swammerdam (who, by the way, although a masterly observer, was always a poor generalizer) conceived the mental picture of the germs of all forthcoming generations having been located in the common mother Eve, all closely encased one within the other, like the boxes of a Japanese juggler. The end of the human race was conceived of by him as a necessity, when the last germ of this wonderful series had been unfolded.

His successors, in efforts to compute the number of homunculi,

* The discovery is also attributed to Hamm, a medical student, and to Hartsoeker, who claimed priority in the discovery.

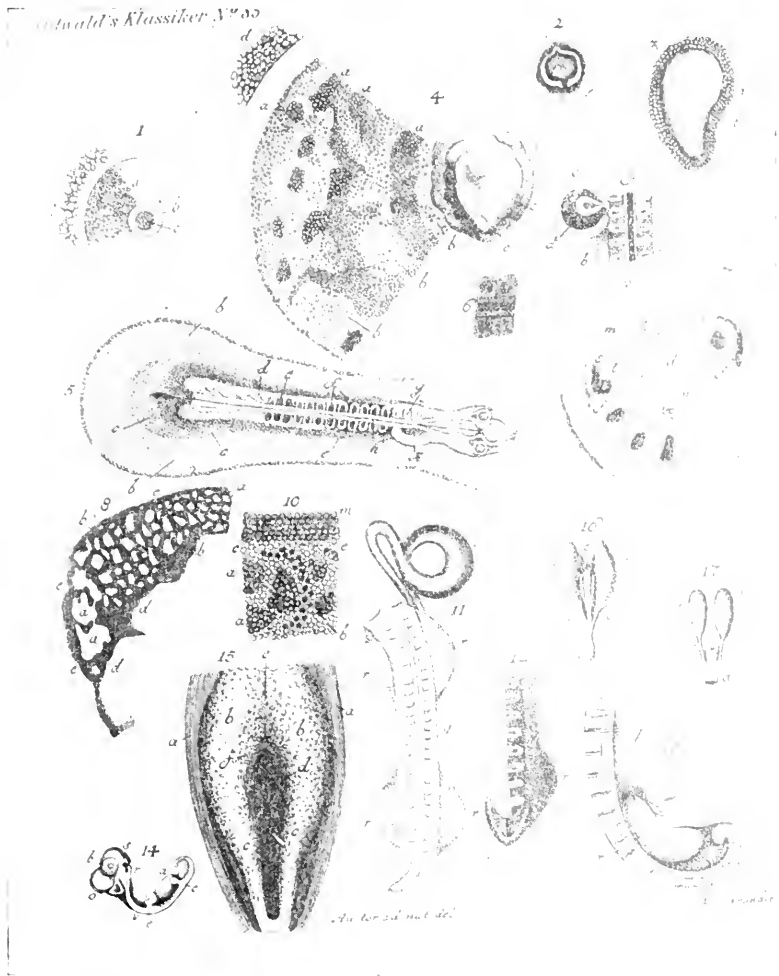


FIG. 6. PLATE FROM WOLFF'S *Theoria Generationis* (1759), SHOWING STAGES IN THE DEVELOPMENT OF THE CHICK.

which must have been condensed in the ovary of Eve, arrived at the amazing result of two hundred millions.

Work of Wolff.—Wolff, as a young man of 26 years, set himself against this grotesque doctrine of preformation and encasement, in his '*Theoria Generationis*,' published in 1759. This consists of three parts: One devoted to the development of plants, one to the development of animals and one to theoretical considerations. He contended that the organs of animals make their appearance gradually, and that he could actually follow their successive stages of formation.

The figures in it illustrating the development of the chick, some of which are shown in Fig. 6, are not, on the whole, so good as Malpighi's. Wolff gives in all seventeen figures, while Malpighi published eighty-

six, and his twenty figures on the development of the heart are more detailed than any of Wolff's. When the figures represent similar stages of development, a comparison of the two men's work is favorable to Malpighi. The latter shows much better, in corresponding stages, the series of cerebral vesicles and their relation to the optic vesicles. Moreover, in the wider range of his work, he shows many things—such as the formation of the neural groove, etc.—not included in Wolff's observations. Wolff, on the other hand, figures for the first time the primitive kidneys, or 'Wolffian bodies,' of which he was the discoverer.

Although Wolff was able to show that development consists of a gradual formation of parts, his theory of development was entirely mystical and unsatisfactory. The fruitful idea of germinal continuity had not yet emerged, and the thought that the egg has inherited an organization from the past was yet to be expressed. Wolff was therefore in the same quandary as his predecessors when he undertook to explain development. Since he assumed a total lack of organization in the beginning, he was obliged to make development 'miraculous' through the action on the egg of a hyperphysical agent. From a total lack of organization, he conceived of its being lifted to the highly organized product, through the action of a '*vis essentialis corporis*.'

He returned to the problem of development later, and, in 1768–69, published his best work in this field on the development of the intestine.* This is a very original and strong piece of observational work. While his observations for the 'Theoria Generationis' did not reach the level of Malpighi's those of the paper of 1768 surpassed it and held the position of the best piece of embryological work up to that of Pander and Von Baer. This work was so highly appreciated by Von Baer that he said: 'It is the greatest masterpiece of scientific observation which we possess.' In it he clearly demonstrated that the development of the intestine, and its appendages, is a true process of becoming. Still later, in 1789, he published further theoretical considerations.

But all Wolff's work was launched into an uncongenial atmosphere. The great physiologist, Haller, could not accept the idea of epigenesis, but opposed it energetically, and, so great was his authority, that the ideas of Wolff gained no currency. This retarded progress in the science of animal development for more than a half century.

In 1812, the elder Meckel, recognizing the great value of Wolff's researches on the development of the intestine, rescued the work from neglect and obscurity, by publishing a German translation of the same, and bringing it to the attention of scholars. From that time onward Wolff's work began to be fruitful.

* 'De Formatione Intestinorum,' *Nova Commentar, Ac. Sci. Petrop., St. Petersburg*, XII., 1768; XIII., 1769.

His 'Formatione Intestinorum' embodies his greatest contribution to embryology rather than his 'Theoria Generationis'; not only is it a more fitting model of observation, but in it he foreshadows the idea of germ-layers in the embryo, which, under Pander and Von Baer, became the fundamental conception in structural embryology. Throughout his work, both early and late, he likens the embryonic rudiments, which precede the formation of organs, to leaflets. In his work of 1768, he describes in detail how the leaf-like layers give rise to the systems of organs: Showing that the nervous system arises first from a leaf-like layer, and is followed, successively, by a flesh-layer, the vascular system and, lastly, by the intestinal canal—all arising from original leaf-like layers.

In these important generalizations, although they are verbally incorrect, he reached the truth as nearly as it was possible at the time, and laid the foundation of the germ-layer theory.

Wolff was a man of great power as an observer, and although his influence was for a long time retarded, he should be recognized as the foremost investigator in embryology before Von Baer.

The little known of his life is gained through his correspondence and a letter by his amanuensis. Through personal neglect, and hostility to his work, he could not secure a foothold in the universities of Germany, and, in 1764, on the invitation of Catharine of Russia, he went to the Academy of Sciences at St. Petersburg, where he spent the last thirty years of his life.

His sincere and generous spirit is shown in his correspondence with Haller, his great opponent. "And as to the matter of contention between us, I think thus: For me, no more than for you glorious man, is truth of the very greatest concern. Whether it chance that organic bodies emerge from an invisible into a visible condition, or form themselves out of the air, there is no reason why I should wish the one were truer than the other, or wish the one and not the other. And this is your view also, glorious man. We are investigating for truth only: we seek that which is true. Why then should I contend with you?"

I have not been able to locate a portrait of Wolff, although I have sought one in various ways for several years. The Secretary of the Academy of Sciences at St. Petersburg writes that no portrait of Wolff exists there, and that they will gratefully receive information regarding any existing portrait of the great academician.

The Period of Von Baer.

What Verworn says of Johannes Müller's position in physiology, may with equal appropriateness be applied to Von Baer in the science of embryology. He was: "One of those monumental figures that the history of every science brings forth but once. They change the whole



FIG. 7. K. ERNST VON BAER AT ABOUT SEVENTY YEARS OF AGE.

aspect of the field in which they work and all later growth is influenced by their labors.”

The greatest classic in embryology is his ‘*Entwicklungsgeschichte der Tiere—Beobachtung und Reflexion*,’ the first part of which was published in 1828, and the work on the second part completed in 1834, although it was not published till 1837. This second part was never finished according to the plan of Von Baer, but was issued by his publisher, after vainly waiting for the finished manuscript. The final portion, which Von Baer had withheld, in order to perfect in some particulars, was published in 1888, after his death, but in the form in which he had left it in 1834.

The observations for the first part began in 1819, after he had received a copy of Pander's researches and covered a period of seven years of close devotion to the subject, and the observations for the last part were carried on at intervals for several years.

It is significant of the character of his 'Reflexionen' that, although published before the announcement of the cell-theory, and before the acceptance of the doctrine of organic evolution, they have exerted a moulding influence upon embryology to the present time. The position of Von Baer in embryology, is due as much to his sagacity in speculation, as to his powers as an observer. "Never again have observation and thought been so successfully combined in embryological work" (Minot).

Von Baer was born in 1792, and lived on to 1876, but his enduring fame in embryology rests on work completed more than forty years before the end of his useful life. After his removal from Königsberg to St. Petersburg, in 1834, he very largely devoted himself to anthropology in its widest sense, and thereby extended his scientific reputation into other fields.

If space permitted, it would be interesting to give the biography* of this extraordinary man, but here, it will be necessary to content ourselves with an examination of his portrait and a brief account of his work.

Several portraits of Von Baer showing him at different periods of his life have been published. A very attractive one, taken in his early manhood, appeared in *Harper's Magazine* for 1898. The expression of the face is poetical, and the picture is interesting to compare with the more matured sage-like countenance forming the frontispiece of Stieda's 'Life of Von Baer.' This, perhaps best of all his portraits, shows him in the full development of his powers. An examination of it impresses one with confidence in his balanced judgment and the thoroughness and profundity of his mental operations.

The portrait of Von Baer at about seventy years of age, reproduced in Fig. 7 is destined to be the one by which he is commonly known to embryologists, since it forms the frontispiece of the great cooperative 'Handbook of Embryology' now appearing under the editorship of Oskar Hertwig.

Apart from special discoveries, Von Baer greatly enriched embryology in three directions: In the first place, he set a higher standard for all work in embryology and thereby lifted the entire science to a higher level. Activity in a great field of this kind is, with the rank and file of workers, so largely imitative that this feature of his influence

* Besides biographical sketches by Stieda, Waldeyer and others, we have a very entertaining autobiography of Von Baer, published in 1864, for private circulation, but afterwards (1866) reprinted and placed on sale.

should not be overlooked. In the second place, he established the germ-layer theory, and, in the third, he made embryology comparative.

In reference to the germ-layer theory, it should be recalled that Wolff had distinctly foreshadowed the idea, by showing that the material out of which the embryo is constructed is, in an early stage of development, arranged in the form of leaf-like layers. He showed specifically that the alimentary canal is produced by one of these sheet-like expansions folding and rolling together.

Pander, by observations on the chick (1817), had extended the knowledge of these layers and elaborated the conception of Wolff. He recognized the presence of three primary layers, an outer, a middle and an inner, out of which the tissues of the body are formed.

But, it remained for Von Baer,* by extending his observations into all the principal groups of animals, to raise this conception to the rank of a general law of development. He was able to show that in all animals except the very lowest, there arises in the course of development leaf-like layers, which become converted into the 'fundamental organs' of the body.

Now, these elementary layers are not definitive tissues of the body, but are embryonic, and therefore, may appropriately be designated 'germ-layers.' The conception that these germ-layers are essentially similar in origin and fate, in all animals, was a fuller and later development of the germ-layer theory, which dominated embryological study until a recent date.

Von Baer recognized four such layers: the outer and inner ones being formed first, and, subsequently budding off a middle layer composed of two sheets. A little later (1845) Remak recognized the double middle layer of Von Baer as a unit, and thus arrived at the fundamental conception of three layers—the ecto-, endo- and mesoderm—which has so long held sway. For a long time after Von Baer, the aim of embryologists was to trace the history of these germ-layers—and so in a wider and much qualified sense it is to-day.

It will ever stand to his credit, as a great achievement, that Von Baer was able to make a very complicated feature of development clear

* It is of more than passing interest to remember that Pander and Von Baer were associated as friends and fellow students, under Döllinger at Würzburg. It was partly through the influence of Von Baer that Pander came to study with Döllinger, and took up investigations on development. His ample private means made it possible for him to bear the expenses connected with the investigation, and to secure the services of a fine artist for making the illustrations. The result was a magnificently illustrated treatise. His unillustrated thesis in Latin (1817) is more commonly known, but the illustrated treatise in German is rarer. Von Baer did not take up his researches seriously until Pander's were published. It is significant of their continued harmonious relations that Von Baer's work is dedicated 'An meinen jugendfreund, Dr. Christian Pander.'

and relatively simple. Given a leaf-like rudiment, with the layers held out by the yolk, as is the case in the hen's egg, and it was no easy matter to conceive of how they are transformed into the nervous system, the body wall, the alimentary canal and other parts, but, Von Baer saw deeply and clearly that the fundamental anatomical features of the body are assumed by the leaf-like rudiments being rolled into tubes.

Fig. 8 shows four sketches taken from the plates illustrating Von Baer's work. At *A* is shown a stage in the formation of the embryonic

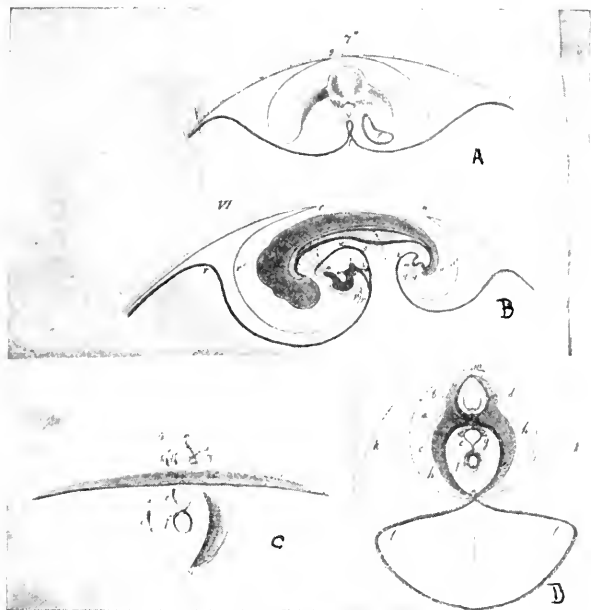


FIG. 8. SKETCHES FROM VON BAER'S EMBRYOLOGICAL TREATISE (1828).

envelope, or amnion, which surrounds the embryos of all animals above the class of amphibia. At *B*, another figure of an ideal section, shows that long before the day of microtomes, Von Baer made use of sections to represent the relationships of his four germ-layers. At *C* and *D* is represented, diagrammatically, the way in which these layers are rolled into tubes. He showed that the central nervous system arose in the form of a tube, from the outer layer, the body-wall in the form of a tube, composed of skin and muscle layers, and the alimentary tube from mucous and vascular layers.

The generalization that embryos in development tend to recapitulate their ancestral history is frequently attributed to Von Baer, but the qualified way in which he suggests something of the sort will not justify one in attaching this conclusion to his work.

Von Baer was the first to make embryology truly comparative, and to point out its great value in anatomy and zoology. By embryological

studies, he recognized four types of organization—as Cuvier had done from the standpoint of comparative anatomy. But, since these types of organization have been greatly changed and sub-divided, the importance of the distinction has faded away. But as a distinct break with the old idea of a linear scale of being it was of moment.

Among his especially noteworthy discoveries may be mentioned that of the egg of the human being and other mammals, and the notochord as occurring in all vertebrate animals.

Von Baer has come to be dignified with the title of the ‘Father of modern embryology.’ No man could have done more in his period, and it is owing to his superb intellect, and talents as an observer, that he accomplished what he did. As Minot says: He ‘worked out, almost as fully as was possible at this time, the genesis of all the principal organs from the germ-layers, instinctively getting at the truth as only a great genius could have done.’

After his masterly work the science of embryology could never return to its former level; he had given it a new direction, and through his influence a period of great activity was inaugurated.

The Period from Von Baer to Balfour.

In the period between Von Baer and Balfour there were great general advances in the knowledge of organic structure which brought the whole process of development into a new light.

Among the most important advances are to be enumerated: the announcement of the cell theory, the discovery of protoplasm, the beginning of the recognition of germinal continuity and the establishment of the doctrine of organic evolution.

The Cell Theory.—The generalization that the tissues of all animals and plants are structurally composed of similar units—called cells—was given to the world through the combined labors of Schleiden and Schwann. Schleiden, the botanist, in 1838, and Schwann, the anatomist, in the following year, published the observations on which this truth rests. The investigations stimulated by the announcement of this theory soon resulted in showing that the conception of the cell entertained by the founders was very imperfect, and, by 1860, the original theory had been molded into the protoplasm doctrine of Max Schultze.

The modification of the cell theory did not, however, affect the original conception that the cell is a unit of organic structure, but showed that the unit is, essentially, a globule of protoplasm containing a nucleus, and not simply a box-like compartment as Schleiden and Schwann had suggested.

The broad-reaching effects of the cell-theory may be easily imagined since it united all animals on the broad plane of similitude in microscopic structure. Now, for the first time, the tissues of the body were

analyzed into their units; now, for the first time, was comprehended the nature of the germ-layers of Von Baer.

Among the first questions to emerge in the light of the new researches were: What is the origin of the cells in the organs, the tissues and the germ-layers? The road to the investigation of these questions was already opened, and it was followed, step by step, until the egg and sperm came to be recognized as modified cells. This position was reached, for the egg, about 1861, when Gegenbaur showed that the eggs of all vertebrated animals, regardless of size and condition, are in reality single cells. The sperm was put in the same category about 1865.

The rest was relatively easy—the egg, a single cell—by successive divisions produces many cells, and the arrangement of these into primary embryonic layers brings us to the starting point of Wolff and Von Baer. The cells, continuing to multiply by division, not only increase in number, but also undergo changes through division of physiological labor, whereby certain groups are set apart to perform a particular part of the work of the body. In this way arise the various tissues of the body—which are, in reality, similar cells performing a similar function. Finally, from combinations of tissues the organs are formed.

But the egg, before entering on the process of development, must be stimulated by the union of the sperm with the nucleus of the egg, and, thus, the starting point of every animal and plant, above the lowest group, proves to be a single cell with protoplasm derived from two parents. While questions regarding the origin of cells in the body were being answered, the foundation for the embryological study of heredity was also laid.

Advances were now more rapid and more sure, flashes of morphological insight began to illuminate the way, and the facts of isolated observations began to fit into a harmonized whole.

Apart from the general advances of this period, mentioned in other connections, the work of a few individuals requires notice.

Rathke and Remak were engaged with the broader aspects of embryology as well as with special investigations. To Rathke is owing great advances in the knowledge of the development of insects and other invertebrates, and Remak is notable for similar work with the vertebrates. As already mentioned, he was the first to recognize the middle layer as a unit—through which the three germ-layers of later embryologists emerged into the literature.

Koelliker, the veteran embryologist, still living in Würzburg, carried on investigations on the segmentation of the egg. Besides work on the invertebrates, later, he followed with care the development of the chick and the rabbit—he encompassed the whole field of embryology—and published, in 1861 and later, in 1876, a general treatise on



FIG. 9 ALBRECHT KOELLIKER. BORN 1817.

vertebrate embryology of high merit. His portrait is shown in Fig. 9.

Huxley took a great step towards unifying the idea of germ-layers throughout the animal kingdom, when he maintained, in 1849, that the two cell-layers in animals like the hydra, and oceanic hydras, correspond to the ectoderm and endoderm of higher animals.

Kowalevsky, whose portrait is shown in Fig. 10, made interesting discoveries of a general bearing. In 1866 he showed the practical identity, in the early stages of development, between one of the lowest vertebrates (*Amphioxus*) and a tunicate. The latter had up to that time been considered an invertebrate, and the effect of

Kowalevsky's work was to break down the sharply limited line, supposed to exist between the invertebrates and the vertebrates. This was of great influence in subsequent work. Kowalevsky also founded the generalization that all animals in development pass through a gastrula stage,—a doctrine associated, since 1874, with the name of Haeckel under the title of the *gastræa* theory.

Beginning of the Idea of Germinal Continuity.—The conception that there is unbroken continuity of germinal substance between all living organisms, and that the egg and sperm are endowed with an inherited organization of great complexity, has become the basis for all current theories of heredity and development. So much is involved in this conception, that, in the present decade, it has been designated (Whitman) 'the central fact of modern biology.' The first clear expression of it is found in Virchow's 'Cellular Pathology' published in 1858. It was not, however, until the period of Balfour, and through the work of Fol, Van Beneden (chromosomes, 1883), Boveri, Hertwig and others, that the great importance of the fact began to be appreciated, and the conception began to be woven into the fundamental ideas of development.

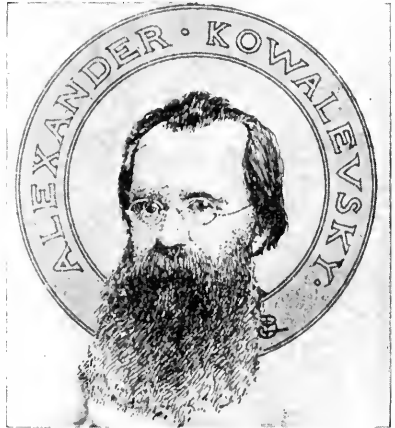


FIG. 10. A. KOWALEVSKY 1840-1901.

Influence of the Doctrine of Organic Evolution.—This doctrine, although founded in its modern sense by Lamarek, in the early part of the nineteenth century, lay dormant until Darwin, in 1859, brought a new feature into its discussion, by emphasizing the factor of natural selection. The general acceptance of the doctrine, which followed after fierce opposition, had, of course, a profound influence on embryology. The latter science is so intimately concerned with the genealogy of animals and plants, that the newly accepted doctrine, as affording an explanation of this genealogy, was what was most needed. The development of organisms was now seen in the light of ancestral history; rudimentary organs began to have meaning as hereditary survivals, and the whole process of development assumed a different aspect. This doctrine supplied a new impulse to the interpretation of nature at large, and of the embryological record in particular. The meaning of the embryological record was so greatly emphasized in the period of Balfour, that it will be commented upon under the next division of our subject.

The period between Von Baer and Balfour proved to be one of great importance on account of the general advances in knowledge of

all organic nature. Observations were all moving towards a better and more consistent conception of the structure of animals and plants. A new comparative anatomy, more profound, and richer in meaning than Cuvier's, was arising. The edifice on the foundation of Von Baer's work was now emerging into recognizable outlines.

The Period of Balfour, with an Indication of Present Tendencies.

The workers of this period inherited all the accumulations of previous efforts, and the time was ripe for a new step. Observations on the development of different animals—vertebrates and invertebrates—had accumulated in great number, but they were scattered through technical periodicals, transactions of learned societies, monographs, etc., and there was no compact science of embryology with definite outlines. Balfour reviewed all this mass of information, digested it, and molded it into an organized whole. The results were published in the form of two volumes with the title of 'Comparative Embryology.' This book of 'almost priceless value' was given to the world in 1880-81. It was a colossal undertaking, but Balfour was a phenomenal worker. Before his untimely death at the age of thirty-one, he had been able to complete this work and to produce, besides, a large number of technical researches. The period of Balfour is taken arbitrarily in this paper, as beginning about 1874, when he published with Michael Foster 'The Elements of Embryology.'

Balfour was born in 1851. During his days of preparation for the university he was a good student, but did not exhibit in any marked way, the powers for which later he became distinguished. At Cambridge, his distinguished teacher, now Sir Michael Foster, recognized his great talents, and encouraged him to begin work in embryology. After his work in this field was once begun, he threw himself into it with great intensity. He rose rapidly to a professorship in Cambridge, and so great was his enthusiasm and earnestness as a lecturer, that in seven years 'voluntary attendance on his classes advanced from ten to ninety.' He was also a stimulator of research, and at the time of his death there were twenty students engaged in his laboratory, on problems of development.

He was distinguished for personal attractiveness, and those who met him were impressed with his great sincerity, as well as his personal charm. He was welcomed as an addition to the select group of distinguished scientific men of England, and a great career was predicted for him. Huxley, when he felt the call, as a great personal sacrifice, to lay aside the more rigorous pursuits of scientific research, and to devote himself to molding science into the lives of the people, said of Balfour: 'He is the only man who can carry out my work.'

But that was not destined to be. The story of his tragic end need be only referred to. After completing the prodigious labor on

the 'Comparative Embryology' he went to Switzerland for recuperation, and met his death, with that of his guide, by slipping from an Alpine height into a chasm. His death occurred in July, 1882. His portrait is shown in Fig. 11.

The memorial edition of his works fills four quarto volumes, but the 'Comparative Embryology' is Balfour's monument, and will give him enduring fame. It is not only a digest of the work of others, but contains, also, general considerations of a far-seeing quality. He saw developmental processes in the light of the hypothesis of organic evolution. His speculations were sufficiently reserved and nearly always luminous. It is significant of the character of this work to say that the speculations contained in the papers of the rank and file of embryological workers, for more than two decades, and often fondly believed to be novel, were for the most part anticipated by Balfour, and also better expressed, with better qualifications.



FIG. 11. FRANCIS M. BALFOUR (1851-1882).

The reading of ancestral history in the stages of development is such a characteristic feature of the embryological work of Balfour's period that some observations concerning it will now be in place.

Interpretation of the Embryological Record.—Perhaps the most impressive feature of animal development is the series of similar changes through which all pass in the embryo. The higher animals, especially, exhibit all stages of organization from the unicellular fertilized ovum to the fully formed animal so far removed from it. The intermediate changes constitute a long record, the possibility of interpreting which has been a stimulus to its careful examination.

Meckel, in 1821, and later Von Baer, indicated the close similarity between embryonic stages of widely different animals: Von Baer, indeed, confessed that he was unable to distinguish positively between a reptile, bird and mammalian embryo in certain early stages of growth. In addition to this similarity—which is a constant feature of the embryological record—there is another one that may be equally significant, viz., in the course of embryonic history, sets of rudimentary organs arise and disappear. Rudimentary teeth make their appearance in the embryo of the whalebone whale, but they are transitory and soon disappear without having been of service to the animal. In the embryos of all higher vertebrates, as is well known, gill-clefts and gill-arches, with an appropriate circulation, make their appearance, but

disappear long before birth. These indications, and similar ones, must have some meaning.

Now whatever qualities an animal exhibits after birth are attributed to heredity. May it not be that all the intermediate stages are also inheritances, and, therefore, represent phases in ancestral history? If they be, indeed, clues to ancestral conditions, may we not, by patching together our observations, be able to interpret the record, just as the history of ancient peoples has been made out from fragments in the shape of coins, vases, implements, hieroglyphic inscriptions, etc.?

The results of reflection in this direction led to the foundation of the *recapitulation theory*, according to which animals are supposed, in their individual development, to recapitulate to a considerable degree phases of their ancestral history. This is one of the widest generalizations of embryology. It was suggested in the writings of Von Baer and Louis Agassiz, but received its first clear and complete expression in 1863, in the work of Fritz Müller.

Although the course of events in development is a record, it is, at best, only a fragmentary and imperfect one. Many stages have been dropped out, others are unduly prolonged or abbreviated, or appear out of chronological order, and, besides this, some of the structures have arisen from adaptation of a particular organism to its conditions of development, and are, therefore, not ancestral at all, but, as it were, recent additions to the text. The interpretation becomes a difficult task which requires much balance of judgment and profound analysis.

The recapitulation theory was a dominant note in all Balfour's speculations, and in that of his contemporary and fellow-student, Marshall. It has received its most sweeping application in the works of Ernst Haeckel.

Widely spread through the recent literature is to be noted a reaction against the too wide and unreserved application of this doctrine. This is to be naturally expected, since it is the common tendency in all fields of scholarship, to demand a more critical estimate in research, and to undergo a reaction from the earlier crude and sweeping conclusions.

Improvement in Methods.—Another feature of the work in Balfour's period was increasing attention to methods of preparing material for study. The great problem is to bring tissues under observation, with the normal relations as little disturbed as possible, so that the prepared material will represent the conditions existing in life and no others. "Many of the most important elements of cell-structure are invisible in life, and can only be brought to view by means of suitable fixation, staining and clearing." One great danger is that pseudo-structures will be artificially formed by the action of reagents. On this account great attention has been given to every

feature of technique, and the success of an investigation may depend, very largely, on the care exercised in the use of reagents and dyes, and the mechanical part of getting sections in shape for observation. Investigations of an earlier period were now repeated with greater refinement of technique, and the result was, a change not only in interpretations, but often in the points of observation.

Establishment of Marine Biological Laboratories.—Among other influences which have contributed to the advancement of embryology—as well as to all biology—has been the establishment of fully equipped sea-side laboratories. These have supplied facilities for working where developing forms are most abundant and most diversified. Also, as distributors of prepared material, they have made a wide range of forms available to investigators. The famous ‘*Stazione Zoologica*,’ founded by Dohrn in 1872, and still under his direction, has exercised a powerful influence. Not only have numerous researches in embryology been carried on there, but, also, prepared material has been shipped to investigators in all parts of the world. Balfour was one of the earliest to avail himself of the opportunities at the Naples Station. The Marine Biological Station at Wood’s Hole, Mass., of which Whitman has been director since its foundation, in 1886, is to be mentioned as second only to that of Naples for the extent of its influence and quality of its work. The many other similar laboratories in this country and abroad have aided in the great advance along embryological lines.

Nearly all problems in anatomy and structural zoology are approached from the embryological side, and, as a consequence, the work of the great army of anatomists and zoologists has been in a measure embryological. Many of them have produced beautiful and important work, but the work is too extended to admit of review in this connection.

Oscar Hertwig, of Berlin, whose portrait is shown in Fig. 12, is one of the representative embryologists of Europe, and lights of the first magnitude in this country are Brooks, Minot, Whitman and E. B. Wilson.

Although no attempt is made to review the researches of the recent period, we can not pass entirely without mention the discovery of chromosomes and of their reduction in the ripening of the egg and in the formation of sperms. This has thrown a flood of light on the phenomena of fertilization, and has led to the recognition of these bodies as, probably, the bearers of heredity.

The work of the late Wilhelm His, whose portrait is shown in Fig. 13, is also deserving of especial notice. His luminous researches on the development of the nervous system, the origin of nerve fibers, and his analysis of the development of the human embryo are all very important.

Recent Tendencies. Experimental Embryology.—Soon after the publication of Balfour's great work on 'Comparative Embryology,' a new tendency in research began to appear which led onward to the establishment of experimental embryology. All previous work in this field had been concerned with the structure or architecture of organisms, but now the physiological side began to receive attention. Whitman has stated with great aptness the interdependence of these two lines of work as follows: "Morphology raises the question, How came the



FIG. 12. OSKAR HERTWIG IN 1890.

organic mechanism into existence? Has it had a history, reaching its present stage of perfection through a long series of gradations, the first term of which was a relatively simple stage? The embryological history is traced out, and the paleontological records are searched, until the evidence from both sources establishes the fact that the organ or organism under study is but the summation of modifications and elaborations of a relatively simple primordial. This point settled, physiology is called upon to complete the story. Have the functions remained the same through the series? or have they undergone a series of modifications, differentiations and improvements more or less parallel with the morphological series?"



FIG. 13. W. HIS AT SIXTY-FOUR YEARS (1831-1904).

Since physiology is an experimental science, all questions of this nature must be investigated with the help of experiments. Organisms undergoing development have been subjected to changed conditions, and their responses to various forms of stimuli have been noted. In the rise of experimental embryology we have one of the most promising of the recent departures from the older aspects of the subject. The results already attained in this attractive and suggestive field make too long a story to justify its telling in this paper. Roux, Herbst, Loeb, Morgan, E. B. Wilson and many others have contributed to the growth of this new division of embryology. Good reasons have been adduced for believing that qualitative changes take place in the protoplasm as development proceeds. And a curb has been put upon that 'great

fault of embryology, the tendency to explain any and every operation of development as merely the result of inheritance.' It has been demonstrated that surrounding conditions have much to do with individual development, and that the course of events may depend largely upon stimuli coming from without, and not exclusively on an inherited tendency.

Cell-Lineage.—Investigations on the structural side have reached a high grade of perfection in studies on cell-lineage. The theoretical conclusions embodied in the germ-layer theory are based upon the assumption of identity in origin of the different layers. But the lack of agreement among observers, especially in reference to the origin of the mesoderm, made it necessary to study more closely the early developmental stages before the establishment of the germ-layers. It is a great triumph of exact observation that, although continually changing, the consecutive history of the individual cells has been followed, from the beginning of segmentation, to the time when the germ-layers are established. Some of the beautifully illustrated memoirs in this field are highly artistic. Blochman (1882) was a pioneer in observations of this kind, and, following him, a number of American investigators have pursued studies on cell-lineage with great success. The work of Whitman, Wilson, Conklin, Kofoed, Lillie, Mead and Castle has given us the history of the origin of the germ-layers, cell by cell, in a variety of animal forms. These studies have shown that there is a lack of uniformity in the origin of, at least, the middle layer, and therefore there can be no strict homology of its derivatives. This makes it apparent that the earlier generalizations of the germ-layer theory were too sweeping, and this theory is retained in a much modified form.

Theoretical Discussions.—Certain theoretical discussions, based on embryological studies, have been rife in recent years. And it is to be recognized without question, that discussions regarding heredity, regeneration, the nature of the developmental process, the question of inherited organization within the egg, or germinal continuity, etc., have done much to advance the subject of embryology.

Embryology is one of the three great departments of biology which, taken in combination, furnish us with a knowledge of living forms along lines of structure, function and development. The embryological method of study is of increasing importance to comparative anatomy and physiology. Formerly it was entirely structural, but is now becoming, also, experimental, and will be of more service to physiology. While it has a strictly technical side, the science of embryology must always remain of interest to intelligent people as embracing one of the most wonderful processes in nature—the development of a complex organism from the single-celled condition, with a panoramic representation of all intermediate stages.

GALILEO.

BY EDWARD S. HOLDEN, ScD., LL.D.,

U. S. MILITARY ACADEMY.

IV.

WHEN the master of the palace examined the published book he discovered that Galileo had not obeyed the orders and injunctions given to him by the Holy Office on February 26, 1616, sixteen years previously. Therefore the *imprimatur* for Rome was wrongly attached. Galileo did not inform the Inquisitor at Florence of the aforesaid injunctions and orders. Therefore the *imprimatur* for Florence was obtained by 'ruse.' Such was substantially the theory held by Galileo's judges at Rome. It was, in strictness, true. The command of the Holy Office (February 26, 1616) not to hold, teach or defend the Copernican opinion had been violated in the *Dialogues* (as indeed it had been violated less flagrantly in *Il Saggiatore* and in the letter on the tides). The orders of Riccardi were obeyed in form but not in substance. If the text of the *Dialogues* had been submitted at Rome, the Roman *imprimatur* would never have been given.

Finally, the general prohibition of March 5, 1616, not to teach the Copernican opinion had been disobeyed in the *Dialogues*, as in the two preceding publications. That no proceedings had been taken regarding the two last-named books did not in their eyes excuse the issuance of the former.

If Galileo had merely desired to promulgate the Copernican truths it would have been perfectly easy and safe for him to have printed his book in Germany, with or without his name. But he wished for an Italian triumph even more than for the spreading of a doctrine that he knew to be true.

The *Dialogues* were received on all hands with the greatest interest. Galileo's friends were delighted as they before had been with *Il Saggiatore*. They expected a similar reception for his new book, and Galileo beyond a doubt shared their expectations. Castelli—who was in favor with the Pope, and in Rome—wrote that he should read nothing else but the *Dialogues* and his Breviary. The enemies of Galileo were for the moment paralyzed with anxiety and rage. The arguments of the *Dialogues* were more dangerous than those of *Il Saggiatore* even. Its attack on Aristotelianism and orthodoxy was even more insidious and vigorous. The upper classes of Italy have always

keenly relished irony and sarcasm. They were now laughing openly at the overthrow of the scholastics. The universities, the Jesuits and many of the clergy, on the other hand, were solidly arrayed against Galileo. The Jesuits were especially inimical. In a juncture like this everything depended upon the Pope. Galileo confidently expected his support, but he had misread the Pope's mind from the very first. The Pope was surrounded by Galileo's enemies. Every point that would tell was made against the book and its author. The dangers that lurked in the Copernican doctrine were exposed; Galileo's former interpretations of Holy Writ were set forth as monstrous, coming, as they did, from the pen of a layman; their obvious weaknesses were pointed out; he was denounced as a rebel to church authority, which had forbidden any one to teach the Copernican doctrine (March 5, 1616); the Pope was convinced that Galileo had intended to portray him in the character of Simplicius.

It is absolutely certain that Galileo had no such intention. Under the circumstances it would have been madness for him to alienate his powerful friend and patron. Exactly why he closed his *Dialogues* with the quotation of the Pope's own words (spoken to Galileo in 1624) it is impossible to say. To us, in the light of events, the quotation seems an inconceivable blunder. But Galileo was very far from a blunderer. He was skilled in fine logic and with his pen. The closing words of the *Dialogues* (containing the quotation) can be read so as to express a humble submission to authority. It was beyond a doubt, Galileo's intention that they should be so read; it is equally certain that the submission was only perfunctory; the reckless irony of all that preceded them made the quoted words appear as mere foolishness in the mouth of the foolish Simplicius. The very name—Simplicius—was offensive to the Pope. It was not until after July, 1636, that he expressed himself as convinced that Galileo had intended no disrespect. It was then too late. On July 26, 1636, Galileo writes: "I hear from Rome that his Eminence Cardinal Antonio Barberini and the French ambassador (de Noailles) have seen his Holiness and tried to convince him that I never had the least idea of perpetrating so sacrilegious an act as to make game of his Holiness, as my malicious foes have persuaded him, which has been the prime cause of all my troubles." The *prime* cause was Urban's conviction that Galileo had brought scandal into the church by teaching a doctrine which was, as yet, unproved.

The storm was about to break. From now onward the story is fully told in the official documents of the inquisition. The further sale of the *Dialogues* was prohibited. Galileo's conduct was referred to a special commission of theologians and men versed in science to investigate. That it was not directly sent to the Holy Office was a

signal mark of favor. A letter, drawn up by Galileo, was despatched by the Grand Duke to the angry Pope. On September 4, 1632, the Pope said to the Tuscan ambassador, Niccolini—Galileo's faithful friend: 'Your Galileo has ventured to meddle with things that he ought not, and with the most important and dangerous subjects.' He added that Galileo's book had been printed by a ruse. As to the objections to the book 'Galileo knows well enough what the objections are . . . because we have talked to him about them, and he has heard them all from us.' The Pope had acted, he said 'with the greatest consideration for Galileo,' and added that his own conduct towards Galileo had been far better than Galileo's to him, for Galileo had deceived him. The Pope was firmly convinced that religion had been imperiled.

The special commission reported after about a month that Galileo has transgressed orders in deviating from hypothetical treatment of the Copernican opinion and by decidedly maintaining it he has erroneously ascribed the phenomena of the tides to the stability of the sun and the motion of the earth, which do not exist; he has been deceitfully silent about the command laid upon him by the Holy Office in 1616, to relinquish the Copernican doctrine 'nor henceforth to hold, teach or defend it in any way whatsoever, verbally or in writing, etc.,' 'which injunction Galileo acquiesced in and promised to obey.' Furthermore, Galileo printed the *imprimatur* of Rome on the title page of the *Dialogues* without authority; he put the saving clause of the book in the mouth of a simpleton, etc. (A full account of this report is given in Gebler's 'Galileo,' English edition, pp. 172-3. It is only incidentally of importance to us here.)

On the fifteenth of September, 1632, the Pope notified Niccolini that Galileo's affair was to be transferred to the inquisition. This was astounding news to the ambassador, who had all along believed that no proceedings would be taken against the astronomer and that the very worst to be feared was perhaps a command to alter certain phrases of the book. In the interview the Pope said 'Galileo was still his friend'—but that the Copernican opinion had been condemned sixteen years previously. At a meeting of the Congregation of the Holy Office held on September 23, it was pronounced that Galileo had disobeyed the command of February 26, 1616, and had concealed the prohibition then received by him from the censor at the time he applied for the *imprimatur* for his book; the inquisitor at Florence was, on the same day, by command of the Pope, directed to summon Galileo to appear before the commissary-general of the Holy Office in Room, 'as soon as possible, in the course of the month of October.' On October 1, Galileo, in writing, acknowledged the receipt of the summons and promised to present himself during October, as directed.

The correspondence of Galileo shows that the summons came as a complete surprise to him, and he could not have received it without grave apprehension. He had risked everything in the belief that the Pope's favor and friendship would continue; but it is plain that this order would never have been despatched unless that favor had been withdrawn; his enemies had triumphed; he was at the mercy of men who would show no mercy to him personally—as in times past he had shown no mercy to them; even his friends among the Roman notabilities were powerless in the face of the Pope's anger; and his most influential supporter—Prince Cesi—was dead. There can have been no moments in all of Galileo's long life so bitter as these. The whole fabric he had built up in his imagination crumbled in an instant. Numberless incidents that he had formerly interpreted in one way must have arisen in his mind demanding new and more veracious interpretations that could be reconciled with the present bewildering reversal of all his hopes and beliefs. The Holy Office would have no difficulty in proving him culpable of disobedience to its orders; the general prohibition binding on all catholics he had openly disobeyed, as well as the prohibitions special to his case.

A letter written on October 13 to one of the cardinals, Barberini,* shows Galileo's consternation and astonishment. He curses the time, he says, devoted to his studies. He begs the cardinal to intercede with the wise fathers in Rome, not to release him from giving an account of himself, which he is ready and anxious to do—but to make it easiest for him to obey. He can give his account in two ways; he can write a full history of his whole connection with the Copernican controversy which will prove to any one free from party malice that he has all along acted piously and as a good catholic; or he can give it verbally to the officers of the Inquisition in Florence. If, however, no dispensation or delay can be granted he will make the journey to Rome in spite of his great age and many bodily infirmities. The Tuscan ambassador at Rome interested himself in the matter, and throughout the whole of Galileo's process was devoted, prudent, wise and unwearied. No son could have been more faithful, nor more delicate. The letter was delivered, but the Pope would not permit delay. Galileo must come to Rome to answer. Niccolini then appealed directly to the Pope, begging for delay on account of Galileo's infirmities. The answer was that he must come—slowly, if necessary—with every comfort—but he must be tried in person, 'for having been so deluded as to involve himself in these difficulties, from which we had relieved him when we were cardinal.' On the ninth of December orders were sent to Florence to compel Galileo to set out. A medical

* Cardinal Antonio Barberini senior was the brother, and Cardinal Antonio junior was the nephew, of the Pope.

certificate of the seventeenth by Galileo's physicians pronounced him unfit to travel. The certificate was not believed in Rome, and Niccolini reported on the thirtieth that it was intended to send a physician from Rome with a commissioner who would, if he were fit to travel, bring him to Rome in chains.

On January 11, 1633, the Grand Duke wrote to Galileo advising him to set out, offering him one of the Court litters to travel in, and the hospitality of the ambassador's palace in Rome. On the twentieth of January Galileo left Florence on his last journey to Rome, arriving there, after a tedious quarantine, on February 13. Galileo, though technically a prisoner, was permitted to reside at the ambassador's palace. He writes to the Tuscan secretary of state that his treatment indicates 'mild and kindly treatment very different from the threatening words, chains and dungeons.' He was allowed to drive out, the shades of the carriage being half-drawn. His letters show that he was full of hope. It was now more than four months since he had been cited to appear, and in this time he must have considered what form the charges were to take and what defense he should make. Niccolini's despatch of February 27, 1633, says:

The main difficulty consists in this—that these gentlemen maintain that in 1616 he [Galileo] was ordered neither to discuss the question [the Copernican opinion] nor to converse about it. He says, on the contrary, that these were not the terms of the injunction which were that that doctrine was not to be held or defended. He considers that he has the means of justifying himself, because it does not at all appear from his book that he does hold or defend the doctrine nor that he regards it as a settled question, as he merely adduces the reasons, *hinc inde*. The other points appear to be of less importance and easier to get over.

From this despatch of Galileo's friend it appears that his defense was settled upon. The certificate of Cardinal Bellarmine was to be submitted to his judges; and it was to be proved from his book that he had obeyed the orders of the cardinal. Nothing was left undone by Niccolini, Castelli, or by the Grand Duke, to forward Galileo's interests. The Duke wrote letters of recommendation to the ten cardinals who made up the Holy Office, and some of the cardinals read the *Dialogues* and discussed them with Castelli. On April 12 Galileo was cited to appear at the Palace of the Inquisition. He acknowledged the *Dialogues* to be his own work. He was then asked to recount the proceedings of 1616 and replied that Cardinal Bellarmine had then told him 'that the aforesaid opinion of Copernicus might be held as a conjecture, as it had been held by Copernicus, and his eminence was aware that, like Copernicus, I only held that opinion as a conjecture,' which is evident from a letter (dated April 12, 1615) from the cardinal to Foscarini, in which he says: "It ap-

pears to me that your Reverence and Signor Galileo act wisely in contenting yourselves with speaking *ex suppositione* and not with certainty."

"In the month of February, 1616, Signor Cardinal Bellarmine told me that as the opinion of Copernicus, if adopted absolutely, was contrary to Holy Scripture, it must neither be held or defended, but that it might be held hypothetically and written about in this sense." Here Galileo presented a copy of the certificate which declares that the doctrine of Copernicus 'is contrary to the Holy Scriptures and therefore can not be defended or held.' The Inquisition then asked if any other command was communicated to him and if he would remember it, if what was then said was read aloud to him. Galileo replied: "I do not remember that anything else was said or enjoined upon me, nor do I know that I should remember what was said to me, even if it were read to me. I say freely what I do remember, because I do not think that I have in any way disobeyed the injunction, that is, have not by any means held or defended the said opinion that the earth moves and the sun is stationary." The Inquisition now remind Galileo that a command was issued to him, before witnesses, enjoining "that he must neither hold, defend nor teach that opinion in any way whatsoever." The annotation commands Galileo to 'relinquish altogether' the Copernican opinion, and forbids him 'henceforth to hold, teach or defend it in any way whatsoever, verbally or in writing; otherwise proceedings would be taken against him in the Holy Office; which injunction the said Galileo acquiesced in and promised to obey."

The Inquisition asks if Galileo remembers how and by whom the words first quoted were intimated to him. He replies: "I do not remember that the command was intimated to me by anybody but by the cardinal verbally; and I remember that the command was 'not to hold or defend.' It may be that 'and not to teach' was also there. I do not remember it, neither the definition 'in any way whatsoever,' but it may be that it was, for I thought no more about it, nor took any pains to impress the words on my memory, as a few months later I received the certificate now produced of the said Signor Cardinal Bellarmine, of twenty-sixth May, in which the injunction 'not to hold or defend' that opinion is expressly to be found. The two other definitions of the said injunction that have just been made known to me, namely, 'not to teach,' and 'in any way,' I have not retained in my memory, I suppose, because they are not mentioned in the said certificate on which I rely and which I have kept as a reminder."

Emphasis is laid by Gebler in his *Galileo* on the difference between an injunction 'not to teach' and one 'not to hold or defend.' I can see no essential difference between forbidding a citizen of Russia, let

us say, from holding or defending anarchistic opinions and forbidding him from holding, teaching or defending such opinions in any way whatsoever, verbally or in writing. The latter prohibition is more formal. It is not more absolute. The annotation of February 26, 1616, is received throughout the process by the Inquisitors as exact in all particulars. *It is not denied by Galileo*; he says merely that he does not recall certain parts of it. It does not formally appear that the witnesses to it were called to testify. If they had been called their recorded testimony would have settled certain points that must now be settled from the text of the annotation itself. I can see no reason to doubt that the words of the text mean precisely what they say.

This is perhaps the place to say that the documents of Galileo's process have been examined again and again and that each examination has proved that the papers have not been tampered with in any manner and that they represent the case as it was understood by the Holy Office with minute accuracy. The hearing for the first day was closed with further questions and answers. Galileo was asked whether after the aforesaid command was issued to him he received permission to write the *Dialogues*. He replied: "After receiving the command aforesaid I did not ask permission to write the book . . . because I did not consider that in writing it I was acting contrary to, far less disobeying, the command not to hold, defend, or teach, the said opinion." The next questions relate to the printing of the book and Galileo is asked if he had informed the censor of the command aforesaid. He replies: "I did not say anything about the command to the master of the palace . . . for I have neither maintained nor defended the opinion that the earth moves and the sun is stationary in that book, but have rather demonstrated the opposite of the Copernican opinion and shown that the arguments of Copernicus are weak and not conclusive." Galileo's defense is here outlined. It is to be that he did not 'hold' the Copernican opinion after 1616. Not holding it, he did not defend it, nor teach it. Hence he had disobeyed no command, he maintains, although it is obvious to all that the *Dialogues*, like his other writings, are a brilliant defense of the system of Copernicus.

An apartment of 'three large and comfortable rooms' was assigned to Galileo in the Palace of the Holy Office, as he was their prisoner. His servants stayed with him. His meals were sent in by the devoted Niccolini, to whom he wrote every day with perfect freedom. His own account of the proceedings of the first day of his examination is as follows:

I arrived in Rome on the tenth of February and I was placed in the element charge of the Inquisition and of the Sovereign pontiff, Urban VIII., who esteemed me although I could not rhyme epigrams and little love-sonnets. I

was placed in arrest in the delicious palace of . . . the Ambassador of Tuscany. The next day I received the visit of P. Lancio, Commissary of the Holy Office, who took me with him in his carriage. On the way he questioned me, showing a great desire that I should repair the scandal I had raised throughout all Italy by maintaining the opinion of the motion of the earth. To all the mathematical reasons that I could bring forward he answered one thing only. *Terra autem in æternum stabit, quia terra in æternum stat*, as the Scripture saith. Thus discoursing, we arrived at the palace of the Holy Office. I was presented, by the commissary, to the assessor with whom I found two Dominican monks. They notified me, with civility, that I should be permitted to explain my reasons to the congregation, and that, subsequently, my excuses would be heard if I were judged culpable. The following Sunday I appeared, in fact, before the congregation and proceeded to set forth my proofs. To my ill-fortune they were not satisfying; no matter what pains I took I could not succeed in making myself understood. My arguments were interrupted by their zeal, they spoke only of the scandal I had caused, always bringing up the passage of Scripture referring to the miracle of Joshua, as the unanswerable portion of the matter. This reminded me of another passage in which the language of the Bible is entirely conformable to popular notions—(The heavens are solid and polished like a mirror of brass). This example seemed to me to be opposite to prove that the words of Joshua could be so interpreted and the conclusion seemed to me to be entirely just. But they gave it no weight and I was answered only by shrugging of shoulders.

Galileo's own account of the proceedings gives a different impression from that of the official record. He was argumentative about texts of Scripture, and when his explanation of Joshua's miracle was not found satisfactory, he suddenly recalls another text which will convince the Inquisitors, he thinks, that Scripture is not to be interpreted literally. They answered by shrugging their shoulders and by again referring to the scandal he has created in the Church. Galileo does not seem to have, even yet, realized the situation. A letter from the commissary-general of the Inquisition to Cardinal Francesco Barberini (dated April 28, 1633) explains the events of the next weeks. The letter states that the commissary has informed the cardinals of the Holy Office regarding Galileo's case, and that they "took into consideration various difficulties with regard to the manner of pursuing the case and of bringing it to an end. More especially as Galileo has in his examination denied what is plainly evident from the book written by him; since in consequence of this denial there would result the necessity for greater rigor of procedure and less regard to other considerations belonging to this business. Finally I suggested a course, namely, that the Holy Congregation should grant me permission to treat extra-judicially with Galileo, in order to render him sensible of his error, and to bring him, if he recognizes it, to a confession of the same . . . permission was granted me. That no time might be lost, I entered into discourse with Galileo yesterday afternoon, and after many arguments and rejoinders had passed between

us, by God's grace I attained my object, for I brought him into a full sense of his error. . . . The affair is being brought to such a point that it may soon be settled without difficulty. The court will maintain its reputation; it will be possible to deal leniently with the culprit. . . .”

Who can say what the arguments of the commissary of the inquisitor were? They were effective. Galileo's attitude was utterly and instantly changed. On the thirtieth of April he again appeared before the Holy Office and read the following confession:

In the course of some days continuous and attentive reflection . . . it occurred to me to reperuse my printed dialogue, which for three years I had not seen, in order carefully to note whether, contrary to my most sincere intention, there had, by inadvertence, fallen from my pen anything from which a reader or the authorities might infer not only some taint of disobedience on my part but also . . . that I had contravened the orders of the Holy Church. . . . I freely confess that in several places it seemed to me set forth in such a form that a reader ignorant of my real purpose might have had reason to suppose that the arguments adduced on the false side, which it was my intention to confute, were so expressed as to be calculated rather to compel conviction by their cogency than to be easy of solution.

Two arguments there are in particular—one taken from the solar spots, the other from the ebb and flow of the tide—which in truth, come to the ear of the reader with far greater show of force and power than ought to have been imparted to them by one who regarded them as inconclusive, and who intended to refute them, as I truly and sincerely held and do hold them to be inconclusive and admitting of refutation.

And, as excuse to myself for having fallen into an error so foreign to my intention, not contenting myself entirely with saying that when a man recites the arguments of the opposite side with the object of refuting them, he should, especially if writing in the form of dialogue, state these in their strictest form, and should not cloak them to the disadvantage of his opponents—not contenting myself, I say, with this excuse—I resorted to that of the natural complacency which every man feels with regard to his own subtleties and in showing himself more skilful than the generality of men, in devising them, even in favor of false propositions, ingenious and plausible arguments. With all this, although with Cicero's '*avidior gloriæ quam satis est*' if I had now to set forth the same reasonings, without doubt I should so weaken them that they should not be able to make an apparent show of that force of which they are really and essentially devoid. My error, then, has been—and I confess it—one of vainglorious ambition, and of pure ignorance and inadvertence.

This is what it occurs to me to say with reference to this particular, and which suggested itself to me during the reperusal of my book.

This confused and almost incoherent confession is totally unlike the precise and elegant phrases of Galileo's writings. It is a complete reversal of his former position. Parts of it are evidently mere reminiscences of his conversation with the commissary-general ('vainglorious ambition,' for instance, is a phrase that he must have accepted, not one originating with himself). The whole is a weak abandonment of a position proudly held and is as different as possible from the

manly attitude of Cremonini—an attitude, be it remarked, which he successfully maintained in the face of the Inquisitors. No one can read it without pity. It can be interpreted in many differing ways. My own interpretation is that Galileo was persuaded to make the confession by representations that the case was very serious indeed and that a general admission of the sort would satisfy the Pope and cardinals; and that after the confession was obtained it was not very difficult for his judges to proceed to the abjuration; while if the abjuration had been first proposed Galileo might have desperately refused to make it, thus precipitating a crisis most unwelcome to the Holy Office. This is mere conjecture and is perhaps not worth recording. Certain it is that, the confession once extorted, all the dignity of Galileo's attitude was lost. By a slight increase of pressure one who had already yielded so much could be made to yield more, and finally to yield all. It seems to be clear that the pressure was gradually applied.

The confession was received by the congregation. Galileo withdrew; but almost immediately returned to offer to write a continuation of his *Dialogues* which should most effectually confute the arguments of the earlier portions. This offer is interpreted by Gebler as 'weakness and insincere obsequiousness.' It appears to me to be simply an attempt on his part to prevent the condemnation and prohibition of his book; and to show that he was, even yet, far from realizing the grimness of the situation. Immediately after the hearing, Galileo, still a prisoner of the Inquisition, was permitted to return to the palace of the Tuscan ambassador. He wrote letters (which are not extant) to friends. Their answers show that he 'entertained the most confident hopes of a successful and speedy termination of his trial.' One of them writes (May 12) from Florence: "I have for a long time had no such consolatory news as that which your letter of the seventh brought me. It gives me well-founded hopes that the calunnies and snares of your enemies will be in vain . . . since you have gained far more than you have lost by the calamity that has fallen upon you. My pleasure is still more enhanced by the news that you expect to be able to report the end of the affair in your next letter."

On May 10, Galileo was again summoned and was informed that eight days would be allowed him to prepare a defense. He, however, had already prepared it and at once submitted the following:

When asked if I had signified to the R. P. the Master of the Palace the injunction privately laid upon me, about sixteen years ago, by orders of the Holy Office, not to hold, defend or 'in any way' teach the doctrine of the motion of the earth and the stability of the sun, I answered that I had not done so. And not being questioned as to the reason why I had not intimated it, I had no opportunity to add anything further. It now appears to me to be necessary to state the reason in order to demonstrate the purity of my in-

tion, ever foreign to the employment of simulation or deceit in any operation I may engage in. I say, then, that as at that time reports were spread abroad by evil-disposed persons, to the effect that I had been summoned by the Lord Cardinal Bellarmine to abjure certain of my opinions and doctrines, and that I had consented to abjure them, and also to submit to punishment for them, I was thus constrained to apply to his Eminence, and to solicit him to furnish me with a certificate, explaining the cause for which I had been summoned before him; which certificate I obtained, in his own handwriting and it is the same that I now produce with the present document.

From this it clearly appears that it was merely announced to me that the doctrine attributed to Copernicus of the motion of the earth and the stability of the sun must not be held or defended and (here the original MS. is defaced) . . . beyond this general announcement affecting every one, any other injunction in particular was intimated to me, no trace thereof appears there. Having, then, as a reminder, this authentic certificate in the handwriting of the very person who intimated the command to me, I made no further application of thought or memory with regard to the words employed in announcing to me the said order not to hold or defend the doctrine in question; so that the two articles of the order—in addition to the injunction not to ‘hold’ or ‘defend’ it—to wit the words ‘nor to teach it’ ‘in any way whatsoever—which I heard are contained in the order intimated to me, and registered—struck me as quite novel and as if I had not heard them before; and I do not think I ought to be disbelieved when I urge that in the course of fourteen or sixteen years I had lost all recollection of them . . . whence it appears to me that I have a reasonable excuse for not having notified to the Master of the Sacred Palace the command privately imposed upon me . . .” [then follows a paragraph declaring that the faults scattered through this book ‘have not been artfully introduced’ but are inadvertent, owing to a vainglorious ambition and complacency . . . which fault he is ready to correct.]

Lastly, it remains for me to pray you to take into consideration my pitiable state of bodily indisposition to which, at the age of seventy years, I have been reduced by ten months of constant mental anxiety . . . ; [and he hopes that his judges may remit (his punishment) and may defend his honor and reputation against the calumnies of ill-wishers].

No one can read this confession and defence without a feeling of deep pity. This is even intensified if we find in it a lack of entire candor as it is hard not to do—‘mistrust in the truthfulness of the accused’—is Gebler’s phrase. Galileo returned to his palace feeling that his confession had served him well and that his trial was to come to a favorable issue. His confession had, however, put him in the power of his judges. They believed that now was the time to make a signal example. It was decided by the congregation (June, 1633) to bring Galileo to trial ‘as to his intention and under threat of torture.’

On the morning of June 21 Galileo appeared before the Holy Office, and after being sworn was questioned. His first answer was:

A long time ago, that is before the decision of the Holy Congregation of the Index . . . I was indifferent and regarded both opinions, namely that of

Ptolemy and that of Copernicus, as open to discussion, inasmuch as either one might be true to nature; but after the said decision, assured of the wisdom of the authorities, I ceased to have any doubt; and I held and still hold, as most true and indisputable, the opinion of Ptolemy, that is to say, the stability of the earth and the motion of the sun.

Questioned upon the publication of his *Dialogues*, he answers in accordance with his previous utterances. 'I am here to obey,' he says, 'and I have not held this opinion since the decision was pronounced.' The protocol of his trial concludes with the words: (Galileo's) 'signature was obtained to his deposition and he was sent back to his place.' This place was not the palace of the Tuscan ambassador. Galileo was detained at the building of the Holy Office till June 24. It is the opinion of the best judges that Galileo was not confined in the dungeons of the Inquisition.

There is not in the Vatican manuscript of the protocol, or in any other place, any evidence or any hint that Galileo was put to the torture at this or at any time. That he was threatened with the torture is equally certain. If he had boldly professed the Copernican opinion the proceedings would have taken a course that had been prescribed in advance (June 16). As he was disposed to abjure this opinion the course was different.

On the twenty-second of June, 1633, Galileo was brought into the presence of his judges, where his sentence was pronounced. The sentence of Galileo is a long document. The following extracts contain the points of especial importance.

We the undersigned (the names are given), by the Mercy of God, Cardinals of the Holy Roman Church, Inquisitors-general throughout all the Christian Republic, deputed by the Holy Seat against heretical perversity:

Whenceas, you, Galileo, son of the late Vincenzo Galilei, Florentine, aged 70 years, were denounced, in 1615, to this Holy Office, for holding as true a false doctrine proposed by several authors, that is to say, that the sun is immovable . . . ; and moreover for having had certain disciples to whom you taught the same doctrine; for having corresponded on this subject with certain mathematicians of Germany; for having made public certain letters on the subject of spots upon the Sun in which you expounded the said doctrine as true; and whereas you answered, when objections were made to you citing to you passages of Scripture, by explaining the said Scripture in your own manner; and whereas a copy of a letter was shown to you, said to have been written by you to one of your former disciples (Castelli), in which you, still maintaining the hypotheses of Copernicus, interpreted several propositions contrary to the meaning and the authority of Holy Writ:

This Holy Tribunal being therefore desirous of proceeding against the disorder and mischief thence resulting . . . the two propositions of the stability of the Sun and the motion of the earth were . . . qualified as follows:

The proposition that the sun is the center of the world and does not move from its place is absurd and false philosophically, and formally heretical, because it is expressly contrary to the Holy Scripture.

The proposition that the earth is not the center of the world and immovable,

but that it moves, and also with a diurnal motion, is equally absurd and false philosophically, and theologically considered, at least erroneous in faith.

But whereas *at the same time* it was our pleasure to proceed against you with benignity, *it was decided in the Holy Congregation . . . February 25, 1616, that the Very Eminent Cardinal Bellarmine should enjoin you to quit entirely the said false doctrine, not to teach it to others, not to defend it, never to treat it, under penalty that, if you failed to agree to this precept you would be thrown into a prison,* and for the execution of this decree, on the following day, in the Palace, in presence of the said Cardinal Bellarmine, after having been benignly admonished by him, *you received from the Commissary of the Holy Office, in the presence of a notary and of witnesses the injunction to desist entirely from the said opinion and for the future it was forbidden to you to defend it, or to teach it in any way, whether by word of mouth or by writing; and having promised obedience, you were dismissed . . . and, whereas, there appeared last year, at Florence, a book whose title named you as the author . . . in which was found a manifest transgression of the aforesaid ordinance intimated to you, and as in that book you defended the opinion that had been condemned, although, in the book, by various devices, you endeavored to persuade that you left that opinion undecided and expressly probable, which is in itself a very grave error, since an opinion cannot be probable when it has been declared and defined to be contrary to Holy Writ:*

It is for this reason that, by our order, you have been called to this Holy Office, where, examined upon oath, *you admitted that the said book was written and published by you; you confessed that it was commenced about twelve years ago, after having received the injunction above-named, and that you asked permission to publish it without signifying to those who were empowered to grant permission, that you had been enjoined from holding, defending or teaching such doctrine in any manner whatsoever.*

You also confessed that the said book in several places is so written that the arguments in favor of a false opinion may appear to be of a nature to force agreement, rather than such as to be easily refutable; *you excused yourself for falling into an error foreign to your intention on account of the dialogue form and because of one's natural inclination to show oneself more acute and more subtle than the generality of men. . . .*

And whereas delay had been granted you to prepare your defense you produced a letter from Cardinal Bellarmine, that you had obtained from him in order to defend yourself from the calumnies of your enemies who had spread abroad that you had abjured and that you had been punished by the Holy Office. This letter declares that you did not abjure nor were you punished; that you had only been notified of the declaration . . . that the doctrine of the motion of the earth . . . is contrary to the Holy Scriptures and that it can not be held or defended; and that as no mention was made in it of the prohibition of teaching in any manner whatever, it is to be believed that in the course of fourteen or sixteen years, this especial thing escaped your memory, and that this is the reason you said nothing of it when asking permission to print, and that in so speaking, *you do not wish to excuse your error which should be imputed to a vainglorious ambition rather than to ill intention. But even this certificate, produced in your defense, only makes your cause worse, since it is there said that the said opinion is contrary to Holy Writ, and nevertheless you have dared to treat and defend it, etc., and the permission (to print) that you obtained by ruse cannot help you. . . .*

And as it appeared to us that you did not speak the whole truth concerning your intentions, we judged it necessary to proceed to a rigorous ex-

amination at which . . . you answered like a good Catholic. . . . Therefore, having considered the merits of your case, with your confessions and excuses, and all that ought justly to be seen and considered, we have arrived at the underwritten final sentence against you . . . we say that *you*, the said *Galileo* . . . *have rendered yourself* . . . *vehemently suspect of heresy* . . . and that consequently you have incurred all the censures and penalties imposed . . . against such delinquents. From which *we are content that you be absolved, provided that first . . . you abjure, curse and detest the aforesaid errors (and) heresies . . . in the form to be prescribed by us, . . . and we ordain that the book of the Dialogues . . . be prohibited by public edict.*

We condemn you to the formal prison of this Holy Office during our pleasure, and by way of salutary penance, we enjoin that for three years you repeat the seven penitential psalms once weekly, reserving to ourselves full liberty to moderate . . . the aforesaid penalties . . . [signatures of seven cardinals—three not being present or not signing.]

The abjuration of Galileo is the last document of the pitiable history:

I, Galileo Galilei, . . . aged seventy years, arraigned personally before this tribunal and kneeling before you . . . swear that I have always believed, do now believe and by God's help will for the future believe, all that is . . . taught by the Holy Catholic and Apostolic Roman Church. But whereas—*after an injunction* had been judicially intimated to me . . . *that I must altogether abandon the false opinion* that the sun is the center of the world and immovable, and that the earth is not the center of the world, and moves, and *that I must not hold, defend or teach in any way* whatever, verbally or in writing, *the said doctrine* and *after* it had been notified to me that *the said doctrine was contrary to Holy Writ—I wrote and printed a book in which I . . . adduce arguments of great cogency in its favor . . . and for this cause I have been pronounced by the Holy Office to be vehemently suspected of heresy . . . therefore desiring to remove . . . this strong suspieion*, reasonably conceived against me, with sincere heart and unfeigned faith *I abjure, curse, and detest the aforesaid errors and heresies . . . and I swear that in future I will never again say or assert verbally or in writing, anything that might furnish occasion for a similar suspicion regarding myself; but that should I known any heretic . . . I will denounce him. . . . I the said Galileo have abjured, sworn, promised and bound myself as above . . . this twenty-second day of June, 1633.*

Of the foregoing documents it is necessary to say that most have been translated from the French of Delambre, as the English translations of Gebler were not accessible at the time of writing. It is believed that the extracts given accurately represent the originals. Certain phrases have been printed in italics to emphasize the essential facts of the story.

It is also necessary to inquire whether the documents, as printed, correctly state the facts of the trial of Galileo, his explanations, confessions and abjurations. It was certainly within the power of the writers of them to state these facts falsely, or to place them in a false light. Every one has to make up his mind for himself whether

the foregoing documents are to be taken as correct statements of the circumstances before and during the trial, or not. It is assumed in this paper that they are, in this respect, correct.

It seems impossible to make any thing more than a verbal distinction between an injunction 'not to teach' and one 'not to hold or defend.' An opinion that is held and defended to others is an opinion taught to them.

The words of Galileo's judges appear to mean precisely what they say. There was no need to distort them, for his confession of April 30 placed him completely at the mercy of his judges.

A discussion by Gebler (pp. 234-239) of the legality of the proceedings against Galileo and of the effect of the sentence against him brings out with complete demonstration the propositions that: 'the sentence of Galileo rests again and again, even on the principles of the ecclesiastical court itself, on an illegal foundation'; that 'Roman Catholic posterity can say to this day'—with truth—"that Paul V. and Urban VIII. were in error 'as men' about the Copernican system, but not 'as Popes'"; and that "the conditions which would have made the decree of the congregation, or the sentence against Galileo, of dogmatic importance were wholly wanting. Both Popes had been too cautious to endanger (the) highest privilege of the papacy, by involving their infallible authority in the decision of a scientific controversy."

There can be no doubt of the validity of these conclusions. The purpose of the prosecution was to check the spread of Copernican doctrines among the faithful and to utterly ruin the authority of Galileo. This purpose was fully attained when notice of his abjuration and punishment was sent to all vicars "so that it may come to the knowledge of all professors of philosophy and mathematics . . . that they may understand the gravity of the fault he has committed as well as the punishment they will have to undergo should they (likewise) fall into it." (July 2, 1633).

There is no need to trace the further history of Galileo's life in detail. He was permitted to return to the neighborhood of Florence and there he lived until his death in 1642—the year of Newton's birth.

His friend and pupil Castelli writes of his death:

The noblest eye which nature ever made is darkened; an eye so privileged, and gifted with such rare powers that it may truly be said to have seen more than the eyes of all that are gone, and to have opened the eyes of all that are to come.

The year 1638 was marked by the publication of his epoch-making book 'Discourses on two new Sciences appertaining to Mechanics and Motion.' This contained the foundation of the modern doctrine of

mechanics and it is the crowning glory of Galileo's life. It attracted instant and universal attention, and at the age of seventy-four Galileo was again recognized by all Europe as a master of science—a founder of doctrine. The troubles of his later years grew light in the satisfaction of his legitimate pride.

Myths have grown up about the history of Galileo that it is not necessary to destroy. The whole distressing story has been told in authentic documents. He never suffered bodily torture; he was humiliated and discredited. He never even dared to whisper: *E pur se muove*. His history, though misinterpreted, has been of the deepest service to the world. It affords a symbol around which the rights of men to freedom of thought have clustered. Just as Benedict Arnold serves as the type of a traitor, so Galileo has been made to serve as a martyr of science. But he was no martyr. A true martyr does not abjure his opinions even in presence of the rack. While his recantation may be excused, it does not testify to moral greatness. We may add a paragraph from Gebler:

Party interests and passions have to a great extent and with few exceptions, guided the pens of those who have written on Galileo's life. The one side has lauded him as an admirable martyr of science, and ascribed more cruelty to the Inquisition than it really inflicted on him; the other has thought proper to enter the lists as defender of the Inquisition, and to wash it white at Galileo's expense. Historic truth contradicts both.

Galileo was a genius of the first order. His title to lasting fame rests principally on his investigations in mechanics and physics, on the theory of the pendulum, the law of falling bodies, the invention of the thermometer, and on the intelligence with which he employed his unique opportunity for telescopic discoveries. His popular reputation will, however, always be based upon his re-invention of the telescope, his advocacy and proof of the Copernican system, his sufferings from the Inquisition, his torture, his abjuration, his seclusion at Arcetri. He will remain preeminently the martyr for science.

THE TEACHING OF LOGIC.

BY PROFESSOR ARTHUR H. DANIELS,
UNIVERSITY OF ILLINOIS.

IT is a well-known fact that logic is not so generally studied to-day as formerly, and that, on the whole, the attitude towards its educational value is one of indifference. If, however, we try to account for its present status in our colleges by granting that logic is an inherently difficult and uninteresting subject, our explanation is both inadequate and unfair to the subject itself. True, logic does require a distinctively analytic and reflective quality of mind. It does not afford the possibility that some subjects do, of getting through it by leaning upon memory, or by appropriating the thoughts of another; but, on the other hand, it constantly demands a conscious effort to think, in the absence of those substitutes for thinking things out for themselves which the weak and lazy-minded resort to. True, logic can make no exclusive claim to being an intellectual discipline. Other academic studies furnish just as severe tests of mental power. The real truth of the matter is that the formal conception and abstract presentation of logic are responsible for a large share of its unattractiveness and needless difficulties.

What I have to write has reference only to elementary or introductory logic. As to the metaphysics or the higher problems of logic I have nothing to say, in this connection, save to express my firm belief that the less an elementary course in logic has to do with metaphysical questions the better. In fact, the discredit into which logic has fallen is in part due to the teaching of the subject from the philosophic standpoint. To hold the place that it deserves in the college curriculum, logic must be shown to have some practical value. I know that this word is in disfavor. We are told of the mathematician who thanked heaven that he had at last discovered a truth which no one would ever be able to make any use of. Perhaps this seeker after truth was but voicing the common antipathy for the word practical. If it is a hopelessly obnoxious term, why not adopt a word used by President Eliot and then always aim to make truth serviceable? It is my purpose in this article to point out some changes in the mode of presenting logic, whereby it may be modernized and made an attractive and useful undergraduate study.

In the first place, the definition of logic should convey to the be-

ginner's mind a comprehension of its scope and purpose as concrete as possible. I can think of no better way of accomplishing this than by stating at the outset that the business of logic is to formulate and systematically present the methods of our thinking for the purpose of acquiring knowledge of the correct methods and skill in their use. This would make logic a science, treating its subject matter descriptively rather than philosophically.

Then proceeding to what is properly the first division of logic, namely, the study of words or terms, it should be made clear that logic treats language from the standpoint of meaning. In reality, logic, so far as its discussion of terms and propositions extends, is one of the trinity of subjects which have to do with the use of language. Its relation to grammar and rhetoric may be best made clear by regarding as the primary interest of logic the function of words as expressing the thought of the speaker or writer. Of course, logical analysis is inseparable from the correct teaching of grammar and rhetoric. But the actual practise is frequently such as to warrant the criticism that sense is sacrificed to grammatical and rhetorical niceties. One is also reminded of that portion of Mr. Huxley's criticism of the teaching of English literature at Oxford, where he writes: "I venture to doubt the wisdom of attempting to mold one's style by any other process than that of striving after clear and forcible expression of definite conceptions; in which process the Glassian precept, 'first catch your conceptions,' is probably the most difficult to obey."*

If students take up logic with the idea, carried over from their study of grammar and their use of dictionaries, that words get their character as nouns, or verbs, or what not, from their origin or form, they should be made to understand early that it is quite an erroneous idea. "The logical character of a name is not something fixed and stable, but quite the reverse. It is function, not structure, that determines logical character, and the function of words in asserting is variable. The different actual uses of names are what logic needs to distinguish, not different sorts of names apart from their actual use, words in their context, not words as grammar conceives them or as they lie side by side in a dictionary. . . . Since words are adaptable instruments of assertion, and not restricted to a single function, we might as well ask whether a penny stamp in the pocket is a receipt stamp or a postage stamp, as ask whether a word apart from its particular use has this or that logical character."† The logical treatment of terms is essentially the question of how they are used in this or that connection.

* 'Life and Letters,' vol. 2, p. 302.

† Sidgwick, 'Use of Words in Reasoning,' p. 243.

The same point of view should be maintained when we come to the next division of logic—the study of propositions. Here, likewise, the meaning side of language, and not the form, is of primary interest. Many students have difficulty in realizing that the meaning of a proposition does not depend upon its form; that affirmative, or negative, or categorical forms are not necessarily expressions of affirmative, or negative, or categorical thoughts. For example, the last clause of the verse, ‘Because strait is the gate, and narrow is the way, which leadeth unto life; and few there be that find it,’ is very frequently interpreted as meaning ‘some do find it.’

In this connection there is another not uncommon error, namely, that of regarding two propositions, worded differently, as different assertions, when, in fact, they assert the same thing.

But traditional logic is of little help in the whole matter of logical analysis. For instance, its treatment of conversion makes dry reading and a perfunctory task for the student. It is even worse; it savors of the artificial and useless. That a subject of such importance as conversion should be presented in a way so unnatural and forbidding as that of the traditional logic is much to be regretted. Logic should teach in this matter, not traditional rules, nor discussions of formal subtleties, but the simple truth that the rightness or wrongness of every converse rests on precisely the same basis as that of the original proposition, namely, known facts and laws. The proposition that ignorant people are superstitious is true because it agrees with the facts. But if we change it into superstitious people are ignorant we do not get a good converse, because this proposition does not agree with the facts.

In the next place, the syllogism needs more radical change in treatment than either of the two previously mentioned divisions of so-called deductive logic. The traditional treatment has overloaded the subject with dry discussions, rules and symbolical schemes, so that there is hardly left the slightest appearance of any connection with actual thinking. Better omit all mention of figure, mood, reduction, and the question whether there are three or four figures, than miss the important lesson of the syllogism. “There is little,” says Mr. Sidgwick,* “that need be taught about the syllogism, since the process itself—which is merely that of bringing a particular case under a general rule—is used instinctively by every one from childhood onwards.” Examples like these, ‘Five francs are a dollar, four shillings are a dollar; therefore five francs are four shillings’; or, ‘Some men are not fools, yet all men are fallible,’ are not suited to bring out the real ‘process,’ much less to train the mind in accurately applying a general truth to a particular case. In fact, too many of the arguments selected

* Sidgwick, ‘Use of Words in Reasoning,’ p. 354.

by authors of text-books for illustration and training in syllogistic reasoning serve little more than to show the machinery of the syllogism. Others are either too hackneyed, transmitted as they have been from one generation of writers to another, or are lifeless fragments and consequently mean scarcely more than so many words. Then, again, cases of faulty argument constitute too large a proportion of text-book exercises. If selected with discretion, defective reasoning may be used to bring out in the most emphatic manner certain mistakes commonly made in thinking. If, however, examples of bad reasoning are too patently wrong, or if they appeal simply to the instinct of curiosity and afford an excess of amusement, they are likely to fail in elucidating principles and establishing correct habits of thought. On the whole, fresh arguments taken from living thought, which are also models of accurate thinking, should be more extensively used.

At this point in the teaching of logic comes the real test of the instructor's skill. Instead of relying upon the text-book, he must depend for illustration upon his own resources. And, as far as possible, the illustrations should be presented in their full form, as actual arguments, and not in the condensed and lifeless way that text-books from lack of space are forced to do. Moreover, what is of even more consequence, he must be able to stimulate students to find material for themselves. There is no more direct and practical way than this for the student to cultivate the critical habit of mind in reading newspapers and periodical literature, as well as the literature of the various subjects of his college course. Such material would constitute what John Morley has somewhere called 'reasoning in real matter.' "It would make such a manual as no other matter could, for opening plain men's eyes to the logical pitfalls among which they go stumbling and crashing when they think they are disputing like Socrates or reasoning like Newton. They would see how a proposition or an expression that looks straightforward and unmistakable is yet, on examination, found to be capable of having several distinct interpretations and meaning several distinct things."

Of course there is danger of using exercises that for one reason or another are beyond the grasp of the sophomore or even the average senior. And yet, I am inclined to think that whatever pedagogical mistakes have been made in this connection have for the most part been in the direction of making the illustrations and problems so commonplace and simple as to seem silly. Indeed there is much to justify the student in real life in making the criticism of the student in the story, who says: "When they spring those tricks on you about the flying arrow not moving, and all the rest, and prove it by pure logic, you learn what pure logic amounts to when it cuts loose from common sense."

It is more evident in the ordinary treatment of inductive logic than in the case of deductive, that the subject is descriptive in character, with its data taken from the work of scientific investigators and discoverers, and its purpose to set forth the approved ways of thinking. Nevertheless, more might be done to anticipate a first impression, not at all uncommon with students, that the subject matter of inductive logic is abstract and quite removed from daily human interests. There is no danger of over-emphasizing the relation of what is taught in the class room to the realities of life, by way of showing that the content of logic is not the invention of text-book writers, and is not esoteric in its nature and use; that the methods described and analyzed in treatises on logic may be said to have their primitive forms in the uncultivated state of the human mind whether in savage or in civilized society. What is scientifically known as the uniformity of nature and the method of difference are but the tendencies of the human mind to expect similar coexistences and sequences under similar conditions, and to regard the new antecedent as the cause of the new phenomenon, tendencies as strong in the savage as in the civilized mind. In brief, we should show the student that the difference between the principles and methods of common life, and those studied in logic, is the difference between spontaneous and attentive observation; between rash and rationally guided theorizing; between verification that is heedless and insufficient, and that which is exact and exhaustive.

Induction should be understood in its proper connotation. To conceive it as simply the reverse process of deduction, to regard it as identical with case-counting, or mere generalization based upon facts, is to remain ignorant of the complex and varied nature of scientific method, in which generalization plays but one part. A logical analysis of inductive method should be so complete as to make it unmistakably evident that to be a scientific investigator is to be more than a collector of facts and a propounder of theories. Darwin once remarked that any fool could generalize and speculate. The verification of theories by appeal to facts and known laws is the step in inductive procedure quite frequently overlooked or hastily taken. And yet the importance of it is emphasized by what has been said of eminent scientific investigators, namely, that the process of deduction has played a more important part in their work than induction; that their days were spent in verifying their theories and establishing the further consequences of them.

The failure to understand the complex nature of inductive method appears now and then in another form. It finds expression in the opinions of those who profess to speak authoritatively upon the study of science from the pedagogical point of view. According to this view, the distinction between the observational and the experimental

sciences is of insignificant value, and the arrangement of science courses might well enough be determined by local and economic conditions.

This misconception should be classed with that of mistaking general for singular terms, as is often done in the case of moral law and natural law. For it regards science as all one and the same, having one invariable procedure in all branches of scientific research, regardless of the peculiar nature of any particular group of phenomena. Consequently a study of any one of the sciences ought to satisfy the modern demand for science study and should qualify the more brilliant students as competent and reliable investigators in any branch of science whatsoever. If this were true, then, so far as pertains to method, the chemist might at once turn psychologist and pursue his work as successfully as though he had received his training in psychology instead of chemistry. The ideal man of science would be the last person to make any such claim. For he well knows that, besides the common features of the scientific method which appear everywhere in their broad outlines, there are numerous variations due to individual characteristics possessed by the data of the various sciences or different groups of sciences, and that to be a good scientist requires a preparation in the field in which one is to work. A better understanding of these facts might do much towards dispelling illusions as to a model science and the superiority of one science over another. Unfortunately scientists often assume an unscientific attitude towards one another. The physicist, for example, declares that for one to undertake the scientific study of psychical phenomena is to sound his death knell as a scientist. There is much need, among investigators in the various fields of human interest, of increased respect for one another's methods and results; of an intelligent conception of the peculiar conditions and difficulties of problems other than one's own; and instead of ridicule and depreciation, a just and cordial recognition of contributions honestly made, even though they lack the precision and finality which characterize results obtained elsewhere.

In addition to an orderly presentation of scientific methods and analysis of important and interesting conceptions such as the uniformity of nature, cause, hypotheses, theory, law, inductive logic should make it very evident that the data of our thinking are varied, and that the character of many conclusions is problematical. The facts of human experience, the problems of the world at large, do not lend themselves to any 'secure method' or yield conclusions that are certain. At one time we must act decisively on inferences which are far from approximating to certainty; and then again when it is not a question of choosing or starving, we need that suspended judgment which has been called the greatest triumph of intellectual discipline. In brief,

a course in minor logic constructed along the following lines will, to my mind, render the best educational service: Definition and classification, with special emphasis upon *use* as determining the meaning of terms. The interpretation of propositions and the relation between form and meaning, with much stress laid upon the complexity of actual thinking rather than upon categories, predicables and symbols. The study of the syllogism as a form to which arguments may be reduced for the purpose of critical analysis. Training in ability to examine the validity of premises and their application to particular cases. And finally, the study of inductive methods with the view of familiarizing students with the actual ways by which knowledge is discovered.

All this means that logic is essentially a psychological rather than a philosophical study; that its content is mental phenomena, because the study of methods is but the study of the human mind engaged in the search of truth; that induction and deduction are in reality two constantly interplaying processes and are never found to be what the time-honored division of text-books suggests. Discussions of controversial topics, in which logicians delight, and from which no text-book, so far as I know, is wholly free, should be excluded. They have little interest for most students and besides obscuring the real content of minor logic, are likely to produce the impression that logic lacks definiteness and substantial basis. It is much better to hand over speculative questions to philosophy proper. Enough will be left for the course in logic in the time usually allotted it. What Professor Hyslop has said is eminently true: "Logic has been made too formal for usefulness and postponed too late in the course. It ought to follow mathematics immediately, to correct the confidence in reasoning that that science inculcates consciously or unconsciously."*

A word, in closing, upon a possible criticism of that part of logic which treats of inductive method. Why study logic in order to become familiar with the methods of science? Why not go directly to the several sciences themselves?

"We sometimes can not see the wood for the trees; and lose the broad outlines in the multiplicity of details." Just as we need to get out from among the trees to look at the wood; to stand some distance from the building to get a full view of it, so the scientist must needs view the structure of scientific knowledge from outside his own special field.

It is a frequent experience that students become so engaged in the multiplicity of fascinating phenomena of one science, or charmed by

* *The Psychological Review*, 1903, p. 180. Sidgwick's 'Use of Words in Reasoning,' and Aikins' 'The Principles of Logic,' show an encouraging tendency away from the traditional treatment of logic.

mechanical manipulations, that they are oblivious to underlying truths shared in common with their own and other subjects, or perhaps fail to appreciate the individual characteristics of a particular subject or group of allied subjects.

It can not be gainsaid that "a scientific habit of mind can be acquired only by the methodical study of some part at least of what the human race has come scientifically to know." But logic may supplement this indispensable kind of training. In it the methods themselves are made the direct objects of study. Brought together from near and far they may be compared, analyzed and classified with the attention focused upon them in their broad outlines. So presented, with a good body of illustrations, they may be above criticism as too formal or abstract, and furnish both layman and specialist with means of cultivating the sense of discrimination and widening their interests and sympathies.

THE MUTATIONS OF LYCOPERSICUM.

BY DR. CHARLES A. WHITE,
SMITHSONIAN INSTITUTION.

DURING the years 1901 to 1903 inclusive I published results of my observations and experiments concerning the horticultural variability, atavic reversion or degeneration, and phylogenetic mutation of the common cultivated tomato. The reader is referred to those publications for such statements of pertinent facts as may be omitted from this one.* The object of the present article is to give in popular form a concise restatement of my experimental observations upon some remarkable cases of saltatory plant mutation and varietal changes of the tomato fruit, together with figures and additional discussions. Although the cases of plant mutation referred to constitute the leading part of my subject, I will first discuss the origination and decadent extinction of the improved fruit varieties which have arisen in connection with, and apparently as a result of, horticultural conservation. These discussions are necessary to the making of a clear distinction between fruit variation and plant mutation as I shall have occasion to refer to them.

The enormous increase in the importance of the tomato as an article of food during the past thirty years has so stimulated its cultivation that very many fruit varieties of fine quality have resulted, figures and descriptions of the more important of which are annually published in seed growers' catalogues. During that time also at least two new specific plant forms have suddenly originated by mutation from the common species,† *Lycopersicum esculentum*, making not less than three species of the cultivated tomato. It is desirable to characterize these species briefly in connection with the discussion of the fruit varieties which they bear. The two new species referred to I have called *L. solanopsis* and *L. latifoliatum*, respectively, of course leaving the original name, *L. esculentum*, with the unmutated, or mother form.

* 'Varietal Mutation in the Tomato,' *Science* (n. s.), vol. xiv., pp. 841-844, New York, Nov. 29, 1901. 'The Saltatory Origin of Species,' *Bull. Torrey Bot. Club*, vol. xxix., pp. 511-522, New York, Aug., 1902. 'My Tomato Experiments,' *The Independent*, vol. liv., pp. 2460-2464, New York, Oct. 16, 1902. 'Aggregate Atavic Mutation of the Tomato,' *Science* (n. s.), vol. xvii., pp. 76-78, New York, Jan. 9, 1903.

† To avoid undue repetition, the terms 'species' and 'plant forms' are used interchangeably; and the term 'mutation' is used in its now accepted sense of sudden origination of species.

This mother form, even as delimited by the mutations just mentioned, is much the most common one in cultivation. Its early stage of growth is fairly represented by the accompanying Fig. 2. The form to which the name *L. solanopsis* is given is well represented in a similar stage of growth by Fig. 1. Short descriptions of these two forms are recorded on a following page. I am not now able to present a figure of *L. latifoliatum*, but it is represented by the plant which bears the fruit variety known to gardeners as the Mikado, or Turner's hybrid. I think the latter name, when applied to the plant, is misleading because this specific plant form doubtless originated by true mutation, as *L. solanopsis* has done; and it is by no means certain that even the fruit variety which it then bore originated by hybridization.



Fig. 1. REPRESENTING *L. solanopsis*,
THE DAUGHTER FORM.



Fig. 2. REPRESENTING *L. esculentum*,
THE MOTHER FORM.

The difference of *L. latifoliatum* from the two other forms mentioned is conspicuously seen in its peculiar foliage, the leaves having decurrent petioles and broad, flattened leaflets with their borders entire instead of notched or crenulated. These three species are as well defined and distinct as are any others of the dozen recognized species of *Lycopersicum*, and as distinct as are many of the recognized species of other plants, whether wild or cultivated, and there is apparently no tendency of the two derived species to revert to the mother form. I do not know of any case of hybridity between any two of them, and no indication of further mutation of the two new species has been observed.

It is from these three specific plant forms that the improved fruit varieties have arisen. The greater part of them have arisen from *L. esculentum*, as that species has been delimited; a considerable number have arisen from *L. solanopsis*, while *L. latifoliatum* has hitherto shown the minimum of varietal change in its fruit. These varieties

differ more or less from one another in shades of color, but their valuable qualities appear in the increased solidity or consistence, size and fine flavor of the fruit. Their origination has, in many cases at least, been sudden and fortuitous; and, although their specific characters are usually heritable, they are so peculiarly subject to degeneration that they hardly possess racial properties. The causes of their origination and extinction appear to be irrelative, and both are independent of specific plant mutation. Still, as I shall show, a few cases of coincidence of their origin with plant mutation are known; and more or less of common plant variation, and even of dwarfing, have sometimes occurred coincidentally. Moreover, all cases of atavic reversion, or degeneration, of fruit varieties from their fine quality have apparently been unaccompanied by any material change in the plants bearing the degenerating fruit. Frequently special reference to those reversions will be made further on, but I will first turn aside for a few more or less theoretical remarks upon the character and manner of origination and extinction of the fruit varieties.

In the simple cases of origination of the fruit varieties of the tomato, unaccompanied with plant mutation, the change occurs only in the pericarp, which becomes the fruit. Also, when atavic reversion occurs it is only the pericarp, that is, the fruit, which is materially affected; and both kinds of these changes are doubtless of molecular origin in the germ cells. Likewise, in all cases of phylogenetic plant mutation the initial act is molecular, and occurs in the germ cell of each ovule which gives origin to a new plant form.* There is no apparent reason to doubt that the mutative acts which thus respectively produced the two new specific forms from *L. esculentum* might have occurred without the coincident production of a new fruit variety, but as a matter of fact a new fruit variety of high quality was coincidentally produced in each case; and the coming change in both plant and fruit was doubtless initiated in one and the same germ cell. Still, because of the essential difference between plant mutation and fruit variation, I think this pericarpal change was only a varietal coincidence, and not an essential part of the phylogenetic process in those cases. Moreover, that change is known to have occurred separately in other cases, and to have resulted only in weakly heritable fruit varieties.

Known cases of degeneration, and final extinction of fine fruit varieties as such, are somewhat numerous, for their instability is very great, although at least most of them remain true to seed from year to year under favorable conditions. Whether the varieties which have

* For exhaustive discussions of this and kindred subjects see 'Intracellulare Pangenesis' by Hugo de Vries. Jena, 1889; and also 'Die Mutationstheorie,' vol. 1, by the same author.

arisen from the two new specific plant forms that were derived by mutation from *L. esculentum* are more permanent than are those of the mother species I do not now know, but all the cases of atavic reversion known to me have occurred with fruit varieties of the mother species. It therefore seems possible that the fruit varieties arising from *L. solanopsis* and *L. latifoliatum* may be less liable to hybridity, or otherwise more permanently heritable, than are those arising from the mother species, *L. esculentum*. The fruit of the two derived species has always been of fine quality and, for them, intraspecific fruit reversion would not be degeneration; but the original fruit of the mother species was very inferior, and any reversion of its improved quality would be degeneration. For those who may have the opportunity, it will be interesting to observe the relative permanence of the fruit varieties arising from the different species, and the course that may be taken in any qualitative changes that may occur in the fine fruit varieties of the two derived species. In the case of the mother species the trend of fruit degeneration is direct, intraspecific and towards the primitive fruit condition. If similar reversional trend in the fruit of the two derived species could occur it would necessarily be accompanied by coincident reversion of specific plant characters, an occurrence which I think improbable, or we should have one and the same kind of degraded fruit borne by different species.

Returning to the practical consideration of atavic reversions of fine fruit varieties, it may first be mentioned that they often occur locally and affect only a few plants, or the crop of a single garden or field, the variety thus affected remaining unchanged elsewhere, but, as I shall show, cases of reversion are often much more extensive. The progress of reversion is sometimes slow and sometimes sudden, the whole change in the latter case often occurring in a single generation. The effect is much the same whether the degenerating process is sudden or slow; and however widely the improved varieties may have differed from one another, the reversional trend of all is towards the comparatively small globular berry that may be properly regarded as the primitive tomato fruit form. In slow degeneration the fruit begins to ripen unevenly; it diminishes in size and becomes comparatively soft, and has a rank taste. The walls and dissepiments become thin, the seed compartments are reduced to four, three, and even to two, and the seed pulp is more abundant and more watery. In sudden reversion the primitive berry condition is reached, or approached, at a bound. These remarks concerning degeneration apply especially to the varieties which have arisen from *L. esculentum*, as delimited, of which cases only I have had personal knowledge.

With the possible exceptions which were merely suggested in a previous paragraph, the duration unimpaired of any of the highly

improved fruit varieties of the tomato is only a few years under favorable conditions; and constant care is necessary to maintain their fine quality. Therefore the tendency to deteriorate is doubtless inherent; but this result is evidently hastened by careless cultivation, repeated planting of the same ground without rotation with other crops, the growing of plants from unharvested seed, cross pollination with inferior kinds, differences in character and fertility of the soil, and the influence of a climate much warmer than, or otherwise different from, the one in which the seed was produced. That this fruit degeneration is sometimes slow and sometimes sudden; that it is imminent and variously excited to action; that it is not confined to sporadic cases of single plants, but may, and often does, equally affect a whole crop, and sometimes all the crops of a wide region, is shown by the following statements of relevant facts.

Every person who habitually visits the vegetable markets of any one of most of our towns and cities which are supplied from neighboring gardens is familiar with the different grades in quality of the tomatoes there on sale. Indeed, it is often easy to recognize among them different stages of reversion from some of the more common improved varieties, notably the Acme. These are too plainly cases of gradual degeneration, resulting from careless cultivation and crossing with inferior kinds, to need explanation. Several of my correspondents have furnished me with important corroborative facts. Dr. Geo. G. Groff writes that he has for many years observed in central Pennsylvania, that tomato plants which sprang from seed of good varieties left in the ground during the winter always produced inferior fruit, usually the small kind called cherry tomatoes. Miss Mary E. Starr informs me that during her residence in Saint Martin's Parish, southern Louisiana, her father found it necessary to procure tomato seed from the north for every crop grown on his plantation, because the seed from even the first crop of tomatoes grown there usually produced very small and inferior fruit. Mr. L. S. Frierson, however, writing from northwestern Louisiana, says that he has produced excellent fruit, true to seed, from his home-grown crops. Mr. H. J. Browne, of Washington, D. C., sent me from a plantation near Havana, Cuba, a small parcel of cherry tomatoes taken from plants which he found growing there luxuriantly. The planter assured him that they were the immediate progeny of the first Cuban crop of a fine large fruited variety, the seed of which he obtained from New York under the well-known varietal name of Trophy. He also asserted that such degeneration was always the result of his attempts to raise tomatoes from Cuban-grown seed, however fine might be the variety from which his original seed was obtained. The fruit of the first Cuban crop, like that of southern Louisiana, was always true to northern seed,

showing that the initial step towards atavistic change took place in the germ cell of every one of the first seeds produced on those southern soils, and that the reversion was therefore sudden and aggregate. Mr. Browne, who has business interests in Calapach island, which lies thirty miles east of the Isle of Pines and eighty miles south of Cuba, also informs me that there are now growing on that island tomato plants which are four or five years old, they having changed from the condition of annual, to that of perennial plants in that tropical climate. Furthermore, the fruit of those plants has changed from a good variety of large size for the first fruitage to the cherry form and size before mentioned for the later fruitages.

These credible facts, gathered from widely different sources, plainly indicate that various exciting causes of varietal fruit degeneration exist, but they throw little light upon the real nature of those causes. The facts mentioned also indicate that many new opportunities are likely to arise for scientific agricultural experimentation with the tomato. Our tropical and subtropical island possessions will doubtless soon be called upon to supply, for our own and other countries, the increasing demand for early tomatoes, just as northern Egypt has been made the early tomato garden of Europe. My present object in referring to these facts, however, is their application to the second part of my subject.

This second part pertains to phylogenetic plant mutation as distinguished from ordinary plant variation and the production of new fruit varieties. The immediately following remarks embrace in narrative form an account of two cases of saltatory plant mutation which have fallen under my experimental observation. In the spring of 1898 I purchased a couple of dozen young tomato plants of the Acme variety which had been germinated by a gardener near Washington, D. C., and transplanted them, before any of their flower buds were formed, in a garden plot of a few hundred square feet, upon my house lot in the city. Short specific descriptions of these plants and their progeny are given for the purpose of showing their differences.

As the plants matured and fruited they were found to possess all the characteristics of the Acme variety, and of typical *L. esculentum*. They early became decumbent, and at full maturity they were large and diffuse; the haulms, which were slender and somewhat numerous, reaching a maximum length of more than two meters; color of the foliage a comparatively light green; the petiole-midribs long and slender; leaflets moderately narrow, distant, petiolulate, and their surfaces only slightly rugose; fruit of moderate size, usually depressed-globular in shape, but sometimes transversely oval, uniformly ripened, fleshy and well flavored, and in ripening the chlorophyll green changed to a deep crimson through more or less of yellow.

I selected seed from the fruit of the best plants of this crop of 1898, cured, and sealed them in a packet, and planted a random portion of them in my garden in 1899. I expected to produce true Acme plants from this sowing because of the well-known comparative stability of that variety and of my care in selecting and preserving the seed; and also because no other tomato plants were grown with them or in the same neighborhood, from which cross fertilization might have occurred. To my surprise, however, all the plants which grew from those seeds were distinctly different from the parent plants, not only as to fruit, but as to specific details of plant structure; and they were all alike in those characteristics. It may be incidentally mentioned that a difference was recognizable in the earliest stage of growth of the plantlets; the cotyledons were proportionately short, placed low on the stem, and in a goodly number of instances, triple; a character which I have never observed in any other tomato plantlets. At maturity the plants were sturdy and compact, standing erect with little support until after the first fruits were visible, and reaching a mature length of only about two thirds of that of the parent plants; haulms strong and comparatively few; foliage dark green; petiole-midribs short and strong; leaflets moderately broad, not distant, sessile or nearly so, and their surfaces strongly rugose; fruit similar to that of the parent plants in size, shape and consistence, but of finer flavor and more delicate in color, changing from a dark chlorophyl green to cherry red or light crimson through a neutral or flesh color, and not through yellow. I preserved no seed from this crop of 1899, and supposed the fruit variety was therefore lost, as indeed it was, but two years later I recovered it, as will presently be shown. This fruit differed considerably from any other of the numerous varieties known to me; but the plants had essentially the same specific characters as those which had previously been produced by gardeners, known as the potato-leaved variety of tomato. It was by those characters that I designated *L. solanopsis* as a distinct species.

In the spring of 1900 I purchased from a Philadelphia company of seed growers a packet of their 'selected Acme tomato seed,' which was grown in 1899 on a Pennsylvania farm, more than a hundred miles from the place where my first Acme plants were grown. From this seed I grew thirty plants to maturity, every one of which, with its fruit, was true to the Acme variety as I have just described it for my crop of 1898. Fig. 2 represents one of those plants as it appeared in the early stage of its growth. Its smaller size than Fig. 1 is due only to the relative size of the growing plants at the time the photographs were taken. The conditions of cultivation in this case were identical with those in the former case; no other tomato plants were grown with them, nor were any grown in the neighborhood; and the

resulting crop of fruit gave no visible indication of impending mutation. I as carefully preserved seed from this crop as I had done in the former case, and planted them in my garden in 1901, believing that I should produce Acme plants, notwithstanding my former experience. On the contrary, the result was an exact duplication of my experience with the crop of 1899, every plant and every fruit partaking fully and uniformly of the duplicated mutation. The plant description, including that of the fruit, which is given in the immediately preceding paragraph applies as exactly to the plants of the crop of 1901 as it does to those of the crop of 1899. Fig. 1 represents a plant of this crop in the early stage of its growth, when it was beginning to shed its first flowers. Its deeper shade of green adds to the difference of aspect between the mother and daughter forms.

The Figures 1 and 2 are copies of photographs which were taken of the plants as they were then growing in my garden.* The plant represented by Fig. 1 bore the new variety, which I have called the Washington. That which is represented by Fig. 2 bore the Acme variety. Although it can not be proved that the particular plant which is represented by Fig. 1 actually came from a seed borne by the plant represented by Fig. 2, I do not hesitate to assert positively that the plant form represented by Fig. 1 is the immediate progeny of the form represented by Fig. 2. I make this statement with all the more confidence because all the work of my garden has been done *con amore* by my own hands, including the planting of the seed, the plucking of the fruit from which the seed was taken, and the curing and preserving of the seed for the next year's planting. In all this work I practised the same conscientious care that I have done in all my other scientific work in other fields. No tomato seed other than that which I have mentioned was in my possession during all the time my experiments were in progress, and I do not admit the possibility that any other seed was at any time substituted. Even if there had been any such substitution, it would not account for the mutations which I have described, which were phylogenetic in character and not the result of hybridization. The fruit of the mutated plant species was also a new variety and would not, in any ordinary case of germination, have been produced by seed of any other variety previously known. This new variety is as distinct as are any other fine varieties, and it has been true to seed every year since its origination. If my Acme plants, in either of the cases mentioned, had received adventitious fertilization by pollen from any other flowers than those of their connate crop associates, the cross fertilization would

* These figures were originally published in an article by Dr. R. Francé, in *Die Umschau*, at Frankfurt am Main. In that article it was unfortunately stated that Fig. 1 represents the mother form, while the reverse is the fact.

certainly have been incomplete as to the whole crop and various as to the kinds of hybrids produced. Even if it were credible that the first case of complete aggregate mutation was due to fortuitous cross fertilization from some unknown source, it would still be too much to believe that exactly the same hybridizing process should have been repeated in the same manner in a following year. It may be added that there is now much reason to doubt that hybridization, although always imminent among tomatoes, has ever been so effective an agent in producing improved varieties of either plants or fruit as has been generally believed. Indeed, saltatory mutation and racial variation have doubtless produced many of the results among plants that have been attributed to hybridization; although the latter has produced many wonderful results.

At the close of this narrative of experimental observations it is well to call special attention to the assumed fact that the mutative process which produced the new plant form that has been described was essentially separate from the accompanying process of fruit variation, although the two processes were intimately associated in both their origin and development. The plant mutation was from *L. esculentum* to *L. solanopsis*; the fruit variation was from the Acme to the Washington variety. The new fruit variety which accompanied the new plant form is of fine quality and therefore of horticultural value; but the origination of any fruit variety is, from a naturalist's point of view, of far less importance than the origination of a species. Plant mutation produces species which are real entities. Fruit variation is limited to changes in the pericarp; and the most improved and heritable fruit variety thus produced may, by degeneration, become disassociated from the plant entity without any impairment of that specific condition.

There are two extraordinary features of the foregoing narrative of my observations. One of them relates to the sudden and complete mutation of every plant of a crop of twenty-four Acme tomato plants to another specific plant form bearing a new variety of fruit. The other relates to a subsequent exact duplication of that mutation in all its details as to both plant and fruit, in a crop of thirty plants, also of the Acme variety. It is apparent that both cases were initiated and consummated in the plants while they were growing in my garden because the germ cells which gave origin to the mutated plants were all formed there; and the mutated plants were there grown to maturity. Another fact, important in this connection, although stated in a previous paragraph, is that this new specific form had been previously produced by gardeners, who had given to it the name of potato-leaved tomato. That is, this one and the same species, *L. solanopsis*, has arisen suddenly and independently from *L. esculentum* at not less than three different times, each in a different locality.

Extraordinary as were the two cases of aggregate phylogenetic plant mutation which came under my observation, they are no more wonderful as natural phenomena than are the numerous cases of sudden and aggregate atavic reversion of previously constant and heritable fruit characters which have been mentioned in this and other publications. Indeed, among tomatoes, the aggregate occurrence of both plant mutation and atavic fruit reversion appears to be quite as normal as does their separate or individual occurrence. In both kinds of these cases, although their results are so different, the initial change has occurred in the germ cell of each of the seed ovules which gave origin to the affected plants. Both kinds are of mysterious, but doubtless natural, origin. Still, I can make no suggestion as to what may be the nature of either the determinate, predisposing or exciting cause in any of these cases.

It is not necessary, but it may not be inappropriate, to say that the foregoing paragraphs have not been written from a biometrical point of view, but from that of an old time naturalist. The principal facts which are there recorded have presented themselves to me with more force than I feel able to present them to others. I am still greatly impressed with their remarkable character, especially because they are not in accord with my own former views. Some of them also are known to be at variance with commonly accepted views of horticulturists, but I present them all with full confidence in their accuracy. Indeed, I do not admit the possible occurrence of any error that could have been instrumental in producing any of the phenomena which are here recorded.

Notwithstanding the peculiar features of these two cases of sudden mutation in the genus *Lycopersicum*, I assume that in their essential nature they are to be classed with those cases of mutation which have been observed in the genus *Oenothera* by Professor de Vries, and which he has used in demonstrating his theory of mutation.* In his experiments with those plants, popularly called evening primroses, he repeatedly observed, in different years, the origination by sudden mutation of a few individual plants of one and the same species among the numerous progeny of the mother species. He also observed the similarly sudden and rare mutation of several new species from a mother species, but he has not reported any case of mutation of all the progeny of any one plant of a mother species; much less the progeny of a whole crop of plants, such as I have observed with reference to the genus *Lycopersicum*.

* See 'Die Mutationstheorie,' von Hugo de Vries, Volumes 1 and 2, Leipzig, 1901, 1902; 'The Mutation Theory of Professor de Vries,' by Charles A. White, Smithsonian Report for 1901, pp. 631-640; and 'A New Theory of the Origin of Species,' by A. Dastre, Smithsonian Report for 1903, pp. 507-517.

The number of specific mutations which were observed in *Ænothera* by Professor de Vries was greater than the number that has yet been observed in *Lycopersicum*; but the scope of mutative action in *Ænothera* embraced only a very small percentage of the abundant progeny of the mother plants; while in the two cases of mutation in *Lycopersicum* which I observed, that action embraced all the progeny of a small crop of mother plants. The mutative period in *Ænothera* occurred as a correlative of the extreme activity of natural reproductiveness and geographical distribution, but that period occurred in *Lycopersicum* as a correlative intensive cultivation. The unusual conditions, although so different in each case, apparently made the mutative opportunity available for the respective species. Other conditions will doubtless be found to give other species that opportunity, with diverse results. When other plants shall have been discovered in their mutative period the scope and diversity of mutative action will probably be found to differ in each case. If so, no one case can be made the absolute standard for such action.

The observations of Professor de Vries, as well as my own, show conclusively, not only that species may originate by sudden mutation, but that one and the same species may thus originate independently at different times and places and from different plants of a mother species. This fact is not without obvious significance in connection with geographical distribution of living species and the origination and distribution of organic forms during geological time.

BIOLOGY IN THE ROCKY MOUNTAINS.

BY T. D. A. COCKERELL,
UNIVERSITY OF COLORADO.*

FOR the purposes of this article the term Rocky Mountains will be understood to mean the states and territory including and surrounding these mountains in the United States; that is to say, New Mexico, Colorado, Wyoming and Montana. The area thus indicated, stretching from north to south, and including both mountains and plains, is of course extraordinarily varied. Because of the different conditions of temperature, moisture, soil, etc., found within its borders, it possesses as a whole a fauna and flora extremely rich in species. It offers, in the high mountains and to the north, a large assemblage of circumpolar types, some exactly like those of northern Europe and Asia, others variously modified. It gives us, on the plains and to the south, a series of species of Austral origin, some of them intruders even from the tropics. Still again, in its valleys and forests, it has developed a large number of endemic types, found nowhere else in the world.

Such a region necessarily presents great attractions to the naturalist. It has been visited by numerous government expeditions and private individuals, beginning early in the nineteenth century, for the purpose of collecting its scientific treasures. It has yielded to these an abundant harvest, not only of living animals and plants, but also of fossil forms. Every museum of any consequence contains Rocky Mountain material, and innumerable publications are devoted to its description and illustration. These being the facts, a superficial observer might very well conclude that the natural history of the Rocky Mountains was thoroughly known. So far, however, is this from being true that it would be more correct to say that the scientific study of Rocky Mountain biology has hardly begun.

Any one who examines the published accounts of Rocky Mountain animals and plants will find, at least in the majority of groups, little more than descriptions of species. Putting aside the enormous number of species still undescribed, we find that the 'known' species are in fact very little known at all. Among the insects, for instance, there are hundreds of which we do not even know the locality, nearer than the name of the state, and those of which we know the life history are comparatively few. The details of geographical distribution, the char-

* Since this paper was written, the writer has moved to the University of Colorado, at Boulder. Mr. L. C. Himebaugh is now in charge of Colorado College Museum.

acter and extent of the variations, the interrelations with other species—these are things rarely mentioned in accounts of species described from our area.

The reason for this state of affairs is evident enough. Nearly everything has been done, until quite recently, by naturalists who resided in the eastern states. It is true that many of them visited the west, but usually to hurriedly gather together such miscellanea as came in their way, to take them home and there study them at their leisure, or turn them over to the appropriate specialists. Very little was done on the ground, except by a few resident naturalists, who were usually at a disadvantage because of the absence of libraries and museums. Even to this day, one comes across that deep reluctance to form independent conclusions, born of the feeling that in biology, as in other things, the wise men of the east hold the keys of knowledge. It is exactly the attitude which Americans of the eastern states, a hundred years ago, used to show to the naturalists of Europe.

Eastern science is the mother of that of the west, and European science is its grandmother. May this relationship never be forgotten; but the time must come when the young fellow will stand for himself. I think and hope that this time is rapidly approaching, and therefore regard with more than ordinary interest the new developments in the educational institutions, which begin (only begin!) to make intellectual independence in biology a possibility.

Such talk as this is not mere bombast; such wishes are not merely born of that mania for supremacy which afflicts so many peoples. We do not wish to do any more than look after our own affairs, and that we surely are entitled to do. The point is that, after all, biology is the study of living things, and the descriptions of museum specimens are only preliminary to the most important part of the work. It is utterly impossible that the innumerable problems raised by different aspects of our fauna and flora (biota, let us say, after Stejneger) can ever be solved except on the ground. And our eastern friends—they have their own region, very far from being exhausted, besides having to look after material from all sorts of countries where there are no resident naturalists, or very few, and adequate facilities are not even in prospect.

I am not proposing a sort of Monroe Doctrine in biology. Professor Underwood, not very long ago, did advocate something of this kind; proposing that Europeans should attend to their own flora, or at least to that of their own hemisphere, while Americans looked after American plants. This, if I understood it rightly (and it was plainly put!), was not a very defensible proposition; for imagine the results of the two halves of the circumpolar flora being studied entirely apart! Indeed, one has only to examine existing publications to see numerous ill results of this provincialism—and it is provincialism, though one's province be as large as the two Americas. So far from wishing to

isolate Rocky Mountain naturalists and their work from that of others, I wish exactly the reverse. The time will come, I think, when no single man will think of producing a monographic work on a group of organisms. He will compile the work, adding to his own contributions those of others from every region inhabited by his chosen beasts. In that day the local naturalist will contribute his part; but the point is, he will make his own observations, and will not merely send material for the all-wise one to ponder over.

The history of Rocky Mountain mammalogy is quite interesting. During the nineteenth century 68 new mammals were described from our area. Of these, six are not now considered distinct, but 62 remain. In the first decade, two were described by Ord. In the twenties, Say made known five, in the thirties Bachman described two, in the forties nothing was added, in the fifties we have six by Baird and one by Audubon and Bachman, in the sixties two by Kennicott and one by Hayden, in the seventies one by Coues, in the eighties one by Shufeldt and one by Merriam. Thus, to the end of the eighties, 22 had been described. Now in the nineties, counting 1900, no less than forty were added, mostly by Merriam and Allen! In 1901 three more were added, and in 1902 five. I first came to Colorado in 1887, and remember very well having the distinct impression that the species and subspecies of Rocky Mountain mammals were very well known. This, indeed, was the accepted view; but how wonderful was the result of assiduous collecting and study during the next ten or twelve years! It is admitted that not all of the newly named animals are very distinct, but some are, and all appear to have their characters.

Of all these descriptions, one was the joint work of two resident naturalists, but the rest were prepared by students living in the east. Perhaps one should make a second exception of the mouse described by Dr. Shufeldt, who resided for a considerable period in New Mexico. The number of new forms described from Colorado, New Mexico and Wyoming is about the same, Colorado being a little in the lead; but only seven, less than half the number of the other states, come from Montana. The northern state, however, can pride itself upon containing the type locality of the grizzly bear; this and the common wood rat (*Neotoma cinerea*), also from Montana, being the two first-described animals from our region.

It is not necessary to similarly outline the history of other groups, but it may be said that the flowering plants are in the midst of a revival period quite equaling that of the mammals, while the description of new insects goes on at a very rapid rate. Of over 500 wild bees collected in the last ten years or so in New Mexico, more than 300 have been described as new.

In order that it may be understood that something is really doing in the Rocky Mountains, I propose to briefly describe the existing

facilities for work and say a little about some of the workers. I begin with Colorado Springs, merely because it is near at hand. We have in this town a few good naturalists. The senior member of the fraternity is Mr. Aiken, after whom the snowbird *Junco aikeni* was named. Mr. Aiken has, I suppose, the best collection of birds in this part of the country, and what is more to the purpose, has a really critical knowledge of them. A few days ago, I had the pleasure of reviewing with him a woodpecker which he believes to be new, and I hope he will publish an account of this and other interesting birds which he has studied. Our other bird man, Mr. Edward R. Warren, is also interested in mammals, and is making a remarkably interesting collection of small mammals. Mr. Warren is much interested in the photography of living wild animals and birds; and some of his photographs, especially those showing the ptarmigan in all plumages, are exceedingly beautiful. Professor Cragin, the well-known paleontologist and zoologist, is resident here, but now devotes himself entirely to the history of the west. The types of most of his new species of fossils are in the museum of Colorado College. Professor Sturgis, formerly of Connecticut, now shares with the present writer a laboratory in the new Palmer Hall, and is very busy working on myxomycetes, making colored drawings of innumerable forms. As a result of his work the boundaries between several so-called species are becoming decidedly obscure.

Palmer Hall, the great new building of Colorado College, is the wonder and admiration of all who see it. From quarters which would have disgraced a high school, the scientific departments have moved into those which would do credit to any university. It is not possible to do everything at once, and it must be confessed that the equipment is not yet nearly up to the standard of the building. At the same time, there are very good facilities for teaching, and the museum contains a large amount of useful material. As regards the means for research, it seems to me that they are even now sufficient to keep any ambitious investigator from idleness. Of course the great opportunities are in the country itself, with the splendid mass of Pikes Peak close at hand, easily ascended by means of the cog railway. In the college, the large series of fossils—especially Cretaceous—collected by Professor Cragin invites study. Most of the material is from Kansas and Texas, but it would be invaluable for comparison to any one engaged in the study of the Colorado Cretaceous. There is also the herbarium of the late Edward Tatnall, of Wilmington, Delaware, which, although not rich in Rocky Mountain plants, is, on the whole, remarkably good, containing apparently most of the standard sets from the United States and Mexico which have been distributed in recent years.

The literature on biology at present possessed by the college is very insufficient, though the library contains many good things. There

is, however, Professor Sturgis's botanical library, very complete for the fungi, and including, I think, all the standard exsiccati, even those of Europe. The books include a complete set of Saccardo, which is now so difficult to obtain. My own library is nearly complete in those groups (Coccidæ, wild bees) which I have especially studied, and contains much besides, among other things the *Zoological Record* from 1889 to date.

On the whole, therefore, Colorado Springs offers good opportunities for resident work along several lines; and I presume the facilities will be improved every year. The other Colorado institutions I do not know so well, but I have within the last few months visited the State University, the Agricultural College and the Normal School.

At the State University, at Boulder, I found Professor C. Juday in charge of the biology, the regular incumbent, Professor Ramaley, having departed on a tour round the world. I do not know very much about Dr. Ramaley's work, except that he has published some interesting studies of the epidermal tissues of flowering plants—a subject of particular interest in the arid west.* Professor Juday is doing some work for the Bureau of Fisheries, on the fishes of Colorado and their food, and the constituents of the plankton of the Colorado lakes. This work, of course, covers a field little explored in our state, and it is very fortunate that it can be undertaken by a resident investigator, though, as I understand it, his residence among us is only temporary. The university museum and herbarium are sufficiently good to be very valuable for teaching purposes, but from the standpoint of an investigator they are disappointing. Perhaps the most pleasing thing in the collection is a nice series of local birds, with full explanatory labels. Judge Junius Henderson, the curator of the museum, has devoted a good deal of attention to the birds, and also to palæontology. The new library building of the university is extremely beautiful and the library arrangement and facilities for getting at the books could scarcely be bettered. I noticed among the books a set of the *Challenger Reports*, *Nature* from the beginning, all of *Pittonia*, Edward's 'Butterflies of North America,' and many other good things.

The Agricultural College, at Fort Collins, is chiefly noted biologically for the entomological work of Professor Gillette and his former assistants Professor Ball, Mr. C. F. Baker and Mr. E. S. G. Titus. From this institution have come the important 'List of the Hemiptera of Colorado,' Professor Gillette's revision of the Typhlocybidæ and many other works known to all entomologists. There is just now ready for publication the first part of a catalogue of the

* Since this was written Dr. Ramaley has returned from his journey round the world, bringing a large and most interesting collection from Java, Ceylon, Japan, etc. He is engaged in special researches on the anatomy of the cotyledon.

Orthoptera of Colorado. As might be supposed, the entomological collections and library are very good, although the latter does not contain everything I expected to see. Professor Gillette is at present assisted by Mr. S. Arthur Johnson, a relative of the well-known curator of the Boston Society of Natural History. Mr. Johnson is doing very nice work on the Hymenoptera, especially on their nesting habits and parasites. He has discovered, for example, the hitherto unknown nest of *Entechnia*, and has definitely proved the association of *Triepeolus* with *Melissodes*. Also with Professor Gillette is Mr. Chas. Jones, a young entomologist who will be heard of in the future. Last summer he worked in a mine at Silverton, Colorado, and spent his leisure moments making by far the largest and best collection yet made of the insects of the Arctic-Alpine zone in the Rocky Mountains. In the Department of Botany and Horticulture at the Agricultural College, Professor Paddock is properly a horticulturist; but his assistant, Mr. F. M. Rolfs, a brother of Professor Rolfs, of Florida, is doing some very interesting work on parasitic fungi. The herbarium of the college gave me much surprise and pleasure. The last time I saw it, several years ago, it was in such a condition as to be of little use for critical work. Now, the Colorado material in it has all been gone over by Dr. P. A. Rydberg, of New York, who has in press a list of the flora of Colorado, *i. e.*, of the flowering plants thereof. The greater part of the named material has been returned to the college, and I was naturally very much interested in the determinations. Although, as I learned from Professor Paddock, the college herbarium contains only about half as many Colorado plants as they have in the New York Botanical Garden, it is by far the best and most useful public herbarium in the state. I say public herbarium because Mr. Geo. Osterhout, of New Windsor, Colo., has long studied the native flora, and is said to have a very fine collection. He has described quite a number of new Colorado plants. At the Normal School, at Greeley, they do not pretend to do much research, but Professor Beardsley has made some studies of the minute fresh-water Crustacea, and of the Protozoa, describing some new species. He has also made a collection of Colorado reptiles and amphibia, and will, I believe, publish a list of them. The library of the Normal School is very well arranged, and contains some good zoological books I did not expect to see.

In Denver, the State Historical and Natural History Society has a collection, poorly housed in the lowest floor of the capitol building. Mr. Ellsworth Bethel, of the Denver West Side High School, has long studied the fungi and flowering plants of Colorado, and has a large collection. He has discovered very many new species, especially among the fungi, but his duties leave him little time for research. The East Side High School in Denver has a herbarium, presented by Miss Alice

Eastwood, the well-known botanist of California, who used to teach in Denver, spending her summers studying the Colorado flora.

In New Mexico, biology is not very much studied. I will only refer at this time to Professor E. O. Wooton and his assistant, Mr. Metcalfe, at the Agricultural College. These botanists have made large collections of the New Mexico flora, and Professor Wooton's writings on the subject are well known.

In Wyoming, one thinks first and last of Professor Aven Nelson, the indefatigable botanist of the University of Wyoming. The herbarium he has accumulated there is by far the best within our region, and his critical studies of the Rocky Mountain flora in the field have given him a knowledge possessed by no other man. He has, of course, described very many new species, and I have heard it stated that he will cooperate with Professor Coulter in the production of a new edition of the latter's 'Rocky Mountain Botany,' now so greatly behind the times. Between Professor Nelson and Dr. Rydberg we seem likely to possess in the near future works which will give a new impetus to the study of Rocky Mountain plants, making easy that which has been getting increasingly difficult. Professor Nelson has already issued a small school flora, including only the commoner and more conspicuous plants.

In Montana, we have Professor Cooley, the entomologist of the experiment station, and Professor Morton J. Elrod, of the University of Montana. The work of Professor Elrod in founding a biological station and studying the mollusca, dragon-flies, etc., is extremely valuable, and one may hope that it will continue to find hearty support. The publications of the University of Montana show that Professor Elrod has been able to interest a number of persons in the 'biological survey' idea, and the work seems to be growing in volume and value every year.

I have not attempted to refer to every Rocky Mountain worker, nor have I said anything about visiting naturalists; but it would be a serious omission not to allude to Dr. Clements, of the University of Nebraska, who for a number of years has been a 'summer resident,' as they say of certain birds. Dr. Clements migrates to the mountains when his teaching work closes in Nebraska, and, with others, occupies a cottage at Minnehaha, which is on Pike's Peak, at an altitude of 8,400 feet. From this point he explores the slopes of the peak and the surrounding country, and makes ecological observations.

The above brief account of Rocky Mountain biology will make it apparent, I hope, that there are at least six places where fairly good facilities, of one sort or another, are offered for biological research. These are the University of Montana, the University of Wyoming, the University of Colorado, Colorado College, the Agricultural College of Colorado and the Agricultural College of New Mexico. In some in-

stances, *e. g.*, the botany at the University of Wyoming, these facilities are extremely good. It will also be clear that there are several resident naturalists within our area pushing forward the work to the best of their ability. Thus the outlook is in many ways satisfactory, but there are still great difficulties to be overcome. It is evident that the men already in the field can not nearly cover it; instead of a dozen or so, we need at least a hundred active workers, and a thousand would not find their hands idle. This is utopian talk, of course; but I do think that the first need is to increase the working force. Then again, those who are at work, almost without exception, have to get their living in other ways, and thus can give comparatively little time to research. In the experiment stations, research is well provided for, but the popular clamor for 'practical' investigations and immediate results usually prevents the undertaking of anything very broad or fundamental. Furthermore, the experiment station officers mostly have to do a large amount of teaching. In the colleges and universities, teaching is naturally to the front, and in our mountain states this does not mean the teaching of graduate students to more than a very limited extent. A short time ago I appealed to the professor of chemistry in one of the Colorado institutions to do a piece of work of scientific and economic value. He immediately said that he longed to do it, 'but what can I do? I am giving seven courses!' This is a fairly typical case, and although I know very well there are many who would not do anything as investigators if they had the time, the fact remains that those who would, and in fact do, are handicapped to an extent little appreciated or understood. It is not that research is disliked; if anything is done it usually meets with approval, but it is not understood that it is fundamentally necessary to progress, and that it requires time as well as space to flourish in. Much of what has stood for culture in the west has been little better than a sort of intellectual parasitism on the east and Europe, and there is not yet an understanding or appreciation of the efforts to form an endemic product.

On the other hand, those who have accumulated wealth, or in some manner have acquired the means of living at the expense of others, will find in the mountain states ample opportunity. There are, of course, many such people, but with very rare exceptions they do not take to biological subjects. The well-to-do amateur is, for some reason, extremely scarce among us, though in England, for instance, his kind has done wonders. Thus there is plenty to praise and plenty to blame; but the only thing to do is to go ahead, and if the car of progress moves slowly, at all events it perceptibly moves.

WHAT IS RESEARCH?

BY PROFESSOR HENRY SHALER WILLIAMS,
CORNELL UNIVERSITY.

THE faculty for research is not some peculiar power of the mind, possessed by some and not possessed by others, but it is a common faculty of all intelligent minds, more active often in youth than later in life, and its exercise in forwarding research depends more upon its discipline and training than upon any so-called original endowment of its possessor. But research is diverse from study, and the legitimate outcome of its exercise is not learning what is already known, but the extending of the boundaries of knowledge beyond the point reached by others.

In order that these faculties may be appreciated and, when in a promising state of development, may be properly trained, it is requisite that the faculties be clearly recognized and understood, and that the kind of exercise necessary to strengthen and develop them be known and appreciated.

What, then, is the particular part of our mental processes by which research is accomplished? An answer to this question may be reached directly by distinguishing research from its most closely related activities, namely, investigation and study.

Study has for its direct aim the acquirement of knowledge; investigation has for its aim the understanding of the reasons and relations of things already known; full comprehension and scientific discernment are the results of its exercise. Pure research beyond both of these has for its aim the discovery of facts, truths and relations not previously known; its results are the extension of the field of knowledge.

Study, when separated from investigation and research, primarily deals with language and the names of things and ideas. Close attention to words and language and a careful cultivation of the power of memory are essential to one who would become a perfect student. In this statement 'words and language' are not restricted to what are technically called the languages, as French, German, Greek, Latin or English, but it applies to the sciences as well. The study of chemistry, botany or astronomy primarily consists in learning the proper words and names to apply to definite objects, or phenomena of nature. The task of the student of science is the learning of the nomenclature and formulas of science, and such learning may be acquired without much

comprehension of the laws of nature or understanding of the principles which are symbolized by the language which the student may have acquired ability to use fluently. In other words, a full knowledge of the names of things may be acquired by study, together with ability to talk fluently about them without much personal comprehension, or, as we say, grasp, of the things described. This possibility I have seen realized particularly among students who from their youth have been rigidly trained in the old classical method of education. Men trained strictly by this method understand words with precision and acquire a full vocabulary. They may be able to speak eloquently on subjects of which they know little. I have seen such scholars (juniors or seniors in college), who upon receiving the clue to the subject on which they were expected to write examination papers, could spin out a creditable set of answers quite superior to those written by their less trained (literarily) companions, whose real comprehension of the subject, as shown by other tests, was vastly superior to their own.

The pure student also may be said to be hindered from doing his best by stopping to investigate either the meaning or the application of the simple statements recorded in the verbal text before him. This learning by rote is an evil result of carrying study to excess, but it is also a definite aim of study pure and simple. A second result, more or less evil and which comes also as a natural result of pure study, is the tendency to lead the learner to accept, without question, the correctness of the statements he learns. He learns to depend upon others for his knowledge, and thus the expression 'getting knowledge at second-hand' becomes an actuality for the pure student. Although a successful student, he may fail not only to comprehend what he learns, but fail to think for himself. Nevertheless, the learning of other people's knowledge is an essential step in educating one's intellectual powers for higher work. We must have a wide knowledge of words and their meanings, and a good facility in the use of language, before we can successfully carry on systematic thought; and the more full and precise his vocabulary the wider and deeper will be the possibilities of both the investigator and the man of original research. Study is thus an essential preparation for investigation; but if the two be mixed too early in one's educational progress, the results will be deficient by virtue both of the inaccuracy of the learning and of the immaturity of the investigation.

A student who begins to investigate too early will, on the one hand, degrade the quality of his scholarship, and, on the other, he will find that the immature conceptions of science which he first forms must often be abandoned upon fuller investigation; or if retained will lessen the value of his results and place him in secondary rank as an investigator.

To attain the best results of study one must become a docile pupil, learning with precision and thoroughness exactly that which the words and language present to him. Taking statements exactly as they are formulated and using words exactly as others have used them before us—only so may be laid the solid foundation on which genuine research can be securely built.

Investigation Distinct from Study.—Investigation is distinctly another mental process from pure study. Its results are different from learning, as different as digestion is from eating, and for its best exercise a difference should be made in the training process, and in the objects to which the attention is given.

Learning has to do with words and language. Investigation deals with meaning, ideas and conceptions. One of the first acts of the investigator, after he has learned to know the thing or phenomenon by its description, consists in transforming the description into new terms. It is like taking a crystal and turning it into a new light in one's hand to see the new reflections due to changed position.

The attempt to express the conception in different language leads to a fuller realization of that which is contained in the description, as distinguished from the description itself. This result is more easily gained when an actual physical object before the investigator is impressing his senses, than when words alone are used. In the field of philosophy and in mathematics, the process of investigation may be carried on without a physical object being present, except in imagination. In this case the discipline of the mental faculties is more direct, and for discipline alone it may possibly be better than the laboratory method. The rudiments of investigation are found in the classical mode of education, as in translating Greek or Latin into English. But investigation methods may be exercised and trained, certainly more easily and with greater pleasure to young minds, when the visible object is before one, as in the laboratory, where it remains constant and can be tested over and over again, while the terms of expressing one's own view of it are gradually perfected. The laboratory is the special place of investigation.

Pure investigation deals with knowledge already attained; as with study the acquisition of the investigator is an acquirement of facts of common knowledge and is not yet research. Experiments are made not to advance knowledge, only to advance the knowledge of the experimenter in fields already familiar to the teacher. In the fields of science, with which I am particularly concerned in this discussion, there is this difference between study and investigation, that investigation deals with the objective things as distinguished from the words describing them. Phenomena are but phases of things, and are included within the general term things, as being together experienced by our senses, inde-

pendently of any names or language by which they may be symbolized. On the other hand, it is important to notice that things and their phenomena are grasped by the mind in the same way that words and language of common speech are learned. By study we gain knowledge of words, by investigation knowledge of the things and phenomena of our experience. The laboratory, the museum, the world at large are the normal fields of this process of investigation; much as books and the words of the lecturer are the normal fields of pure study. This brings us to the definition of research.

Original research goes beyond investigation in that the things sought for are not only undescribed, but, when the research begins, are actually out of sight, that is, unseen. The field of research may be visible, but the genuine meaning of research is a looking beyond what can be seen; herein is found the most essential characteristic of successful research, viz., a comprehensive, a keen and a disciplined imagination of things and truths before they become objects of experience. We must distinguish, too, between scientific research and haphazard stumbling upon strange things in out of the way places. Curiosity hunters may discover novel and undescribed things, and may even point the way to their source, but it is the trained scientific investigator who discriminates their true value, orients them in the known world of things and makes them available for the use of man.

Research, as was noted at the outset, is not a special faculty possessed by a few, but a common faculty specially trained and systematically exercised by but the few, for whom it becomes a tool of the highest value, and the means of opening up new fields of knowledge to mankind.

The underlying principle of original research is simple inquisitiveness; that trait so characteristic of the Yankee and the fox. I use the term Yankee as the name for a typical American, not a local or political term, but the name for the smart, shrewd, inventive man, who depends upon his own resources and, if without learning or education, still succeeds in penetrating untried fields, and in making headway under all manner of reverses, hindrances and difficulties, always exhibiting a quickness to observe differences and to interpret the meaning of things. All kinds of successful pioneers are made of such stuff.

This quality is generally more active in youth than in grown men; the common methods of education repress rather than encourage its activity; and the old classical system of education is particularly effective in this direction. This repressing result is reached, however, not by direct means, but by the very perfection with which study, pure and simple, is fostered. It is a conspicuous fact in schools that often the keenest and brightest boy is not always the best student; he may know more and observe more closely than any other, but he gets low marks in spelling, reading and, may be, in arithmetic, even in geography as

it was formerly taught, and particularly in grammar, which, I believe, is not now made so much of as formerly in common schools. The education which represses curiosity and inquisitiveness, and only educates memory for words, makes learned men of the pedantic kind; so far it discourages and neglects the discipline of the research quality. The fact that the classical system of education trains the study quality to the neglect of research does not, however, diminish the importance of the kind of training it supplies as a fitting for a man for research. It is the neglected part to which attention is directed. I know of no better kind of discipline in study than the thorough and refined methods of the old classical system, supplemented by an early and continuous use of science. It is the neglect of this method which makes the slipshod, careless work which all scientific scholars regret, and unfits many students of science for successful investigation or research. This discipline produces results which may be likened to the tempering of steel, which shows after the steel is hammered into shape and sharpened for its specific purposes. The man who lacks this tempering is incapable of holding the keen edge, or of making the fine and far-reaching discriminations, which a mind well tempered by the rigid discipline of the classical system has acquired.

From the objective side research is the attacking of unsolved problems, the examination of facts undescribed and unexplored, the seeking for truths imagined, but not hitherto formulated. New discoveries of truths, the correction of partial statements of truth, the formation and formulations of new conceptions, these are the results of research. What are the disciplines which foster research?

The first requisite in the discipline required for successful research is the keeping alive of the original faculty of inquisitiveness. It must not be stifled while the student is being taught language and the content of language from the books.

The second point is that the method of exact study must be thoroughly acquired, and applied in a wide field of knowledge, whatever may be the particular field of original research later to be chosen. One of the greatest difficulties met with in selecting men to take up original research in particular fields (as brought to light in the deliberations of the Carnegie Institution) is to find men sufficiently well trained to be competent to go on without guidance in new and untried fields. It is also a great mistake, since it necessarily leads to later disappointment, to tempt, or allow, unripe men to try their hand at deep problems of research—to putter over serious problems which the expert and experienced hand knowingly hesitates to attempt. There is no better way to acquire this part of the discipline than by a thorough classical training, such as might be given in what is called an arts course in our college, with a carefully selected and systematically

arranged series of science studies added. In this study of science care should be taken to begin courses in which lessons are to be learned, and learned upon authority and with exactitude, later to be perfected by laboratory practise; such is, in my judgment, the finest kind of preliminary discipline for a man of research. For it takes a learned man to tell the truth with precision, even when he is its discoverer; and, moreover, only the learned man knows when he has discovered a new truth. Ability to study deeply and accurately is then the second essential qualification to the making of a man of research.

Thirdly, to undertake original research a man must be a trained investigator. He must know the methods by which other men have discovered truths and interpreted things. To learn this he must have gone through the exercise of a personal discovery of the meaning of things —have tested for himself the reality of the descriptions written in the books. Such training is best given in the laboratory; analysis and experiment leading to already known results must be gone over by the investigator in careful detail, and the steps of the progress, the associated conditions, the order of sequence of phenomena must be closely observed and recorded; and the relation of the phenomena to one another and the results of experiments clearly understood, formulated and, best of all, fully written out.

Fourth, the man of research should have a vivid imagination, which should be trained to be accurate and to be his servant, not his master. This faculty, I fear, is often trained out of men by what is called experience. Not only does the dry, matter of fact, world of every day tend to keep one down to thoughts of the immediate present, but the immensity of science and its practical applications, by the very abundance of the known facts, crowds out of use all mental pictures of hypothetical conditions not known to common experience. Nevertheless, as has been already noted, the very function of research is to go beyond the field of present knowledge, and in it the attention must be fixed steadily upon concepts, the realization of which has not yet been attained. The scientific imagination may be exercised and disciplined by the study of mathematics. The architect's work is a definite application of imagination to projecting new construction. What are called 'working hypotheses' are the results of this exercise of imagination in advancing research. The discipline of the faculty of imagination is necessary to enable the researcher to distinguish between his concepts of imagination and his concepts of experience. If he knows how to distinguish them, his imagination becomes his valuable assistant, if ignorant or unobservant of the difference, his results become speculative and ineffective.

A fifth trait marking the typical man of research is a wide, open mind. Philosophically he should be a whole man, not simply a one-

sided specialist. Many a man attempting research has come short of really advancing knowledge on account of his prejudices. Darwin was a typical example of a philosophically whole man; whatever personal opinions he may have had, they were never allowed to prejudice any hypothesis he was examining, nor to interfere with conclusions toward which the observed facts logically led him.

Faraday was another such man. He wrote the following words early in his scientific career and his life work was an expression of their truth:

The philosopher should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be governed by appearances, have no favorite hypothesis, be of no school, and in doctrine have no master. He should not be a respecter of persons, but of things. Truth should be his primary object. If to these qualities he added industry, he may indeed hope to walk within the veil of the temple of nature.

Again he wrote:

We may be sure of facts, but our interpretation of facts we should doubt. He is the wisest philosopher who holds his theory with some doubt; who is able to proportion his judgment and confidence to the value of the evidence set before him, taking a fact for a fact and a supposition for a supposition. (Gladstone's, 'Life of Mr. Faraday,' pp. 93 and 94.)

Sixth, research must be protected from interference. I take this expression from the game of football; the man who runs with the ball requires the protection of all the rest of the team. So research can not be carried on to successful issue, except by a man who is permitted to devote the best that is in him to the problem of research, and to do so he must have the way opened for him. Many may help to give him the opportunity, but the one thing essential is that he be left free and unimpeded to pursue the problem, wherever it leads him. Time and occasion and money must be at his disposal to such extent as his problem demands.

Research work must be regarded as the very flower of a university system, and should not be lightly valued or carelessly managed. Only men thoroughly fitted by the training of study and the training of investigation, and the training of mental discipline, should be allowed the privilege of entering upon research in our universities; but whenever the proper man is found, the providing of a way for his pursuit of research work, in the field for which he is best fitted, becomes a contribution direct to the progress of science in the world, of which any university may be proud. The university may well scrutinize with consummate care the qualities demanded for research, provide rigidly for the discrimination of those qualities wherever they are highly developed, and may wisely provide with liberality for the true man of research when he is discovered and is properly trained for his work. But in

order to help the right man in his work of research, too great care can not be given to the importance of study and investigation as preliminary steps in the preparation for research. A brilliant student, who lacks power of investigation, may be unfit and inadequate to carry on research; and the most capable man of research may still come short of being a ready or able learner of words. Many a man by indomitable energy may overcome great deficiencies, but this fact should not excuse a university from the most rigid discrimination of the essential elements of merit in a man seeking to undertake research work.

As the highest aim of the literary scholar is the production of lasting literary creations, so the highest aim of the research scholar is the advancement of the boundaries of actual scientific knowledge and the discovery of new truths. In both cases the aim must be toward the highest, or the attainment will be unworthy. It is given to but very few to make marked success in either line. The man of research must be willing to devote his life to his work, to sacrifice most of the enjoyable things otherwise within his reach. He must not be deceived as to the measurement of success. Research can not be weighed by its practical value, to apply the term in its every-day sense, for practical value depends upon the financial productiveness of the energy expended. As with a newly discovered country, years of toil and great expenditure of money, and it may be loss of life, may be demanded before any profit results from the discovery. Even in fields in which rich results have already been attained great expenditure of thought, energy and expense may be required before practical results become evident from new research. We can recall many such cases. Success in research can not be measured by applause, or even by recognition from other scientific investigators. For appreciation comes only from those who appreciate; only those thoroughly conversant with a particular field of knowledge can distinguish an advance or enlargement of the boundaries of that field. The man of research must, therefore, be content to be alone in most of his work; unappreciated and unapplauded, using energy and money on tasks which may seem to all about him useless and wasteful. For these reasons this field of activity should not be entered upon lightly.

We as teachers should ever be on the watch for men of the right quality for such advanced work, but should never tempt mere enthusiasts to undertake a task which for success requires the toughness of a soldier, the temper of a saint and the training of a scholar.

PLANTS THAT HIDE FROM ANIMALS.

BY PROFESSOR W. J. BEAL,
AGRICULTURAL COLLEGE, MICH.

Plants Protected by Growing under Thorn Bushes and Thistles.—C. G. Pringle, for many years a famous plant collector, especially in Mexico and the arid regions of the United States, speaks of a native grass of northern Mexico, *Muhlenbergia Texana*, as such a great favorite with all grazing animals that it is usually exterminated or nearly so, except when growing under the protection of thorny shrubs, usually mesquite bushes. In Arizona during the winter and spring, the Indians bring it long distances into the towns to sell. He adds, ‘How many times I have contended with the horrid mesquite bushes to gather an armful of this grass to carry joyfully to my hungry and jaded horses.’ In such cases the thorns, spines and perhaps bitter taste of the bushes not only protect the young growth and leaves of certain plants, but furnish shelter for other tender and nutritious herbage.

In arid regions, especially, similar instances of protection by thorn bushes are numerous.

Plants retire beneath the Surface of the Ground and are protected from Animals.—At the close of the growing season, large numbers of plants, especially in regions subject to protracted droughts or to severe cold, cast off their leaves, take on a condensed form and remain secure beneath the surface of the ground for months at a time in the form of bulbs, tubers and rootstocks. At such times they are nearly sure to escape destruction by animals. I only need to mention as examples Solomon’s seal, Dutchman’s breeches, May apple, goldenrod, artichoke.

Plants Protected from Animals by Water.—Not only the flowers of many species of plants as they project above the surface of the water are protected from most unwelcome insects, but the whole plants as well.

Mud turtles, certain fishes, water snails, larvæ of insects, eat aquatic plants, but most other animals are unable to reach them in such places.

Water-plantain, wild rice, pond lilies, arrow-head, pickerel-weed, pondweed, lizard’s tail, bulrush, bur-reed, cat-tail flag, water dock, and many more of their associates, root at the bottom with leaves floating on the surface or projecting above.

Innumerable low forms, known as algae, are at home in lakes, ponds and streams or on the surface of the water, while other kinds thrive in salt or brackish water. These aquatics find protection below

the surface or by extending above it, not only from numerous animals, but they have no competition with others which can only grow on dry or moist soil.

Aquatics and marine plants and algae are also protected from extremes of cold and heat. During the winter of a cold or temperate climate the rootstocks and buds severed from the tips or branches, and even the entire plant of some species, remain safe and dormant in the mud at the bottom, ready on the approach of mild weather to begin growing again.

Some are amphibious, able to thrive when the land is flooded or when the floods have subsided. Plants with such habits have little competition.

By climbing Trees and Bushes Many Vines get beyond the Reach of Cattle.—

A considerable number of plants practise economy by growing slender stems instead of producing large tree-trunks for self-support.

Great numbers of climbing plants or vines are favored above some others in their ability to reach the light and thrive, even though their stems are very weak and slender. This habit brings most of the leaves and flowers of many of them beyond the reach of cattle and other herbivores.

Plant Traps in the Water catch Fish and Worms to eat.—A few plants not only defend themselves, but are aggressive fighters because they put to good use the animals they capture.

The bladderwort is a water plant and catches much of its food. Underneath the surface of the water in which the plant floats are a number of lax, leafy branches spread out in all directions and attached to these are large numbers of little flattened sacks or bladders, sometimes one sixth of an inch long. The small end of each little bladder is surrounded by a cluster of bristles forming a sort of hollow funnel leading into the mouth below, and this is covered inside by a perfect little trap door, which fits closely, but opens with the least

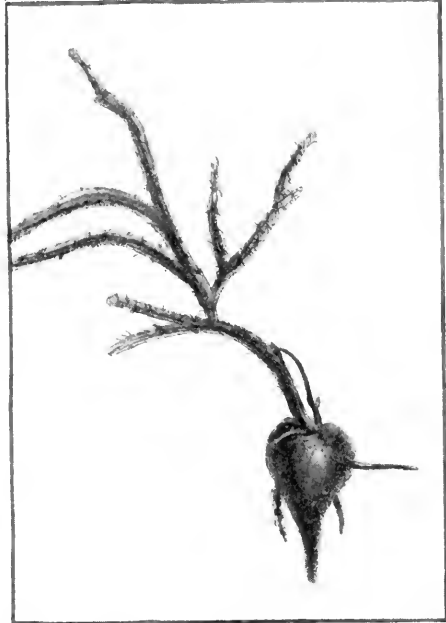


FIG. 1. A NIGHT BLOOMING CEREUS, *Cereus Greggii*, SHOWING THE LARGE SUCCULENT ROOTS WHICH SERVE AS A STOREHOUSE FOR WATER (Much reduced.)

pressure from without. A little worm or insect, or even a very small fish, can pass within, but never back again. The sack acts like an ell trap or a catch-'em-alive mouse trap. These little sacks actually allure very small animals by displaying glandular hairs about the entrance. The small animals are imprisoned and soon perish and decay to nourish the wicked plant.



FIG. 2. BLADDERWORT, *Utricularia vulgaris*, A FLOATING AQUATIC, THE FLOWERS, AT LEAST ARE PROTECTED FROM CRAWLING INSECTS. (Slightly reduced.)

It is not the purpose of these pages to go into details regarding the methods of insectivorous plants, but to tell how plants defend or protect themselves.

When scattered by Bursling Pods, the Seeds are seldom found by Animals.—When mature, the pistils of certain plants burst quickly and with considerable force, scattering the seeds in every direction. The small size and the inconspicuous colors of the seeds make it certain that few of them will ever be found and destroyed by insects or mice. Plants of this kind are euphorbias or spurges, violets, peas, beans, witch hazel, castor-oil plants, balsams and many more.

The bearded chaff enclosing the grains of porcupine grass and wild

barley are irritating to the mouths of grazing animals, which attempt to eat them, though it is not probable that cattle avoid these plants on this account.

Gardeners often overlook some of the Weeds.—For many years the writer has had the oversight of two or three acres on which were grown some 2,000 kinds of plants. It is the exception to pass over a bed after a workman has 'dressed it up' and not find a number of weeds left among the cultivated plants. They are overlooked because of some resemblance of the weed to the plant desired. I enumerate a few examples found one day in the month of May: A few wild onions are left in the asparagus; wild seedling lilies in a plat of Solomon's seal and in a bed of turtle-head; June grass lurks in plats of several sorts of pinks, of *Phlox* and of many other plants; narrow-leaved dock is often abundant, and some of it is left in a plat of dandelions, of teasels, of rhubarb, of buttercups, of rue anemone; pig weeds

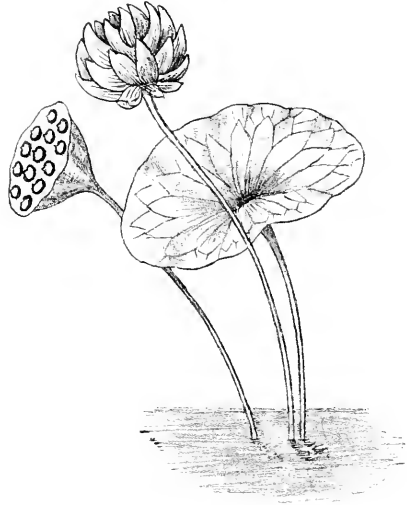


FIG. 3. LEAF AND FLOWER AND RIPENING FRUIT OF THE LOTUS, *Netumbium*, PROTRUDING ABOVE THE WATER, WHICH PROTECTS THESE PLANTS FROM MANY ANIMALS. (Much reduced.)

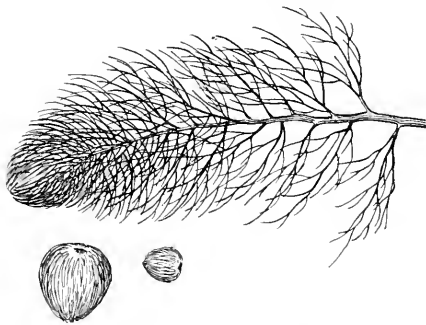


FIG. 4. BUDS OR TIPS OF BRANCHES OF BLADDERWORT SEPARATED FROM THE MAIN STEM AND ARE SOON READY TO SINK TO THE BOTTOM OF A POND AND THERE REMAIN DURING THE WINTER.

of alsike clover, red clover and black medick; young plants of climbing fumitory are left in beds of ginseng, Dutchman's breeches and yellow puceon; seedling wild cherries are overlooked among winter berries; ground-nut escapes notice as it comes up among hog pea-nuts, vetches, or

are left to go to seed among potatoes and tomatoes; the brittle joints of prickly pear are left to grow among other species which they resemble; seeds of violets in variety spring up in plats of other violets where they were shot by the mother plants; chick-weeds are rarely ever all discovered in plats of speedwells; while speedwell lurks among the snap-dragons; white clover is not all removed from plats

wild peas; matrimony vine is left to grow awhile among plants of bitter-sweet, ground cherry, horse-nettle and buffalo bur; the Oswego tea

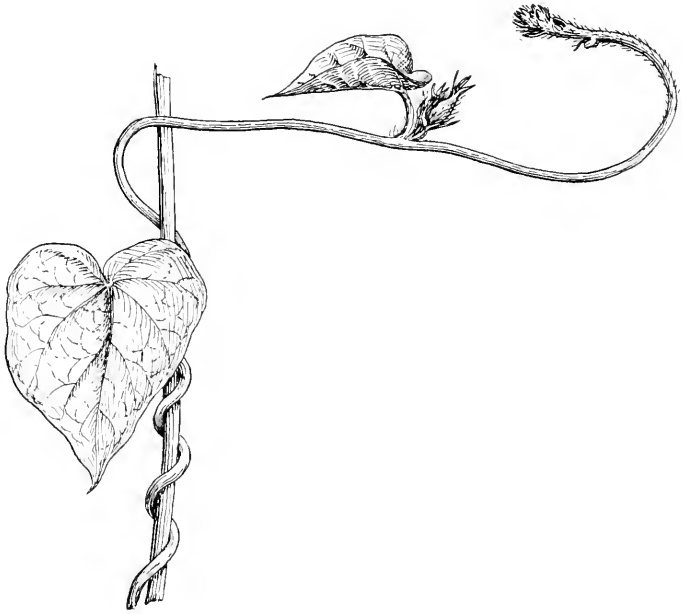


FIG. 5. TWINING PLANT, WILD MORNING-GLORY. (Reduced.)

shies its rootstocks all about and many appear and remain for a time with peppermint, spearmint, sage, origanum and motherwort; worm-wood visits ox-eye daisy and the two agree well together; Canadian golden-rod creeps into plats of low-land grasses, sedges, wild asters and artichokes; the enterprising dandelion is found in plats of hawkweed, chicory, wild lettuce sow-thistle, and is often overlooked; and squaw-weed finds a welcome with sweet-colt's-foot.

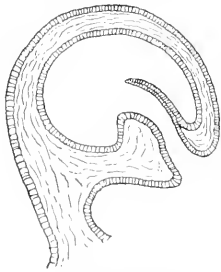


FIG. 6. A CROSS SECTION MUCH ENLARGED OF A BLADDER-LIKE TRAP WHICH CATCHES WORMS. (After Darwin.)

the green leaves of the plants are spared to work for future crops of seeds.

An Iris that imitates a Rattlesnake.—In portions of Washington rattlesnakes are very abundant, and are much dreaded by cattle and horses which graze large portions of the state.

In this region grow large quantities of *Iris Missouriensis* and when ripe the rattle of the seed in the pods closely resembles the rattle of the snake. Grazing animals invariably step back after hitting these pods, and thus the

For this observation I am indebted to Matt Crosby, of the U. S. Bureau of Forestry.

Seeds that mimic Pebbles.—Seeds are frequently met with that are mottled or striped or of an inconspicuous color difficult to find when dropped on the soil or among small pebbles. Seeds of this character are least liable to be destroyed. By a process of selection for many generations, no doubt, seeds have acquired their present colors, and some of them are still undergoing this process.

Certain sorts of cow peas resemble the red soil found in some regions. Caster-oil beans have been mentioned as examples of those which are mottled. Some of the cacti have an irregular shape and a dull gray color much resembling stones of the desert.

On the coast of some of the Philippine Islands, a coarse briar produces beans more or less approaching a sphere in shape.* They are about the size of the finger tips of a man and some of them, like peas crowded in the pod, have two flat surfaces. The color varies from moderately dark to light drab, some giving a faint greenish tinge, while the luster of many is exactly that of chert pebbles. Nearly all the specimens show a series of approximately parallel darker lines passing around, very suggestive of stratification. All are quite hard, cut only



FIG. 7. THREE SEEDS OF CASTOR BEANS, BROWN AND MOTTLED, NOT EASILY FOUND WHEN THROWN ON THE GROUND. (Slightly enlarged.)



FIG. 8. REPRESENTING FOUR SEEDS WHICH CLOSELY RESEMBLE PEBBLES, AMONG WHICH THEY WERE ACCIDENTALLY GATHERED.

with difficulty with a knife, and when shaken together in the hand give that clinking sound, only somewhat duller, which is characteristic of pebbles. The mimicry then is that of mixed quartz pebbles, and covers *shape, size, luster, hardness and stratification*. It is so complete and perfect that it can not be regarded as mere coincidence. Placed in water, the beans are found to be buoyant. Undoubtedly this mimicry of pebbles has saved many a seed from destruction by fish, bird or reptile.

* W. H. Sherzer, *Bot. Gaz.*, Vol. XXI.

THE PROGRESS OF SCIENCE.

THE CARNEGIE FOUNDATION.

MR. ANDREW CARNEGIE has added to his vast gifts for public purposes a foundation to provide pensions for college teachers. He has selected twenty-five trustees, all but three of whom are heads of educational institutions, and has addressed to them a letter in which he states that he has transferred to them \$10,000,000 five per cent. first mortgage bonds of the U. S. Steel Corporation to provide retiring pensions for the teachers of universities, colleges and technical schools in the United States, Canada and Newfoundland. Mr. Carnegie says: "I have reached the conclusion that the least rewarded of all the professions is that of the teacher in our higher educational institutions. New York City, generously, and very wisely, provides retiring pensions for teachers in her public schools and also for her policemen. Very few indeed of our colleges are able to do so. The consequences are grievous. Able men hesitate to adopt teaching as a career, and many old professors whose places should be occupied by younger men can not be retired." Strictly sectarian institutions and those supported by the state are excluded from participation.

This foundation opens up many problems of extreme importance. If it should be administered as a fund for indigent and disabled professors it would be an intolerable nuisance; but the trustees are of course too wise to permit any such outcome. Still it will be somewhat difficult to prevent it from becoming a charity. About ninety-five institutions are included in the preliminary list of those coming within the scope of the foundation.

It would doubtless have been better to have distributed the money *pro rata* among such of these institutions as would agree to establish a pension system, and, as far as we can see, it would be best to distribute the income in this way. The obvious objection is that the demands of each institution would vary greatly from time to time. One of our leading universities with five hundred officers has a pension system, and we believe that there is at present only one professor on the retired list, whereas twenty years hence there may be a dozen. Still if the income were distributed among the institutions as a trust fund on condition that they establish a pension system, things would come out even in the long run. The expenses and machinery of administration would be reduced to a minimum, and the objectionable charity features would be avoided.

When an institution has a pension system, the professor who accepts a position in it does so under a business contract, and there is no question of any patronage or charity. Thus the statutes of Columbia University read: "Any professor who has been fifteen successive years or upwards in the service of the University, and who is also sixty-five years of age, or over, may at his own request signified to the president in writing, or upon motion of the trustees, be made an emeritus professor on half-pay from the beginning of the next succeeding fiscal year." When a man becomes a professor at Columbia University at the age of forty years, he has an expectation of life of about thirty years, and may look, say, to five years of half pay in

retirement. As part of his salary an annuity is paid for by the university at the rate perhaps of \$300 a year, and his salary is that much larger than the sum he receives. The income of the Carnegie Foundation should be administered in some such way. One of the most important results of the scheme will be the pressure brought on the state universities to establish pension systems. The College of the City of New York has already provided liberal pensions, and the example will doubtless be followed elsewhere.

If eleemosynary features can be eliminated from the Carnegie Foundation, the matter is reduced to a phase of the world-wide conflict between individualism and socialism. Should the college teacher be taken care of by society, or should he take care of himself? Much can certainly be urged in favor of life tenure of office, fixed salaries and pensions for university professors. They are thereby set free to do their work, exempt to a considerable extent from anxiety over their material support, from commercial standards, from intrigues and possible injustice, from hasty work, from fear of the consequences of free speech. There are many who will develop the highest scholarship and produce the best research work under these conditions. But there are some who go to sleep comfortably in such a utopia and others who find it irksome. It tends towards dependence on the part of the professor and despotism on the part of the administration, to small salaries, to petty rivalries for honors in place of the serious competition of real life, to a kind of panmixia, where all are chosen who are called and there is but little selection of the best. Probably most people who take thought look forward to socialism as a necessary outcome of the increased complexity of social conditions, but there will be division of opinion as to whether steps in this direction such as Mr. Carnegie's foundation should be welcomed or regretted.

THE CONFERENCE OF ANATOMISTS AT THE WISTAR INSTITUTE.

THE conference of anatomists held on April 11 and 12 at the Wistar Institute of Anatomy, Philadelphia, portends an important step in the advancement of the science of anatomy in America. The men called to this conference differ widely in their interests, in their methods of work and interpretation, yet all are interested in the one great problem of anatomy in its broad sense. They were selected for this reason, as representing the various phases of activity in morphology. They were invited by the Wistar Institute of Anatomy at the suggestion of its director, Dr. M. J. Greenman, to meet in Philadelphia and discuss the relations which the institute might, with mutual advantage, bear to other forces in the promotion of anatomical research.

The following anatomists took part in the conference:

Dr. Lewellys F. Barker, professor of anatomy, University of Chicago, Chicago, Ills.

Dr. Edwin G. Conklin, professor of zoology, University of Pennsylvania, Philadelphia, Pa.

Dr. Henry H. Donaldson, professor of neurology, University of Chicago, Chicago, Ills.

Mr. Simon H. Gage, professor of embryology, Cornell University, Ithaca, N. Y.

Dr. G. Carl Huber, professor of embryology and histology, University of Michigan, Ann Arbor, Mich.

Dr. George S. Huntington, professor of anatomy, Columbia University, New York City.

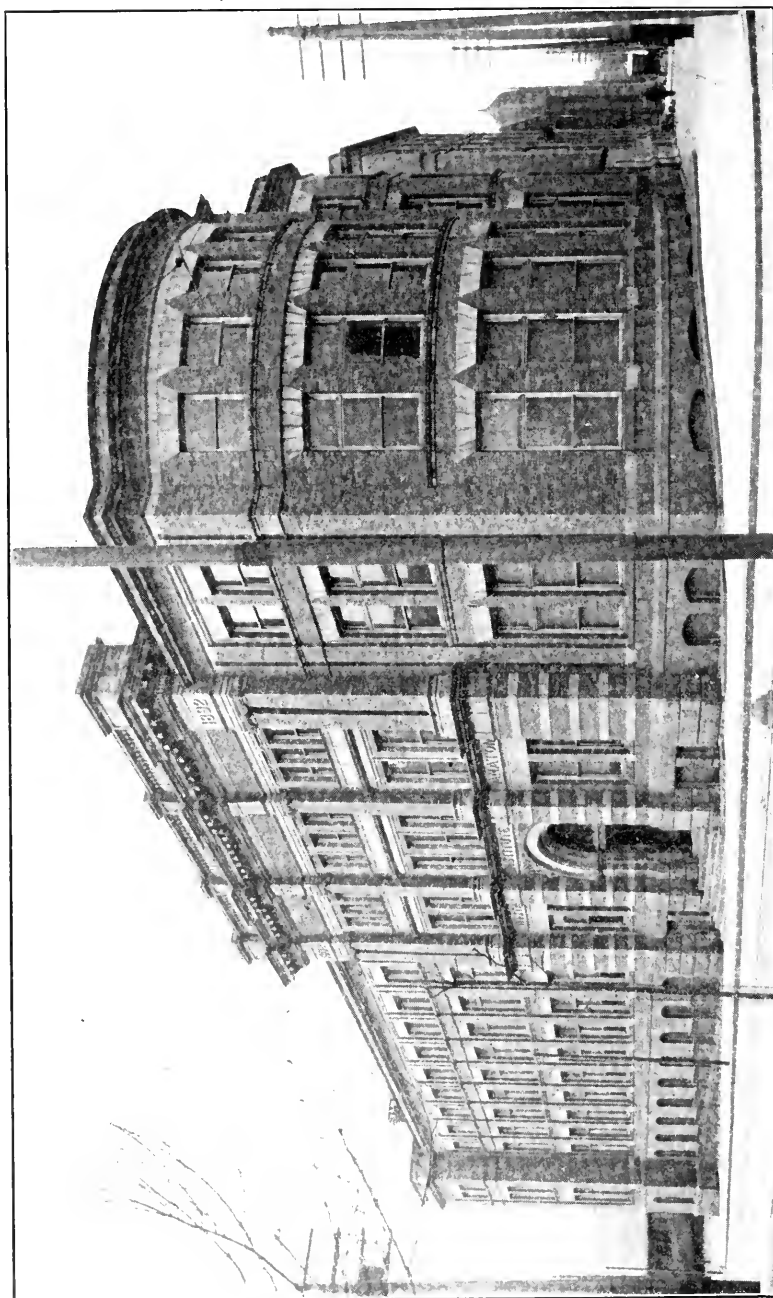
Dr. Franklin P. Mall, professor of anatomy, Johns Hopkins University, Baltimore, Md.

Dr. J. Playfair McMurrich, professor of anatomy, University of Michigan, Ann Arbor, Mich.

Dr. Charles S. Minot, professor of embryology, Harvard Medical School, Boston, Mass.

Dr. George S. Piersol, professor of anatomy, University of Pennsylvania, Philadelphia, Pa.

The belief of the institute authorities that there is much of common value to be gained by a cooperation of the institute with the anatomical forces of America is shared by many others, and it is the common opinion that the Wistar Institute, on account of its independent organization, will be of great value in supplementing the work



THE WISTAR INSTITUTE OF ANATOMY, WOODLAND AVENUE AND 30TH ST., PHILADELPHIA.

of other research schools and museums and especially in acting as a central institution for the collection and distribution of research materials and a storehouse for valuable morphological material which has been studied and is to be conserved for future comparisons.

The Wistar Museum was instituted in 1808 by Dr. Casper Wistar and incorporated as an independent institution in 1893 to foster and increase and make useful the museum originally known as the Wistar, or Wistar and

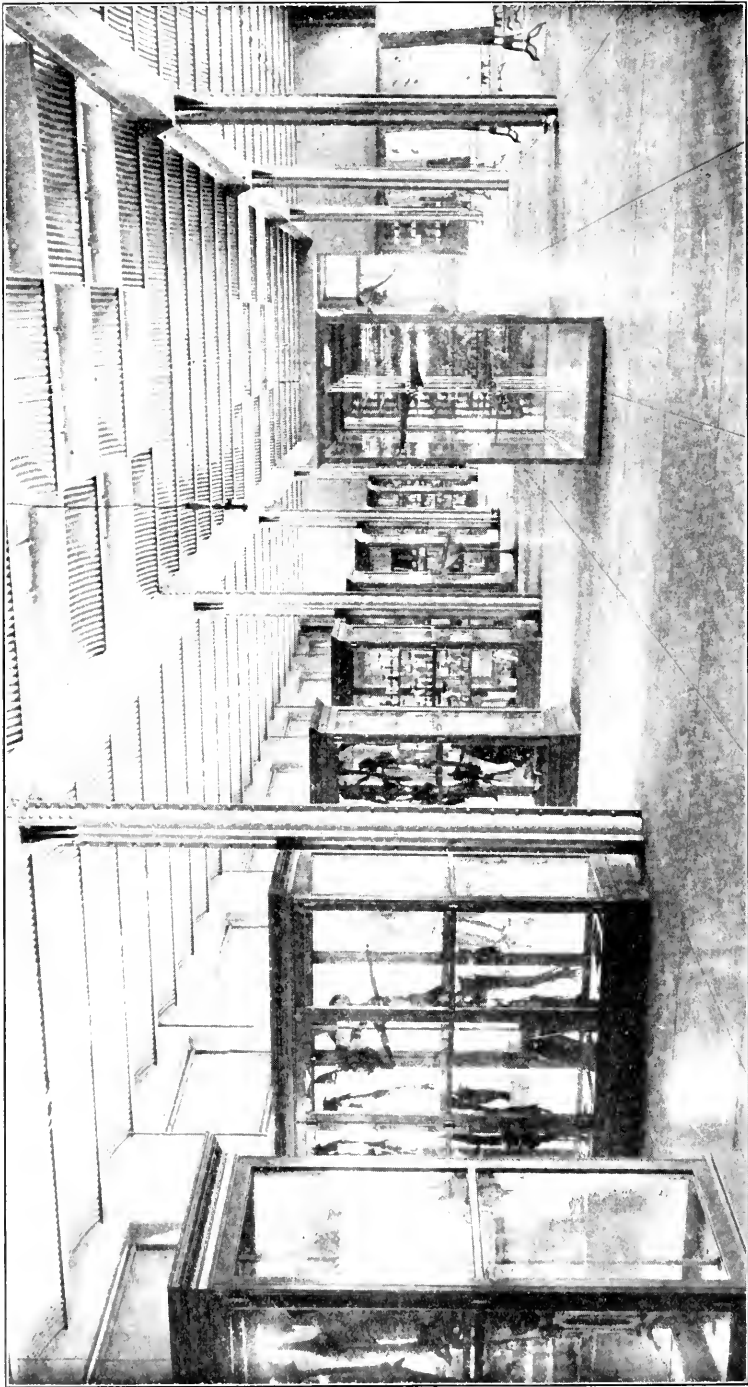
of managers. During the past twelve years the museum of the institute has multiplied its collections by six and their value by fifty, researches have been encouraged and much valuable work has been turned out, not to mention the great use which has been made of its museum (which is open free to the public), by students of medicine and natural history from the various educational institutions. The line in which the Wistar Institute has made decided progress is in museum technique; the



METHOD OF STORING VALUABLE OSTEOLOGICAL MATERIAL IN DUST-PROOF STEEL CASES: THE SPECIMENS ARE IN TRAYS.

Horner Museum—the first museum of human anatomy in America—and to promote researches in human and comparative anatomy. A charter was secured from the state of Pennsylvania, a modern fireproof building and endowment being given by General Isaac J. Wistar to maintain the equipment. This endowment has been most generously doubled and quadrupled several times over since 1893 by the same donor, almost without the knowledge of its board

development of new methods of exhibiting specimens, new dust proof steel and glass cases, new form of glass exhibition vessels, the value of which has been recognized both at home and abroad. Most of this work, especially the experimental part, is done in its own machine shops, and it is likely that a high degree of technical skill will be developed here. This in itself enables the institute to be of great assistance to research anatomy, especially in those



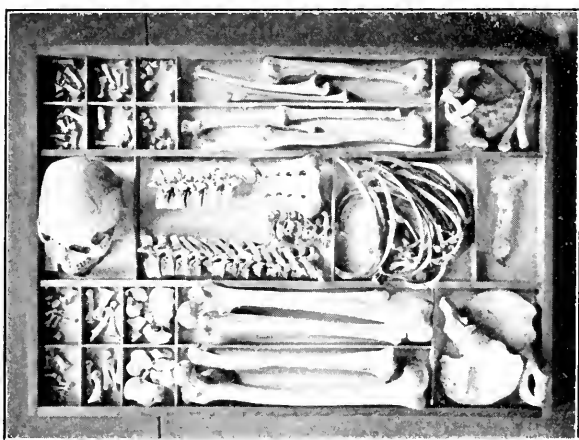
MUSEUM HALL OF FIRST FLOOR.

branches of the work where serial sections and other difficult preparations are to be made.

With an equipment for anatomical work equal to any in the country, with an endowment equal to the sum total expended by the three great anatomical schools in the states, with no energies expended in teaching undergraduate students, the Wistar Institute, organized as an independent research institution, stands unique in this country for the substantial support and encouragement of anatomy. How can it be

late certain suggestions to be discussed at the second session of the conference; this committee presented the following propositions:

Notes taken at the meeting of the committee yesterday are presented in the following order: (1) The principal object of the institute to be research and under these headings: (a) a chief of investigation, (b) research assistants or assistantships and men who shall divide their services between the museum proper and research, (c) technical assistants. (2) Research and materials: (a) research shall be in the field of neurology, (b) comparative anatomy and embryology. (3) Relations: (a) committee recommends that the subvention to the *Journal of Anatomy* be granted, (b) committee be ap-

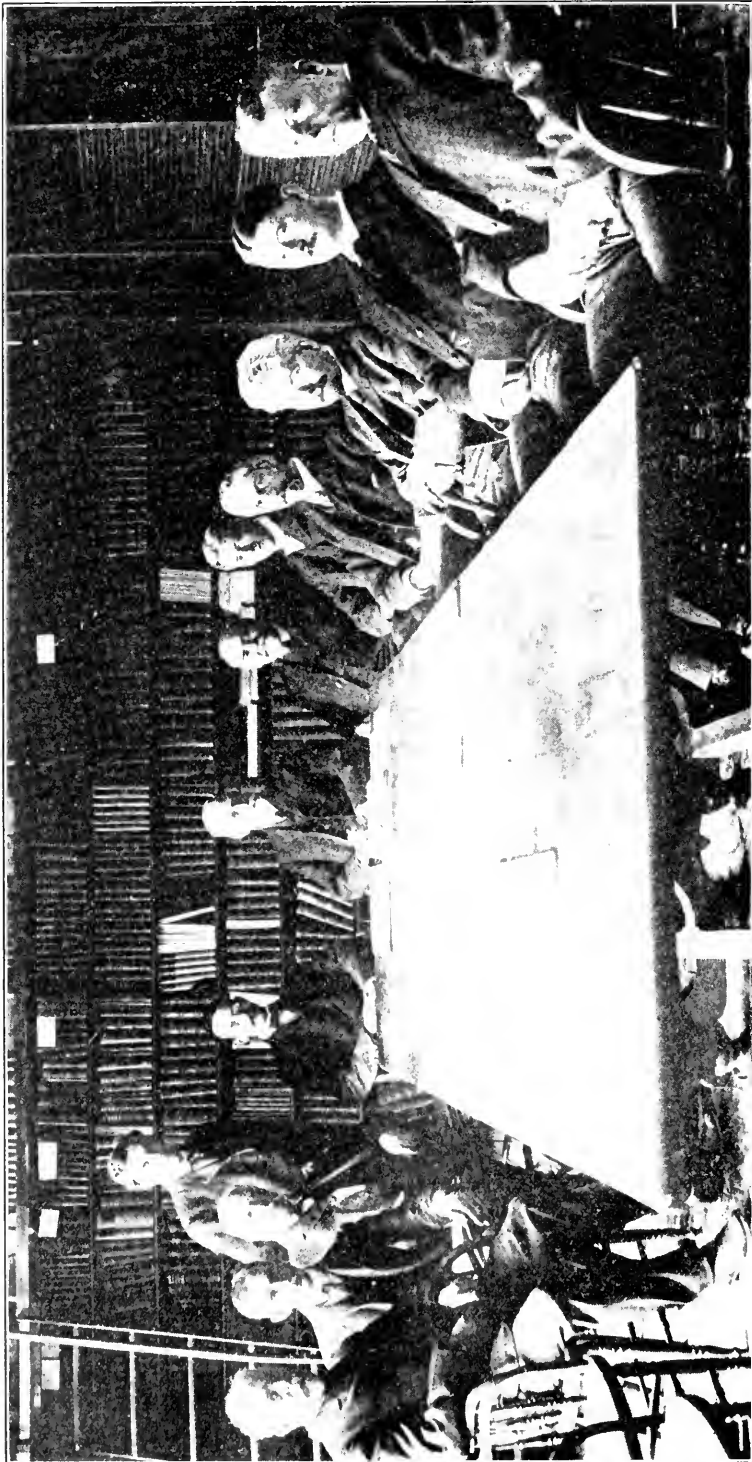


METHOD OF STORING A HUMAN SKELETON IN A TRAY.

made of greatest use to the science? This problem, coupled with the fact that there is no central institute for anatomy in America devoted solely to the one purpose, where research materials may be collected together, properly prepared and sent freely to interpreters who can not come to the institute, was the reason for calling together ten leaders in the science. They discussed it from their various standpoints and were unanimous in their opinion as to the work which might be accomplished. It was fully agreed at the first session that the development of a museum and the pursuit of research are inseparably united. A committee was then appointed to formu-

lated to consider relations of the Wistar Institute to American anatomists, (c) the Wistar Institute to apply to the Association of American Anatomists for cooperation. (4) That an advisory board of ten be appointed for general purposes: (a) to form a sub-committee on neurology as well as other sub-committees that may be needed, (b) to establish relations with the committee of the International Association of Academies for Brain Investigation and with other committees for collective investigation, (c) the committee recommends that the board bear in mind that while the general trend of work above outlined is recommended there is no intention to advise limitation of the functions of the institute to it exclusively.

This report was briefly discussed on the following day and presented to the Wistar Institute as the finished work of the conference. The institute accepted it and suggested that the ad-



GAGE, MALL, WISTER, GREENMAN (standing), CONKLIN, MINOT, PIERSON, BARKER, McMURRICH, DONALDSON, HUBER, HUNTINGDON.

CONFERENCE OF ANATOMISTS HELD AT THE WISTAR INSTITUTE ON APRIL 11 AND 12, 1905.

visory board organize at once and outline any work that might seem proper, pending the approval of the board of managers of the institute. This was done by electing Dr. Charles S. Minot as chairman and Dr. M. J. Greenman as permanent secretary.

The advisory board proceeded to appoint the following committees: on neurology and the establishment of relations with the International Association of Academies, Dr. L. F. Barker, Dr. H. H. Donaldson, Dr. F. P. Mall, Dr. J. P. McMurrich, Dr. C. S. Minot (this committee to elect its own chairman); on relations of the Wistar Institute to American Anatomists, Professor S. H. Gage, chairman, Dr. Geo. A. Piersol, Dr. G. Carl Huber; on comparative anatomy and embryology, Dr. Geo. S. Huntington, chairman, Dr. E. G. Conklin, Dr. F. P. Mall.

This move on the part of the Wistar Institute places its future development largely in the hands of a national board of leaders in anatomy, a feature as unusual as it is desirable, and through the Wistar Institute the work of anatomical schools may be supplemented and strengthened and brought into cooperation. If the plan is carried out as successfully as it has been started, there will be a decided increase in the efficiency of every effort put forth in the science.

It is expected that through the advisory board the facilities and opportunities offered by the Wistar Institute will be brought to the notice of active American anatomists, that difficult problems for cooperative research will be proposed, especially in neurology. Material will be collected, prepared and distributed to workers who are unable to come to the institute laboratories. The Wistar Institute asks nothing in return for its opportunities and the material it sends out, neither does it require papers to be published in any particular journal. The returns are sufficient so long as the science is aided,

and the greater service it can be to research workers in the development and spread of original knowledge the more nearly will its purpose be achieved. That the Wistar Institute appreciates the cooperation and suggestions of the anatomists is shown by the prompt manner in which its board of managers created the advisory board and elected to its membership the anatomists who took part in the conference. It is understood that the suggestions made at this conference will be carried out in every detail as fast as the resources of the institute will permit.

SCIENTIFIC ITEMS.

WE record with regret the deaths of Professor Otto Struve, director of the Poulkova Observatory from 1862 to 1890; of Dr. Joseph Everett Dutton, who died in the Congo, where he was sent by the Liverpool School of Tropical Medicine to investigate trypanosomiasis and tick fever; of M. Henri de Saussure, the French zoologist; of Mr. H. B. Medlicott, F.R.S., director of the Geological Survey of India from 1876 to 1887, and of Colonel Nicholas Pike, known for his contributions to the natural history of birds, reptiles and amphibia.

THE National Academy of Sciences has elected to membership Professors John C. Branner, of Stanford University; William H. Holmes, of the Bureau of American Ethnology; William H. Howell, of Johns Hopkins University; Arthur A. Noyes, of the Massachusetts Institute of Technology, and Michael I. Pupin, of Columbia University. M. Henri Becquerel, of Paris, and Professor Paul von Groth, of Munich, have been elected foreign associates.

PROFESSOR E. B. FROST has been appointed director of the Yerkes Observatory by the trustees of the University of Chicago, in succession to Professor G. E. Hale, who gives his whole time to the establishment of the new Solar

Observatory of the Carnegie Institution at Mt. Wilson, Cal.—Professor John F. Jameson, head of the department of history at the University of Chicago, has been offered the post of director of the Bureau of Historical Research in the Carnegie Institution, Washington, D. C. This position is vacant through the return of Professor J. Lawrence Laughlin to the University of Michigan.

LORD RAYLEIGH is about to retire from the professorship of natural philosophy at the Royal Institution, which he has held for eighteen years. He will be made honorary professor. Lord Rayleigh has given twenty-three Friday evening discourses and twenty-one courses of afternoon lectures at the institution.—Sir Patrick Manson has been invited to give the Lane lectures at the Cooper Medical College, California, this year. He will lecture on some aspect of tropical diseases.—Professor Hugo Münsterberg, of Harvard University, has declined the offer of a chair of philosophy, tendered to him by the University of Königsberg.

DR. E. F. NICHOLS, professor of physics at Columbia University, has been awarded the Ernest Kempton Adams research fellowship, recently established at Columbia University by Mr. E. D. Adams in memory of his son. Professor Nichols has at present leave of absence and is working at Cambridge University.—Dr. Nettie Maria Stevens, of San Jose, California, associate in experimental morphology at Bryn Mawr College, has been awarded the prize of \$1,000 offered every two years by the

Association for Maintaining the American Woman's Table at the Zoological Station at Naples and for Promoting Scientific Research by Women.—The Smithsonian Institution has made a grant of \$250 from the Hodgkins Fund to Professor W. P. Bradley, of Wesleyan University for an experimental study of the flow of air at high pressure through a nozzle.—The following appropriations have recently been made from the Rumford Fund of the American Academy of Arts and Sciences: To Professor Charles B. Thwing, of Syracuse University, \$150 in aid of his research on the thermo-electromotive force of metals and alloys; to Dr. Harry W. Morse, of Harvard University, \$500 in aid of his research on fluorescence.

DR. C. J. MARTIN, director of the Lister Institute, London, has been sent to India to investigate the plague. It is understood that with several bacteriologists he will carry on work at Kasauli. The deaths from the plague in India average more than 30,000 a week in spite of all efforts which have been made to check its ravages.

PLANS have been filed for a fifteen-story building to cost \$975,000, which Mr. Andrew Carnegie is to present to the Associated Societies of Engineers of New York. It is to be erected on the large plot from 25 to 33 West Thirty-ninth Street, and immediately adjoining it in the rear, facing at 32 and 34 West Fortieth Street, will be a thirteen-story club-house, which is to cost an additional \$375,000, also part of Mr. Carnegie's gift.

THE POPULAR SCIENCE MONTHLY.

JULY, 1905.

RECENT DISCOVERIES IN HEREDITY AND THEIR BEARING ON ANIMAL BREEDING.*

BY PROFESSOR W. E. CASTLE,
HARVARD UNIVERSITY, CAMBRIDGE, MASS.

EVERY breeder of animals is familiar with the great complexity of hereditary processes. He knows that characters of the most varied sorts are inherited. These relate not only to general size and proportions, but also to the structure of individual parts; and not merely to structural, but to functional peculiarities as well. Thus, in certain races or strains of animals, we find inherited great fecundity, or early maturity, or ability to put on fat, or to produce abundant milk; in other cases, speed, keen scent, fierce or gentle disposition, and numberless other characteristics are plainly inherited. Very rarely are any two heritable traits *necessarily* associated. The cow with a good flow of milk may or may not be gentle; the keen-scented dog may or may not be speedy. Accordingly, we must conclude that different hereditary characters are inherited independently of one another, and are probably represented by different structural elements in the sexual element or germ. We know, further, that the laws of transmission of different characters are different, so that we can not estimate the force of heredity in the lump, but must fix our attention on one character at a time if we wish to analyze the complex processes in operation.

Francis Galton (1889) was the first to recognize that in the case of certain characters the result of inheritance is a *blend* of the conditions

* Published by permission of the Carnegie Institution of Washington, to whose officers the author is deeply indebted for aid in the prosecution of his studies, and in particular for the loan of figures 4-14 of this article.

found in the two parents, while in other characters inheritance is *alternative* between the conditions found in the parents.



FIG. 1. A BROWN-COATED, LOP-EARED RABBIT.



FIG. 2. AN ALBINO, SHORT-EARED ANGORA RABBIT.

A good illustration of blending inheritance is found among rabbits which differ in size of ear. Lop-eared rabbits have ears two or three times as long and as wide as those of ordinary rabbits. (Compare Figs. 1 and 2.) A cross between lop-eared rabbits and ordinary ones

produces offspring with ears of intermediate size, which sometimes stand erect and sometimes lop. (See Fig. 3.) The ear-characters which were so distinct in the parents have in this case lost their identity in the offspring, and apparently can not be recovered again in their original condition, for the offspring transmit to their young the blended character, rather than the extreme conditions found in their respective parents.

It has been thought until quite recently that hereditary processes in general were of this sort and that any result other than a blend was exceptional. But recent investigations do not bear out this idea.



FIG. 3. A BLACK COATED, HALF-LOP RABBIT, son of the two rabbits shown in Figs. 1 and 2, respectively.

Alternative inheritance is illustrated in a cross between the so-called Belgian hare and an albino rabbit. The Belgian hare is simply a gray-coated variety of the European rabbit, while albino rabbits are pink-eyed animals of the same species and have white hair; the Belgian is pigmented like the wild European rabbit, the albino is essentially unpigmented. A cross between the two produces offspring all of which have the pigmented or Belgian coat, none being albinos. Compare Fig. 3; in this case the parents were an albino and a brown pigmented animal, respectively. The young, nine in number, were all black pigmented, like the one shown in Fig. 3.

The effect of crossing a pigmented rabbit with an albino is similar to that produced when two pieces of glass, one transparent, the other opaque, are held up together. We see only the opaque one. Nevertheless, the two conditions have not blended: each retains its original dis-

tinctness, and the two can be separated again at will. So it is in the Belgian produced by cross-breeding with an albino. The albino character is there, though unseen, and will appear as a distinct entity when the cross-bred reproduces, for it will be represented in approximately half of the sex-cells formed by the cross-bred animal, the alternative or Belgian character being represented in the other half. It is as if the two pieces of glass, combined originally to illustrate the formation of a cross-bred animal, were separated again to illustrate the formation of the reproductive elements by the cross-bred. For every element formed having the opaque character, there will be another



FIG. 1. A GUINEA-PIG WITH LONG, ROUGH, ALBINO COAT.

having the transparent character, but there will be no elements of an intermediate nature.

This simple principle, that in alternative inheritance sex-cells of two sorts are formed by cross-bred individuals, constitutes one of the most important discoveries ever made in the study of heredity. The discovery was made about forty years ago by an Austrian monk, Gregor Mendel, who was engaged in the study of cross-bred garden peas. It, however, attracted little attention at the time and was soon forgotten. Meanwhile, a great body of workers was studying with great minuteness the material basis of heredity, the sexual elements. Their investigations disclosed in the cell a complete basis for just this kind of alternative inheritance and led up to the rediscovery of Mendel's law simultaneously by several different experimental breeders, foremost among whom was the Dutch botanist, de Vries.

Mendel found that in cross-breeding between alternative characters, one uniformly dominates in the offspring from its very nature, while the other disappears. Just as, when the two pieces of glass are held up together we see only the opaque one, the transparent one being invisible. Mendel called the character seen in the offspring *dominant*, the unseen one he called *recessive*. In rabbits, the gray pigmented or Belgian hare coat is dominant over the albino coat, the latter being recessive (unseen) in cross-bred animals. Similarly, in mice, guinea-pigs, and even in man, mating of an albino with a pure, pigmented individual produces only pigmented offspring. In guinea-pigs the rosetted or rough coat is dominant over smooth (normal) coat (see

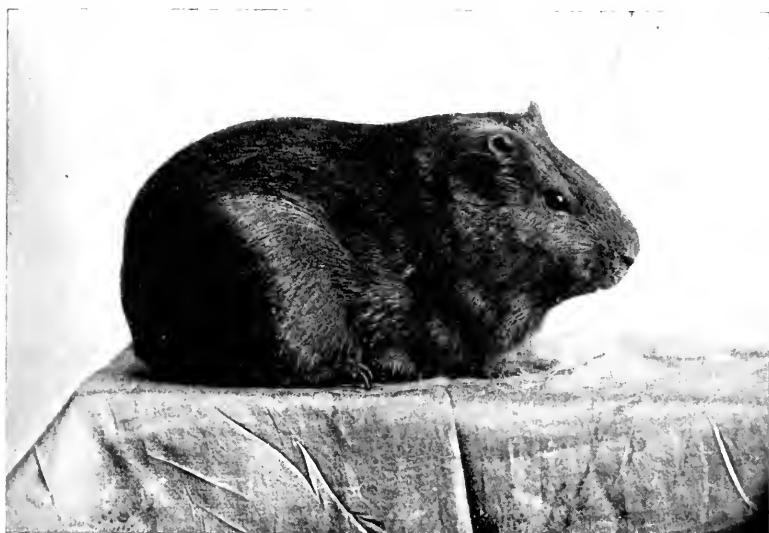


FIG. 5. A GUINEA-PIG WITH SHORT, SMOOTH, PIGMENTED COAT.

Fig. 6); and short coat is dominant over long (or angora) coat (Fig. 8). In rabbits, also, the normal or short coat dominates over the angora coat (Fig. 3), and the same is probably true in cats and goats as well.

Among guinea-pigs there occurs a series of alternative pigment types which show Mendelian relations one to another. If we write them in this order, (1) *agouti* (*i. e.*, black ticked with yellow, the ancestral or wild type of coat), (2) *black*, (3) *yellow*, (4) *albino*, we may say that each is dominant over all which follow it, and recessive in relation to all which precede it. Thus agouti mated with black, yellow or albino gives only agouti offspring; black mated with yellow or albino gives either black or agouti, but never yellow or albino, while yellow dominates over the albino only. In man, a condition of

hypophylangia (two-jointed instead of three-jointed digits) is dominant over the normal condition. In mice, the peculiar waltzing habit of so-



FIG. 6. A GUINEA-PIG WITH SHORT, PIGMENTED COAT. Its parents were the animal shown in Fig. 4 and one like that shown in Fig. 5.

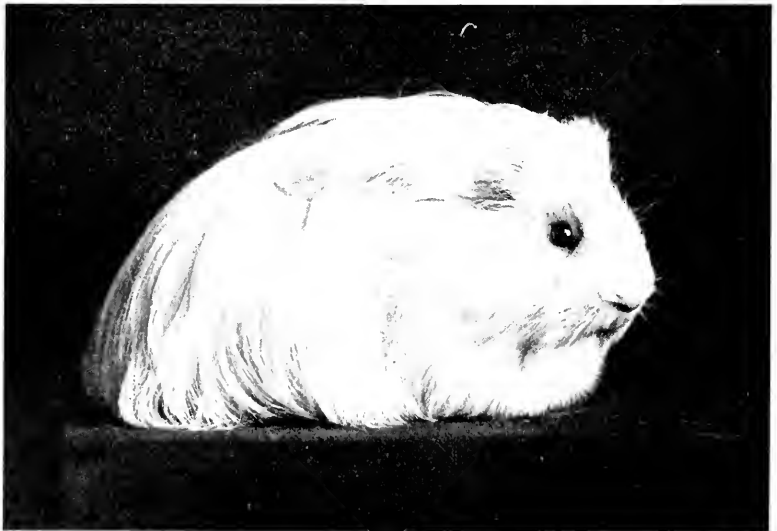


FIG. 7. A GUINEA-PIG WITH LONG, SMOOTH, ALBINO COAT. These three characters are all recessive in nature.

called Japanese mice is a recessive character in heredity. In man, a peculiar dark-colored condition of the urine, known as alkaptonuria, is

inherited as a Mendelian recessive character. Many other illustrations might be given, but these will, perhaps, suffice to show that Mendelian



FIG. 8. A SHORT-HAIRED, SMOOTH, PIGMENTED GUINEA-PIG, illustrating the result of mating two animals like those shown in Figs. 5 and 7 respectively.

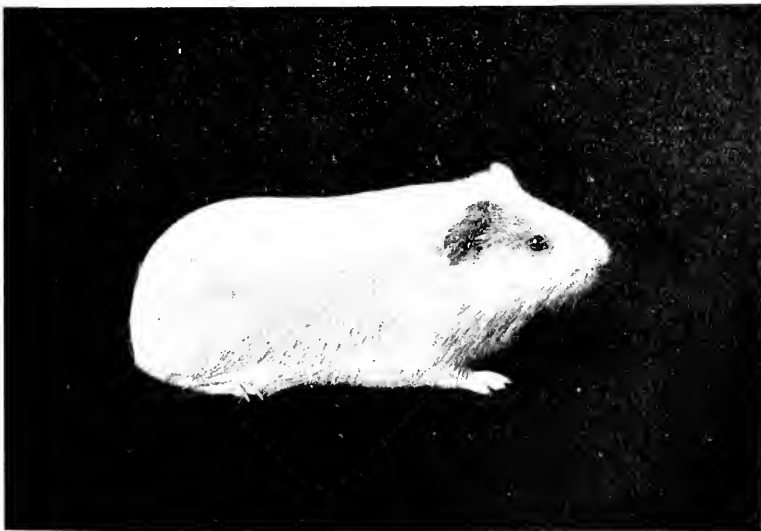


FIG. 9. A SHORT-HAIRED, SMOOTH, ALBINO GUINEA-PIG.

or alternative inheritance is neither a rare nor an exceptional phenomenon, and that it applies to the inheritance not only of characters purely structural, but also to those which are physiological.

From the facts that cross-bred animals form sexual elements (or gametes) of two sorts, and that the two sorts are equally numerous, it follows that among their offspring dominant and recessive individuals will occur in definite proportions. It has been found by experiment that when two cross-bred (or hybrid) dominant animals are mated together, the offspring consist of a mixture of dominant with recessive individuals in approximately the proportions, three dominant to one recessive. Further, when a hybrid dominant is mated with a recessive animal, half the offspring are hybrid dominants, half recessives. These proportions of necessity result, provided neither sort of gamete has greater affinity for one kind than for the other. For consider all the possible unions between two sets of gametes each D and R (the case in which two hybrid dominants are bred together):

$$\begin{array}{c}
 D \text{ and } R \\
 \\
 \\
 \\
 \frac{D \text{ and } R}{\underbrace{DD + 2D(R) + RR}} \\
 \quad \quad \quad 3 \qquad \quad 1
 \end{array}$$

They are 1 DD , 2 DR and 1 RR , or three unions involving the D character to one involving the R character only; hence three dominant individuals will be produced to one recessive. Further, one of the three dominants (DD) will be pure, while the other two are hybrid in character. Recessive individuals are, however, necessarily pure and breed true *inter se*. Thus, smooth-coated guinea-pigs produce only smooth-coated offspring, albinos only albino offspring, and long-haired ones only long-haired offspring, when mated to animals like themselves. The reason for this will be clear if we return to the illustration with the glass plates. Pairs of transparent plates can be separated only into transparent pieces, and these can be recombined only into transparent pairs.

With the dominant offspring of hybrids, however, the case is different. Only pure dominants (DD) will breed true when mated *inter se*; hybrid dominants (DR) will continue to give a mixed progeny. For pairs of opaque plates, when separated, can be recombined only into opaque pairs; but pairs composed each of an opaque and a transparent plate, when separated, may be recombined either into opaque pairs or into transparent pairs, the chance frequencies of the two sorts of combination being as three to one.

Accordingly, any pair of recessive individuals may form the beginning of a pure race of recessives, but in starting a pure race of dominants we must test each animal used, to make sure that it does not

contain, unseen, the recessive character. Otherwise we may keep getting mixed lots of offspring. The simplest and surest way of making such a test is to mate the dominant animal with a recessive. For in that case, if the dominant is pure, all the offspring will be dominants; but if the dominant parent is a hybrid, half the offspring will be recessives, half dominants. When the purity of two dominant animals of opposite sex has once been established by breeding-test, we may use them as the starting point of a race of dominants which we may be sure will breed true.

We must not, however, fall into the error of supposing that any pair of dominants which produces only dominant offspring is, therefore, pure. For progeny of this sort will be obtained if only *one* of the parents is pure, the other being hybrid. In starting a race of dominants which will breed true we must test each animal individually, by mating it, preferably with a recessive, or else with a dominant known to be hybrid in character. A test of the former sort should, as stated, give 50 per cent. of recessive individuals if the dominant is impure; a test of the latter sort should give 25 per cent. of recessives, if the dominant is impure. Either sort of test should give only dominant offspring if the dominant tested is pure.

The statement has already been made that many characters are independent of one another in heredity; I hope now to demonstrate the correctness of this idea in cases of alternative inheritance, even when the independent characters relate to the same bodily parts. For this purpose the coat-characters of guinea-pigs and rabbits are well adapted, since they are exterior structures easily studied in the living animal. I hope to show first that pigmentation of the hair is inherited quite independently of its length, and secondly that hair-arrangement (in smooth or rough coat) is inherited quite independently of both pigmentation and length of hair.

When an ordinary short-haired guinea-pig (Fig. 5) is mated with a long-haired albino guinea-pig (Fig. 7), all the young produced are short-haired and pigmented, these being the dominant characters. (See Fig. 8.) Now if the cross-bred young are bred together, offspring of four different sorts are produced. Two of the four sorts are identical with the grandparents in character; they are short-haired pigmented animals (Fig. 5) and long-haired albinos (Fig. 7), respectively. But the other two sorts represent new combinations of characters; they are short-haired albinos (Fig. 9), and long-haired pigmented animals (Fig. 10). Further, these four sorts of individuals occur on the average in definite numerical proportions, viz:

- 9 short-haired pigmented animals,
- 3 short-haired albino animals,
- 3 long-haired pigmented animals, and
- 1 long-haired albino.

Considering pigmentation and hair-length separately, we see, first, that there are 12 pigmented animals to 4 albinos, or 3 to 1, as expected; and, secondly, that there are 12 short-haired to 4 long-haired animals, again 3 dominants to 1 recessive. But if we consider the relation of each pair of characters to the other, we find absolutely no correlation between them. Albinism may or may not be associated with long hair, and pigmented coat may or may not be associated with short coat in the offspring, though they were so associated in the grandparents. As a matter of fact, when the animals are tested one by one, to determine the presence of recessive characters, we find that albinism, visibly present in 4 out of 16 offspring, is present recessive in 4 others, and that in half



FIG. 10. A LONG-HAIRED, SMOOTH, PIGMENTED, GUINEA-PIG.

of these cases it is associated with short coat, while in the other half it is associated with long coat.

In another experiment which I have performed with guinea-pigs, a cross was made involving three pairs of alternative coat-characters, length, pigmentation and roughness of coat. A long-haired rough albino (Fig. 4) was mated with short-haired smooth pigmented animals (Fig. 5). The young were all short-haired, rough and pigmented (Fig. 6). The coat-characters seen in these offspring are the three dominant characters, two of which were received from one parent, one from the other; the three alternative recessive characters are present but unseen.

When the young were bred together, they produced offspring of eight different sorts, including all possible combinations of the three pairs of alternative characters.

One large class was like the parents, short-haired, rough and pigmented. Two other classes were like the grand-parents, viz. short-haired smooth pigmented, and long-haired rough albino. In addition, there were five other new classes not represented among the parents or grandparents. These were: short-haired rough albino (Fig. 11), short-haired smooth albino (Fig. 9), long-haired smooth albino (Fig. 7), long-haired smooth pigmented (Fig. 10), and long-haired rough pigmented (Fig. 12).

The eight classes of young produced in this experiment are not all equally numerous. The largest class is that which contains the three dominant characters (Fig. 6), the smallest that which contains the



FIG. 11. A SHORT-HAIRED, ROUGH, ALBINO GUINEA-PIG.

three recessive characters (Fig. 7). Theoretically, they should number 27 individuals and 1 individual, respectively, in a total of 64 young. These proportions are roughly approximated in the observed result.

This experiment illustrates two important principles in heredity: First, if as regards the hair alone there exists such a variety of characters separately heritable, how great must be the number of such characters in the body as a whole, and how remote the probability that any animal will in all characters resemble any individual ancestor, provided that in a considerable number of heritable characters a choice is offered between³ alternative conditions. Secondly, the experiment shows how a variety of new organic forms may quickly be produced by cross-breeding, leading to the combination in one race of characters previously found separately in different races. Thus, in

guinea-pigs, one can obtain within two generations any desired combination of the three pairs of alternative coat-characters, if one pro-



FIG. 12. A LONG-HAIRED, ROUGH, PIGMENTED GUINEA-PIG.



FIG. 13. AN IMPERFECTLY LONG-HAIRED GUINEA-PIG. Compare Figs. 4, 7 and 12.

duces a sufficiently large number of individuals; but to obtain the desired combination in individuals which will *breed true* is not so simple a matter. If the desired combination consists wholly of recess-

sive characters, any pair of individuals manifesting that combination will breed true. But if the desired combination contains one or more dominant characters, then each animal selected must be tested for the presence of undesirable recessives before one can be sure that the new race will breed true. In practise it is found best by the breeder not to work with too many characters at a time, but to eliminate the undesirable recessives one by one. Otherwise the search for the one individual in a large number which will breed true may prove a long and tedious process. If we deal with one character at a time, the chances are that one in four of the second generation of animals reared will meet our ideal; if we deal with two characters at a time, the chances are one in sixteen; while if we deal with three characters at a time the chances are only one in sixty-four; and so on, with the chances of success diminishing in a geometrical series.

From what has thus far been said it would appear that in alternative inheritance characters behave as units, and, more than that, as *wholly independent* units, so that to forecast the outcome of matings is merely a matter of mathematics. While this is in a measure true, it is, fortunately or unfortunately, not the *whole* truth. In alternative inheritance characters do behave as units independent of one another, but the union of dominant character with recessive in a cross-bred animal is not so simple a process as putting together two pieces of glass, nor is their segregation at the formation of gametes so complete in many cases as the separation of the two glass plates. The union of maternal and paternal substance in the germ-cells of the cross-bred animal is evidently a fairly intimate one, and the segregation which they undergo when the sexual elements are formed is more like cutting apart two kinds of differently colored wax fused in adjacent layers of a common lump. Work carefully as we will, traces of one layer are almost certain to be included in the other, so that while the two strata retain their identity, each is slightly modified by their previous union in a common lump.

Thus, when we cross short-haired with long-haired guinea-pigs, we get among the second-generation offspring a certain number of long-haired animals with hair *less* long than that of the long-haired grandparent, or with long hair on *part* of the body only (Fig. 13). Further, certain of the short-haired animals have hair a little longer and a little softer than that of the short-haired grandparent. Again, rough-coated guinea-pigs produced by cross-breds often have coats less fully rough than that of their rough ancestor, lacking certain of the typical rosettes (Fig. 14). Finally, when an albino is crossed with a fully pigmented animal, the result may be not a wholly pigmented animal, but one spotted with white. While such a cross-bred animal forms a full quota (one-half) of albino gametes, the pigment-bearing gametes formed by it frequently bear this spotted or modified pigmented condition.

Cross-breeding, accordingly, is a two-edged sword which must be handled carefully. It can be used by the breeder to combine in one race characters found separately in different races, but care must be exercised if it is desired to keep those characters unmodified. If modification of characters is desired at the same time as new combinations, then cross-breeding becomes doubly advantageous, for it is a means of inducing variability in characters, as, for example, in the intensity of pigmentation and in the length of hair, quite apart from the formation of new groupings of characters. Sometimes it causes a complex character to break up into simpler units, as the agouti coat of the wild guinea-pig into segregated black and yellow, or total pigmentation into



FIG. 11. AN IMPERFECTLY ROUGH-COATED GUINEA-PIG. Compare Fig. 6.

a definite series of pigmented spots. In other cases it operates by bringing into activity characters which have previously been latent in one or other of the parental forms. Compare Fig. 3 with Figs. 1 and 2. Black pigmentation was latent in the albino parent (Fig. 2) and was brought into full activity by a cross with a brown-pigmented animal.

Now, what bearing, we may ask, have these theoretical matters on the practical work of the breeder? They show (1) that a race of animals is for practical purposes a group of characters separately heritable, and (2) that the breeder who desires in any way to modify a character found in this group, or to add a new character to the group, should first consider carefully how the character in question is inherited.

If the character is alternative in heredity to some other character,

cross-breeding between the two, followed by selection for pure individuals, will within two generations give the desired combination of characters in individuals which will breed true. This process of selection is simplest when the characters to be combined are recessive in nature, but individual breeding-tests become necessary when dominant characters are included in the combination desired.

If a character gives blending inheritance, it must be treated in a different way. Suppose, for example, that we desire to combine lop-ears in rabbits with albinism, but that our lop-eared stock consists wholly of pigmented animals. How shall we proceed? First, mate a pigmented lop- (Fig. 1) with a short-eared albino (Fig. 2). The offspring will be pigmented half-lops (Fig. 3). If two of these be bred together their young will all be half-lops, and about one in four of them will be albinos. Now these albino half-lops may be mated with pure pigmented lops. The young will again all be pigmented, but will this time be *three-quarter* lops, and by breeding these together albino three-quarter lops may be obtained in the next generation. By continuing this process of back-crossing with the lop-eared stock, and selecting the albino offspring obtained, the lop-eared character may be steadily improved in the albinos until it is practically as good as in the original lop-eared stock. The rate of improvement possible can be readily calculated. The albino young will be :

- After 2 generations, one half lops,
- After 4 generations, three fourths lops,
- After 6 generations, seven eighths lops,
- After 8 generations, fifteen sixteenths lops,
- After 10 generations, thirty-one thirty-seconds lops, etc.

This will be the result on the hypothesis that no secondary variation occurs in the lop-eared character. If, however, variation is induced by the cross-breeding, then it is possible that the desired end may be reached sooner, or that an even better lop may be obtained in the albino cross-breeds, than that of the original pigmented stock.

Latent characters are an important element in practical breeding. Sometimes they greatly aid the breeder's work; sometimes they impede it. If a stock contains undesirable latent characters which are brought into activity by cross-breeding, these latent characters will have to be eliminated, or a new stock tried.

Since cross-breeding is likely to modify characters even when these conform to the laws of alternative inheritance, and is certain to modify them when they give blended inheritance, it should be practised with extreme caution, and only by the breeder who has a definite end in view and a fairly clear idea of how he is going to attain it.

. The purity of standard breeds should be carefully guarded, and

much attention should be given to pedigrees; for even when individual excellence is not apparent, it may be present in a recessive or else in a latent state, which suitable matings will bring into full realization, provided the ancestors were superior animals.

At the same time the breeder should be on the lookout for individual peculiarities of merit. And he should not be discouraged if these are not transmitted to the immediate offspring. Ordinarily a desirable character which disappears from the children, but reappears among the grandchildren, can at once be made a racial character, for it is recessive in heredity.

Inbreeding is not invariably an evil. It is often necessary to cause the reappearance of a vanished recessive character, and is indispensable in the formation of races which will breed true. Two or three generations of close inbreeding usually suffice to realize the practical benefits of the process, if intelligently carried on. The inbreeding should then be discontinued as soon as the desired end has been attained. Otherwise, loss of vigor or infertility may result.

PRESENT MONETARY PROBLEMS.*

BY PROFESSOR J. LAURENCE LAUGHLIN,
UNIVERSITY OF CHICAGO.

I.

THE development of thinking about money is the most interesting portion of the history of political economy. The first dawn of economic principles came with the discussion of monetary phenomena, and monetary science has not only always had a peculiar practical interest of its own, leading to its constant appearance in political campaigns in all countries, but it has also had an organic life persisting in its full vigor to the present day. In the United States, the monetary question is not at this very moment—as it has been—the football of the political parties; but there has been very recently an active upheaval in scientific discussion which is healthy and worthy of attention. In Europe, while the active discussions of bimetallism have simmered down to relative quiet, yet the interest in the fundamental monetary questions among scholars is burning with a clear flame. These present monetary problems are not only enlisting the interest of economic thinkers and reach the very center of systematic exposition, but they also happen to be those which have to do with the truth or error of convictions which are widespread among great masses of our countrymen.

It is passing strange that the vast literature of money has not been marked by a burning zeal for the statement of an organic body of principles. Discussions of money have usually been started in some local, or practical, problem; and interest has centered largely in the acquisition of historical data, without any considerable success in the formulation of the principles explaining such data. Once the problem of special interest to the public had been settled for good or for ill, the real scientific interest seemed to wane. To-day, in my judgment, the case is entirely different. The attention now being given by scholars in both Europe and America to the vital questions of monetary doctrine is nearly as intense as that given to questions of wages and interest.

II. *Functions of Money.*

Since the time of Ricardo there has been a magnificent confidence that the theory of money has been so well settled that there was little

* Read at the International Congress of Arts and Science, at the Universal Exposition, St. Louis, in September, 1904.

more to be said on the subject. The economic dogma of money, at least, was supposed to be fairly complete. And yet—in my judgment—the systematic treatment of the principles of money has remained undeveloped almost to the present day. There is scarcely any part of the field which can be regarded as thoroughly disposed of. Indeed, the very definition of money itself is to-day under the most critical examination; and with the definition goes the question as to the functions performed by money. On these points—like investigators in other sciences—we must frankly admit our lack of agreement.

First of all, it should be emphasized that the dispute about the definition and functions of money is not merely a question of words; it relates, in truth, to fundamental problems of great practical import. Every day the statesman and man of affairs are confronted by difficulties connected with the primary effect of 'money' on prices in general; but it is at once patent that the relation of the value, or quantity, of 'money' to prices can not be disposed of until we have determined what we mean by 'money.' As at present used, 'money' has no scientific precision; it is often carelessly employed in many different senses by one and the same author.

Evidently, before a rational definition of money can be found, some agreement based upon an analysis and description of the functions actually performed by money must be reached. If several dissimilar services are rendered by monetary instruments; if each of these services is associated by usage with 'money'; and if it happens that different things are employed in these different services—then, while authors may agree as to many of the functions of money, it may easily happen that they may still disagree as to which shall be regarded as essential to the definition of money. Money may have different meanings according as it is made to include, or exclude, some or any unquestioned services associated by usage with money. In such ways, an important difference might arise between that which is money in an economic, or true sense, and that which is money in a legal sense. In fact, the economic relations of money ought to be scientifically ascertained before legal functions should be assigned to it. If, for instance, the state should apply the quality of legal tender loosely to some instrument which does not completely fulfil all the functions of money, then that money is not made thereby in the economic sense true money. It thus often happens that incomplete forms of money exist, which give the public much difficulty to classify and define. The expressions 'substitutes for money,' or 'surrogates,' or 'representative money,' have arisen which depend for exactness upon the primary meaning assigned to the money on which they depend. The very functions of money need careful limitation.

Among writers as late as John Stuart Mill, there is practically no separation of these functions. The term money was applied indifferently to an instrument which served only as a medium of exchange, or only as a standard, as the case might be. Obviously, it would not be possible here to summarize all the different ways in which the functions of money have been viewed: they vary with each writer. In the main, there is a discussion upon the merits of the following separate functions:

1. A medium of exchange.
2. A standard, or measure of value.
3. A standard of deferred payments.
4. A legal means of payment.
5. A store of value.
6. A means for transferring value or capital.

The most recent German writer, the distinguished scholar, Helfferich, in an epoch-making treatise,* holds that there are only two primary functions of money, neither being secondary to the other: (1) Medium of exchange, (2) means of payment. He does not regard the standard function as essential to the conception of money, believing that any such service as may be included under a measure of value has been derived from the two primary functions given above. With several other writers, he finds that the medium of exchange was the thing which first developed, and then came into general use as a standard, or measure of value. He practically defines money as everything serving to facilitate exchange between economic factors. Thus, Helfferich would hold that the state, by giving legal tender power to things worthless in themselves, such as irredeemable paper, created a means of payment for debts, and therefore he would include even such instruments as these under money, because they fall under one of his primary divisions.

Whatever conclusions may be reached in regard to the functions of money, their application to the system of any one country would raise difficult questions as to the classification of money. If one of the necessary functions is lacking to any one form of money, is it, or is it not, true money? For instance, in the United States, no one would hesitate to say that gold coin is true money, and yet it is very little used as an actual medium of exchange. Therefore, we may easily call that true money which does not serve principally as a medium of exchange. Also, silver dollars, and French five-franc pieces, in the so-called 'limping gold standard,' could not be called true money in all senses, because their value is dependent on a primary form of money. Like national bank-notes and greenbacks, they are only 'surrogates,' they are, perhaps, legal, but not economic, money in the fullest sense.

* 'Das Geld,' von Karl Helfferich, Leipzig, 1903, Svo, pp. x + 590.

One may well doubt if the function of a means of payment can be distinguished from that of a medium of exchange. At least, most writers seem to agree that the medium-of-exchange function is essential to money; but if the standard function be neglected, could we possibly define that which acts only as a medium of exchange as true money? Of course not. Deposit-currency (*i. e.*, bank checks) certainly acts as a medium of exchange, and as a means of payment; but we should, in all common sense, be obliged to place such currency in a very different class from gold coin.

Therefore, every one must agree that the critical discussion of the meaning and functions of money is fundamental to scientific progress, and to all serious treatment of the main problems of money, such as the theory of prices.

III. *Credit.*

In regard to another unsettled problem of money, credit, it is to be said, not only that it has been very much misunderstood, but that it has been given very little real study. There is to-day no commonly accepted definition of credit: the element of futurity in a credit-transaction is generally admitted, but 'confidence' is by some regarded as the essential element; and yet 'confidence' can play its rôle only because futurity exists in the credit operation.

Nor is there any received opinion as to the real nature and functions of credit. We seem, in the whole field of credit, to be on the frontier of knowledge. In any true sense, the economic end of society is the possession and use of goods which satisfy wants. Credit has been devised as one of many means to aid in accomplishing this end. In its fundamental relations it has to do with goods and their increase. To some, however, it is related only to money. The truth of this concept, to my mind, depends upon the nature of money. If it be only a means to an end, and if it does not alter the elemental principles of value, but aids and cheapens the exchange of goods, then it is easy to understand that a borrower in reality obtains the use of goods, as the purpose of a loan, and that money and credit are but the instruments devised by society for effectually carrying out that purpose. Hence the credit operation, as regards extension or contraction, is primarily based on transactions in goods; its relation to money is a secondary, and incidental, connection. Credit being a transfer of goods involving the return of an equivalent in the future, forms of credit appear only as a consequence of transactions in goods. More transactions, not more money, cause an increase of forms of credit; and, by an interesting process of evolution, forms of credit—especially the deposit-currency of banks—act as a medium of exchange, obviating recourse to money. The belief, however, that credit depends on money,

and not on goods, is widespread, and much discussion is probably before us on this point.

The relation of credit to the theory of prices is not so clear: some think that all the money, plus all the credit (whatever that may be), act primarily to fix the level of prices; but any sane person will see at a glance that the forms of credit, such as bills, drafts, etc., arising from the movement of the wheat crop, have no effect on the price of that crop—the price having been made antecedent to the creation of the forms of credit which came into existence only because of the actual sales of wheat. Does a farmer wait until he sees how many wheat bills are drawn before fixing the price of his wheat? Evidently not; and the popular conception needs thorough criticism.*

When men speak of 'our expansion of credit,' they have a very vague and general idea in their minds. The definite and distinct forces at work are covered with darkness; and, when a revulsion of trade comes, the results are accepted as coming from some undefined and mysterious force which can only be felt, but not explained. It remains the duty of the economic thinker to outline with scientific exactness the forces uniting in the upward wave of over-trading, and to state with equal definiteness the causes of the receding movement. Principles must be sought for which will explain the differing actualities of each special crisis.

IV. *Theory of Prices.*

Only after the honest student has come to a satisfactory conclusion in regard to the nature of money and credit is he in a position to discuss with profit the pivotal problem of this field—the theory of prices. Perhaps I may be criticized for treating here the present monetary problems from too theoretical a point of view; and it may be urged that I should have presented the practical problems confronting each leading nation, and discussed their relations to the several monetary systems actually in use. But I must respectfully insist that the moment any practical problem in any existing monetary system is taken up, one is instantly faced by the difficulty of agreement upon the terms in use, and in fact upon the simplest monetary principles involved in the examination of each case. Every practical reformer in the field of money is in fact using some theory of prices, true or false, in all the premises laid down in his propositions. One might as well go into practical engineering without a knowledge of thermodynamics as to discuss practical monetary schemes without first settling basic monetary principles. But, unfortunately, the thinking, even among so-called economists, is to-day unsettled on so pivotal a ques-

* For a full discussion of credit, see my 'Principles of Money,' Chap. IV. (1903).

tion as the theory of prices. Practical monetary legislation, in more than one country, would be radically modified, accordingly as the so-called 'quantity-theory' of money is accepted or not. In my humble opinion, that theory is indefensible and erroneous; and yet our great politicians in the United States, in their fencing on the monetary problem, have decided that the question of the gold standard has been definitively settled, because of the large recent production of gold. The partisans of gold have thus accepted the principle on which the demands for an extension of the circulation of silver and greenbacks have been based in the past; and the position is absolutely untenable.

The issues in this crucial problem are unmistakable; and they must be threshed out to a conclusion before any practical applications can be attempted. These issues may be briefly stated in the following heads:

1. Is the price of goods the quantity of some standard commodity for which they will exchange, or is it the relation between goods and a variety of several media of exchange?

2. If true money is a commodity, like gold, then what determines the exchange value between goods and that commodity? Is the problem in any way different from that of obtaining the exchange value of any two commodities?

3. What is the actual process of evaluation between goods and gold?

4. If demand and supply regulate the value of money (cost of production apart), what is the exact meaning of demand for money, and of supply of money?

5. Is the demand for a money-metal only the monetary demand? Is the demand for a commodity *as money* something *sui generis*?

6. In the theory of prices, what is meant by 'money'? Is it only gold, or gold together with everything, such as deposit-currency, which acts as a medium of exchange? In short, what constitutes the supply of money?

7. If prices are influenced by 'purchasing power,' is that synonymous with the sum of the existing media of exchange, multiplied by their rapidity of circulation? Or, is purchasing power in its ultimate analysis synonymous with the offer of saleable goods?

8. Have the expenses of production, or progress in the arts, no influence on the general level of prices?

9. What is the effect of credit on general prices?

10. How do fluctuations in bank reserves actually affect general prices? Does the rate of interest, being paid for capital and not for money, have an effect on prices through its effect on loans?

11. By what economic process would a great new supply of gold influence general prices? Only by being directly offered for goods as a medium of exchange?

12. Does the Ricardian reasoning in favor of the quantity theory of prices hold in monetary systems where free coinage of the standard money exists, and where other devices are used as media of exchange? If mints are open, how can the coin differ in value from the bullion of which it is made?

It is safe to say that the thorough discussion of these points, and a satisfactory disposal of them, will aid in the solution of the central monetary problem, not only of the past, but of the present time. It is one which can not be blinked. It arises at every step in popular monetary discussions, and the economists have not given it necessary attention. On the settlement of the theory of prices, of the value of money, a host of minor questions, which have caused endless and fruitless differences of opinion, will disappear. The solution of this matter of theory is of the greatest practical import; it is as important to practical monetary action as a theory of heat is to mechanics. Therefore let us not be deterred from a struggle with a fundamental matter of theory by any slighting and cheap sarcasm about the futility of theoretical and abstract discussions. As well scoff at the mathematics which lies behind physics and astronomy as theoretical.

Nor will it be wise to minimize the differences between the old and new points of view in the theory of prices. It may be said that the quantity of money would have an influence on general prices in any theory. True; but that does not touch the crucial point at issue. The quantity theorists make the process of evaluation between goods and 'money' dependent on the actual offer of the medium of exchange and goods for each other; an increase of transactions in goods is an increased demand for money, resulting, unless the quantity of money is increased, in falling prices. It is needless to say that the facts do not agree with these statements. An inductive economist, who would be unwilling to state any principle which had not been the outcome of a study of concrete data, could never, under any possible circumstances, have arrived at the quantity theory of money. In no case coming under my observation has there ever been any correspondence between the movement of general prices and the known facts as to the quantity of circulation, or the money-work to be done. If I am wrong, it lies in the power of induction to disprove my statement by the facts. In truth, the quantity-theory was the product of the metaphysicians, and not of the men of affairs; and it never has been in accord with the data of inductive study, so far as I know.

It is true that a great increase in the supply of gold would lower its value, other things remaining the same; but the effect on general prices would be a simple one, such as would be produced by any cheapening of the standard, like a change to a depreciated paper standard. But this change in the value of the standard is a radically

different economic process from that by which prices are said to be influenced only by changes in the quantity of the media of exchange actually offered for goods. One or the other must be wrong.

V. *Prices and the International Movement of Metallic Money.*

The settlement of the theory of prices, or the principles determining the value of money (suitably defined) has an importance reaching out into the field of the international movements of specie. We can not properly formulate the methods by which the shifting of specie and goods act upon each other in international trade without having previously reached a definite conclusion upon the theory of prices. Thus the examination of and agreement upon the theory of prices will largely determine the statements made concerning the relation between the shipments of specie and the level of prices within a country.

With the Ricardian formula, derived from the experience of England in the early part of the last century, writers have attempted to solve this problem by using the quantity of money in a country as the force regulating the general level of prices; if gold is exported, prices must fall; if gold is imported, prices must rise. In brief, the originating cause of a change in the general level of prices, so far as international trade is concerned, is the shipment of specie. The movement of goods is a consequence of the change of prices brought about by the addition or subtraction of specie. That is, the quantity-theory has been relied upon to solve this highly important and practical problem of money.

The original statement of Ricardo has, of course, been added to and emended; but, in the main, it is intended to show that any one country obtains a part of the world's circulation of specie in the proportion that its trade bears to that of other countries. This quota of gold, for instance, is retained in a country by influences working automatically on the price level through changes in the quantity of gold within that nation. If gold is withdrawn, prices fall, exports of goods are increased, and in due time the gold begins to return until the country's quota of gold reaches an equilibrium adjusted to the relative demands of other countries. The movement of goods forms the variable in the process which aims at a correction of the quota of gold, whenever the equilibrium has been disturbed. The shipment of gold is the initial cause; the movement of goods is a consequence.

In support of this view—the orthodox view—it is held that gold will flow wherever its exchange value is highest. The flow of gold will make it abundant in the receiving nation, and thus, because it is cheap, will raise general gold prices there; or, *vice versa*, will lower prices in the countries from which gold is taken. The possession of

the proper amount of gold seems to be the main consequence, while commerce is regarded as the means to the end.

This manner of treating the problem, however, reverses the true order of events. Commerce is the real objective which lies behind all other phenomena, such as the methods of payment; the movement of money is a secondary operation, dependent on the direction and extent of the shipment of goods. Moreover, to say that gold, like other goods, flows where its exchange value is highest, is a truism; the real question to be settled is, how does the flow of gold take its effect on prices? To say that because it is abundant it raises prices is to assume the whole problem at issue. How does a cheapened mass of gold adjust itself to other goods? What is the price-making process? Are goods priced only by an actual exchange of those goods against the increasing flow of gold? On this point the adherents of the orthodox teaching of Ricardo have offered no light.

The trouble with many symmetrical monetary theories is that they do not agree with the facts. For instance, it has been pointed out that the gold stock of the United States has increased three and one half times from \$326,000,000 in 1880 to \$1,174,000,000 in 1902; and yet that gold prices in the United States in that period have fallen. This discrepancy between fact and theory is dogmatically disposed of by assuming that the growth of our trade has outstripped the supply of gold. This position is far from tenable; there are no statistical data in existence worth a fig, which could give us the truth as to the money-work, or demand, for gold. To say that our gold has increased at all only because of our phenomenal increase in trade relatively to other countries is to make a statement without proof. Possibly our deplorable silver legislation of the past has forced us to carry more gold than we ought to have held; just as men on the frontier must invest considerable means in firearms for protection from purely local dangers. Other countries than ours have enormously increased their trade, but they have not added in the same proportion to their gold circulation. In truth, the old-fashioned theory on international price-changes needs restatement in vital parts. It will be found that forces affecting the prices of goods, such as demand and supply of those goods, are of primary influence in affecting prices, quite independent of the action of a medium of exchange—which chiefly comes into existence, in fact, as a consequence of the exchange of goods. The movement of specie is not the end of commerce, but specie moves as an instant consequence of commerce. The monetary changes follow, and do not precede the operations in merchandise and securities.

VI. *Bimetallism.*

Bimetallism was eagerly taken up by writers as a means of increasing what was once regarded as a deficient supply of the world's metallic circulation. The decline of prices,—which in this country began in 1866 and not in 1873—was attributed to a scarcity of 'money' throughout the world. Therefore, if silver could be added to, or retained with, the circulation of gold, the larger quantity of metallic money would, it was believed, support, or even raise, the general level of prices. The theory of prices, assumed as a matter of course in this exposition of bimetallism, was the quantity-theory.

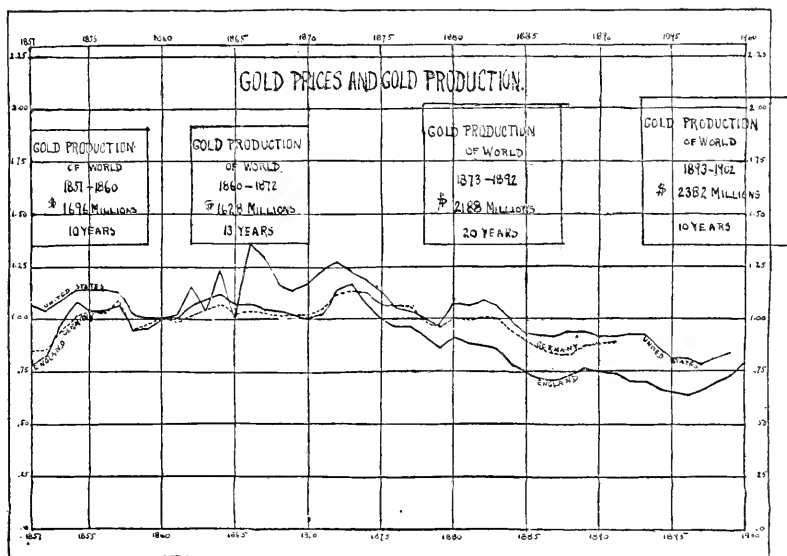
Throughout the recent writing and speaking on monetary topics, in both Europe and America—if not also in Asia—there has been a very general subsidence of interest in bimetallism. The demand for silver has been believed to be unnecessary because of the enormous production of gold in recent years. That is, by the old quantity theory on which bimetallism was based, some authorities—and more politicians—have saved their consistency by accepting the gold standard.

The logic and character of bimetallism can not escape so easily. If the quantity-theory falls, the whole artificial structure of bimetallic argument falls; and the gold standard can not possibly be supported by intelligent minds on any such basis of theory. The facts are too ugly. In the accompanying diagram it must appear to the most casual student that if the fall of prices on or about 1873 was due to a scarcity of gold, then not only because the supply of silver has been greatly increased, but especially also because the supply of gold has been about quadrupled since 1850, we ought to have witnessed a phenomenal rise of prices in the last decade or two. The movement of prices on the diagram, however, has been generally downward, or at least not seriously rising, during all the years when the production of gold has been so astonishingly large. The facts oblige us to question a theory which presents such evident disparities as this; and one is obliged, in all fair-mindedness, to accept the truth that many other and potent influences, besides the quantity of the media of exchange, have a powerful effect upon the price-level. When this admission is made, then the investigator is in a position to understand the remarkable influences of the great industrial revolution of the last thirty years upon the expenses of production of all articles, and hence upon their market prices. Thus, the sweep of economic forces, in the natural tide of events, is bringing us to a saner and very different point of view than that of the scientific bimetallist of past years.

VII. *Stability of Exchange.*

Consistency is a jewel; but it may be questioned whether it is always worth the price. The escape from the pitfalls of bimetallism

and the quantity-theory has led to some new and surprising formulations. It has been the hope of the bimetallists to secure a parity of exchange between countries now using gold and silver standards. If gold could be maintained permanently at a given ratio with silver, this happy result might have been brought about. It is needless to say that bimetallism proved to be a political impossibility, even in the countries of the Latin Union. By force of business requirements, such



silver as has remained in general circulation was effectively kept at a value in gold equal to its face value by varying devices in different countries, all of which had a common principle—practically equivalent in a more or less evident form of redemption in gold. In the case of India, it is frankly accepted that the value of the rupee has been maintained at a fixed price in gold by a machinery which amounts to the establishment of the gold standard, involving a quasi-redemption of silver rupees in gold at 16*d*.

If, however, there are some silver-loving sensibilities to placate, such a process is not spoken of as the establishment of the gold standard through the indirect redemption of inferior silver by gold, but it has been discovered that a uniform ratio of exchange between gold and silver-using countries can be established, not by the gold standard, but by a 'gold-exchange standard.' In the recent proposals laid before Mexico and China this new form of statement has been employed. It is difficult to know what the new term means. A bill of exchange in a silver country drawn on a gold country is nothing

but the amount of silver coins of the one nation which must be given to buy a stated sum of gold coins of the other nation. The silver bill varies relatively to gold coins in proportion to the changes in the value of silver bullion relatively to gold—unless the silver coins, under the laws of token-money, are kept at an artificial value, above the market value of the silver bullion in them, by some method, more or less direct, of redemption in gold. When silver bills are offered in the exchange market, they are simply offers for the sales of so much silver to be paid for in gold. If, then, the treasury of the silver-using country buys the bills, in certain emergencies of the exchange market, it is paying gold for silver; or, in other words, it is to that extent redeeming amounts of silver in gold.

Stripped of its enveloping mystery, the only way in which the new proposals for Mexico and China can establish stability of exchange is to establish the gold standard. For that purpose, if the silver coins in common use are to be rated in gold above the market value of the silver content of the coins, the only way in which parity in daily business, or in the exchanges, can be maintained is by creating a gold reserve large enough to redeem coins at par, or buy exchange at par, if no direct redemption is allowed. The whole operation, therefore, harks back to the principles regulating the value of such money as token-coins, bearing a seigniorage, or paper money, which has no value in itself. The worship of quantity as a regulator of value of money may do for those who are unwilling to test their theories by the facts; but inevitably one is obliged to admit that other forces are far more potent than quantity.

VIII. *The Value of Paper Money.*

I have said that the pivotal problem in the whole field of money is the theory of prices or the value of money. How true this is may be seen by the recurrence of this issue in each of the problems noted in this paper; and in the last one which I shall take up it again reappears. What regulates the value of those forms of money which circulate at a rate above their content is a question which forces itself to the front whenever we study a case of paper money. In times past, it has been sufficient to explain the value of paper money by referring its rise or fall to an increase or diminution of its quantity. This blind reliance on quantity as the main force controlling the value of money can not now, with our knowledge of the facts, be consistently held.

The amount of notes which a merchant can put out, provided he redeems them promptly, is limited only by the extent of his transactions. So it is with a nation. Given a certain set of business operations, as many notes can be kept in circulation as are needed by the

community, and no more; and these notes will remain at par only if there is a recognized system—not of ultimate, but of immediate redemption. No matter what quantity of notes may be put out, if there is no system of immediate redemption, the notes will depreciate. But, if there is an effective system of immediate redemption in operation, then no matter what the amount issued, none of it can depreciate, and only that quantity which is needed by the convenience of the business public will remain outstanding. In this way it may be realized that the element of quantity is incidental to the more dominant factor of redemption.

The connection of the value of the standard money with the paper promises to pay in that standard coin is the one important consideration in determining the value of paper money. Redemption is the only sure means of ascertaining automatically what quantity of paper is needed by the public. Redemption determines both the quantity and the value of the paper.

In the case of irredeemable paper, however, it is often assumed that, in the absence of redemption, the value of the paper is determined directly by the amount outstanding as compared with the uses to which such money can be put. There is believed to be an imperative demand for money, as a medium of exchange, which must be satisfied in some way; and in default of anything better, irredeemable paper will be required, and a value will be given to it by this imperative demand. Then, only if issued in excess of this demand, will even irredeemable paper depreciate. This is the usual explanation of the fact that irredeemable paper, worthless in itself, bears any value at all.

THE VEGETABLE FIBERS OF THE PHILIPPINE ISLANDS.

BY H. TAYLOR EDWARDS,

BUREAU OF AGRICULTURE, MANILA.

THERE is probably no country of equal size in the world having a greater variety or wealth of vegetable fibers than the Philippine Islands. These fibers are of every class and of every description. They are obtained from the bast of the largest forest trees and from the slender stems of twining ferns. Their uses range from the manufacture of the most delicate and beautiful of textile fabrics to the construction of cables, furniture and houses. As an article of commerce, the one fiber, manila hemp, exceeds in value the combined values of all other products of the islands. As a factor in the domestic economy of the Filipino people, the fibrous plants of field and forest furnish, with the exception of food, nearly all the necessities of life.

The Relative Importance of the Fiber Industry.

The relative position that the vegetable fibers hold among the various agricultural products of the Philippine Islands is a subject that is neither clearly nor generally understood. The development of the various branches of the fiber industry will, in no inconsiderable degree, determine the future industrial condition of the islands. Until very recently there has been practically no machinery, no modern methods of cultivation, no introduction of improved species and varieties of plants; and yet, even under these unfavorable conditions, the production of fiber has grown to be the leading industry of the islands. To-day the vegetable fibers and fiber products form the most important source of wealth of the archipelago. A brief investigation of several of the more important of the fiber-producing plants should be sufficient to give some little idea of the vegetable fiber in the Philippines as a commercial product. Such an investigation, however, must leave entirely out of consideration the greater part of the four or five hundred so-called 'local' fibers, the use of which plays an interesting and important part in the every-day life of the Filipino. To fully appreciate the extensive use of these local fibers, one must go into the fields and villages and homes of the native people.

But two fibers are now exported from the Philippine Islands, manila hemp and maguey. The latter has been, up to the present time, of comparatively little importance: the annual exports of maguey fiber amounting to something more than one thousand tons. Manila hemp, however, is not only the leading article of export, but it con-

stitutes more than two thirds of the total value of all exported products. Its position is indicated by the following table.

EXPORTS FROM THE PHILIPPINE ISLANDS FOR THE YEAR 1903.		
Article.	Value.	Per cent. of Total Exports.
Manila hemp	\$21,701,575	66
Copra	4,473,029	14
Sugar	3,955,568	12
Tobacco	1,882,012	5
All other	1,109,596	3
	\$33,121,780	100

The production of manila hemp is a well-established and very profitable industry, the development of which requires only an improvement in methods of cultivation and the introduction of fiber-extracting machinery. Maguey is a comparatively new product, and its value is not as yet well known throughout the islands. Cotton and kapok (tree cotton) are widely distributed and have a general local use. Coir (cocoanut fiber) is produced in enormous quantities, but is not utilized, because of the lack of fiber-extracting machinery. Jute grows in several of the provinces, but is not produced in quantities sufficient for export. These six vegetable fibers, which are among the most important commercial fibers of the world, are all Philippine products, and can be economically and profitably produced throughout the archipelago.

Classification of Fibers.

Vegetable fibers may be classified either according to their structure or to their uses. The former classification includes the 'bast fibers,' obtained from the inner bark of dicotyledonous plants; the 'structural fibers,' obtained from the stalks, leaf stems and leaves of monocotyledonous plants; the 'surface fibers,' or hair-like growths surrounding the seeds of certain plants, and the 'woody fibers,' consisting of the whole or a part of the stems, roots or wood of various plants.

Any economic classification is unsatisfactory for the reason that the same fiber frequently has several entirely different uses. Thus, for example, manila hemp, primarily a cordage fiber, is extensively used in the Philippines for textile purposes; while cotton, a textile fiber, is also used for cordage. Considering only their more important uses, we have the following general economic divisions, together with one or more of the leading Philippine fibers of each division.

Cordage fibers.	Plaiting and Thatch Material.
Abacá.	Nipa.
Maguey.	Burri.
Textile Fibers.	Tie Material.
Cotton.	The Rattans.
Piña.	Malobago.
Stuffing and Filling Material.	Abacá (Manila Hemp), <i>Musa textilis</i> .
Kapok (tree cotton).	

The fiber produced by the plant *Musa textilis* is known throughout the civilized world as manila, or manila hemp. In the Philippine Islands the name abacá (pronounced ab-a-kár) is applied to both plant and fiber. This fiber is distinctly a Philippine product, for the abacá plant, though introduced into India, Borneo and other countries, has never been successfully cultivated other than in the Philippine Islands. Manila hemp was first exported from the Philippines a century or more ago. In 1820 samples of the fiber were brought to Salem, Massachusetts by John White, a lieutenant in the United States navy, and from 1824 to 1827 it began to be used quite extensively in Salem and Boston. The growth of the industry is indicated by the increase in exports of fiber, from 41 tons in 1818 to 137,752 tons in 1903.

The common banana, *Musa sapientum*, the plantain, *M. paradisiaca*, and abacá, *M. textilis*, are closely related species of the same genus. The banana plant produces a fiber similar in appearance to manila hemp, but lacking in strength; while the fruit of abacá resembles the banana, except that it is filled with large black seeds and has no economic value. The abacá plant is a large tree-like herb fifteen to twenty-five feet high, a single rootstock bearing from twelve to twenty stalks. These stalks, from which the fiber is obtained, are formed of a series of thick, fleshy, overlapping sheaths, each sheath being the petiole of a leaf.

At the time of flowering, which occurs when the plant is from two and a half to three years old, the stalk is cut close to the ground and the leaves are removed. The native laborer, sitting on the ground, inserts under the bark or fibrous covering of one of the outer leaf sheaths a small piece of bone called the 'loenit,' and with it tears off a long ribbon-like strip of fibrous material. Each successive layer is similarly treated down to the central stem of the trunk. The fiber ribbons are collected in the field and are taken to a small bamboo hut where the fiber extracting apparatus has been set up. This crude machine, the 'panguijan,' consisting of a large knife fastened upon a block of wood and operated by means of a bamboo spring and foot lever, is the only method that has ever been discovered for extracting manila hemp. The work of hemp-stripping is very exhausting, the average result of a day's work being about twenty-five pounds of fiber. The record of the numerous attempts and failures to perfect an abacá-cleaning machine forms one of the most interesting chapters in the industrial history of the islands. The introduction of such a machine will be of almost incalculable benefit and will revolutionize the entire hemp industry.

The only treatment of hemp, after the completion of the stripping process, is a few hours' drying in the sun. The fiber is then made up into rough bales and packed over the mountains, or shipped in native boats down the rivers, to the nearest seaport. From here it is taken

in a small coastwise steamer to the baling presses and warehouses of Manila and Cebu.

Maguey, Agave sp.

Several different species of the genus *Agave*, including *A. Americana*, *A. vivipara* and *A. rigida*, are found in the Philippine Islands. Both the plant and fiber are known throughout the archipelago as 'maguey'; while the fiber, in the commercial world, bears the name 'Manila aloë.'

This plant was probably first brought to the Philippines from



FIG. 1. STRIPPING ABACÁ.

Mexico or Central America; but when, or by whom, there are no records to determine. It is now grown on all of the larger islands, and as a fiber producing plant is next in importance to abacá. Maguey fiber is used locally in many of the provinces both as a cordage and as a textile material. It is produced in sufficient quantities for export only in the provinces of Ilocos and Union of northern Luzon. In this district rice and corn are cultivated in the more fertile fields, the stony hillsides and other so-called 'waste land' being utilized for maguey. For several reasons maguey seems destined to become an important Philippine product. It is not seriously injured by the long dry season, it can be successfully grown on 'light,' dry soils, and its cultivation requires comparatively little labor and but few draught animals, all of which characteristics make it eminently suited to conditions found in many parts of the islands.

The maguey plant consists of a short thick stem which bears an

aloe-like cluster of from twenty to forty fleshy leaves. These leaves are light green in color, bear sharp lateral teeth and a terminal spine, and are from three to five feet long. The leaf is composed of pulpy material interspersed with the vascular bundles which furnish the fiber. When the plant matures, which requires from seven to fifteen years, a central stalk, or 'pole,' grows to a height of fifteen to twenty feet. This stalk first bears flowers and afterward a large number of small bulbs. The growth of the 'pole' is followed by the death of the plant.

The process of fiber extraction consists in separating the fibro-vascular bundles from the pulpy portion of the leaf. Where machines are used for this work, the leaf is run under the surface of rapidly revolving wheels or rollers which scrape the pulp from the fiber. In the Philippines the fiber is extracted by the process known as 'retting.' The mature leaves are harvested and tied in bunches. These bunches are then placed in the streams and rivers, where they are allowed to remain under water for eight or ten days. This 'retting,' or rotting, results in the disintegration of the substances which surround the filaments. After the leaves have been sufficiently retted they are removed from the water, dried in the sun, and are then shaken and beaten to remove all extraneous material that may still adhere to the fiber. This retting process is slow, expensive, and gives an inferior quality of fiber. Improved fiber-extracting machinery has recently been imported into the Philippine Islands and the general use of such machinery should give a decided stimulus to the maguery industry.

Cotton, Gossypium sp.

Cotton has been grown in the Philippine Islands for hundreds of years. In 1601 three hundred pieces of 'Ilocos cloth' were sent from Manila to the Moluccas, and throughout the earliest Spanish records of the islands we find frequent references to cotton and cotton-growing. At one time the production of this fiber occupied a position of considerable importance and domestic cotton was an article of inter-island trade, but the importation of cheap cotton goods was followed by a decline of the local industry and it has never regained its former position. The Spanish authorities endeavored to foster the industry by means of ordinances and government regulations, but without any appreciable results. To-day we find small 'patches' of cotton scattered throughout the islands from northern Luzon to southern Mindanao. Occasional shipments of a few bales each are received every year in Manila, principally from the province of Ilocos. In many different towns and villages small quantities of cotton are collected, cleaned by hand and woven into a coarse cloth. There is nothing in the archipelago at the present time, however, worthy of being called a cotton-growing industry.

There is every reason why the cultivation of this plant should be

encouraged, as cotton and cotton goods form one of the largest items of imports into the islands. Experiments that have been made during the past year, to say nothing of earlier efforts in the same direction, have demonstrated that a satisfactory yield of good cotton can be obtained in the Philippines. Insect enemies will have to be overcome and methods of cultivation regulated to suit an early or late rainy season, but, in general, soil and climate conditions are favorable. A great deal of interest is now being shown in regard to this subject by Filipino planters. Large quantities of seed have been distributed in the provinces, and the next year promises to show at least a begin-

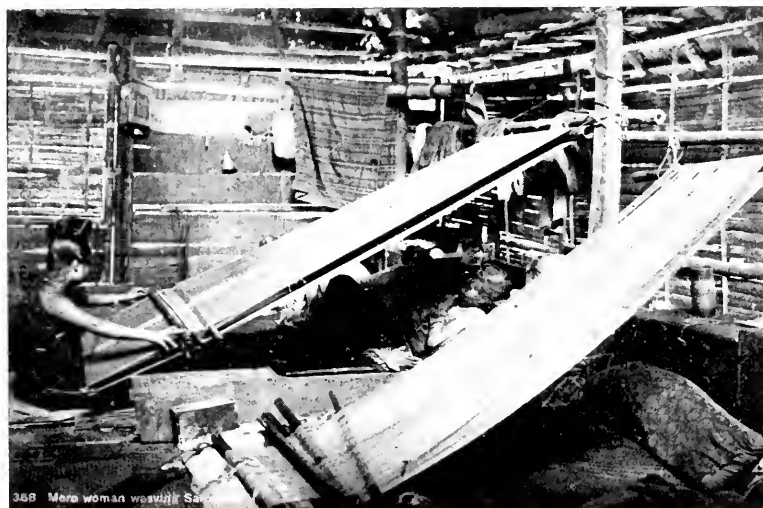


FIG. 2. MORRO WOMAN WEAVING SARONG.

ning towards the establishment of a Philippine cotton-growing industry.

Piña (Pineapple), Ananas sativa.

Pineapple fiber, or piña, is of peculiar interest as furnishing the material for the beautiful and justly celebrated piña cloth. This fiber is obtained from the leaves of the same plant that produces the well-known fruit. The pineapple plant is grown quite extensively in the Philippine Islands both for its fruit and for its fiber, but when utilized as a fiber plant the undeveloped fruit is usually cut shortly after the time of flowering.

Pineapple fiber is one of the finest and strongest of all of the vegetable fibers. It is the former quality that prevents its more extensive use, as the extreme delicacy of piña makes its extraction from the leaf an extremely slow and difficult operation. A very simple and primitive method is used in the Philippines for the extraction of this

fiber. A single freshly cut leaf is placed upon a smooth board and is then scraped with an old plate or piece of earthenware. This scraping removes the pulpy material and lays bare a layer of fiber which is deftly lifted with the finger or a small spatula. After the fiber has been thus extracted it is washed in running water and dried in the sun. Frequently the washing and drying are repeated several times before the required degree of softness and fineness is obtained. It is estimated that twenty-one thousand leaves are required to produce fifty pounds of fiber. When it is considered that each separate leaf must be slowly and laboriously scraped, the small production and high price of piña fabrics are not surprising. Before piña can become a product of any considerable commercial importance, a machine must be perfected for the extraction of the fiber.

Kapok (Tree Cotton), Ceiba pentandra.

The white cotton tree with its tall straight trunk, its almost horizontal branches, and large odd-looking seed pods is well known to any one who has traveled through the Philippine provinces. This tree is found in nearly all parts of the tropical world. In Java there are extensive kapok plantations, but in other countries we usually find the cotton tree growing along the roadsides, scattered through the forests; or, as in India, planted about the old Buddhist temples. There are no kapok plantations in the Philippines, but the cotton tree grows in nearly all of the provinces and the fiber is very generally used for local purposes.

Kapok is the floss obtained from the seeds of the cotton tree and, in a structural classification, is one of the 'surface fibers.' The fiber is too short a staple, and also too brittle and elastic, to be spun, but these very properties make it the most valuable of all the vegetable fibers as a stuffing and filling material. Its harshness and elasticity prevent its becoming matted when used for cushions, pillows and mattresses. For bandages and surgical dressings it is cooler and more elastic than cotton.

Not only does the cotton tree produce a valuable fiber, but it has, also, a number of other economic uses. The tree itself, with its horizontal branches, is used for living telegraph poles and as a shade tree on coffee plantations. The wood, which is light and soft, is utilized for tanning leather and for making toys. The sap and tender leaves have a medicinal value. The bark yields a reddish fiber from which cordage and paper are made. The roots, when powdered and mixed with the sap, is a cure for dysentery. The fruit has some value as a food product. The seed yields an excellent oil and the seed cake is used both for cattle-feeding and as a fertilizer.

In Java the production of kapok is rapidly becoming a leading industry, and this fiber is getting to be more generally known and more

fully appreciated throughout the civilized world. The more extensive cultivation of the cotton tree in the Philippine Islands is greatly to be desired, as the development of this industry will add another valuable commercial fiber to the list of our exported products.

Nipa, Nipa fruticans.

One of the most widely known of all Philippine objects is the nipa house, or 'shack.' The material used for the construction of this house is the fibrous leaf of the nipa palm. This palm grows along the shores and in the deltas of rivers. Its leaf, consisting of a long

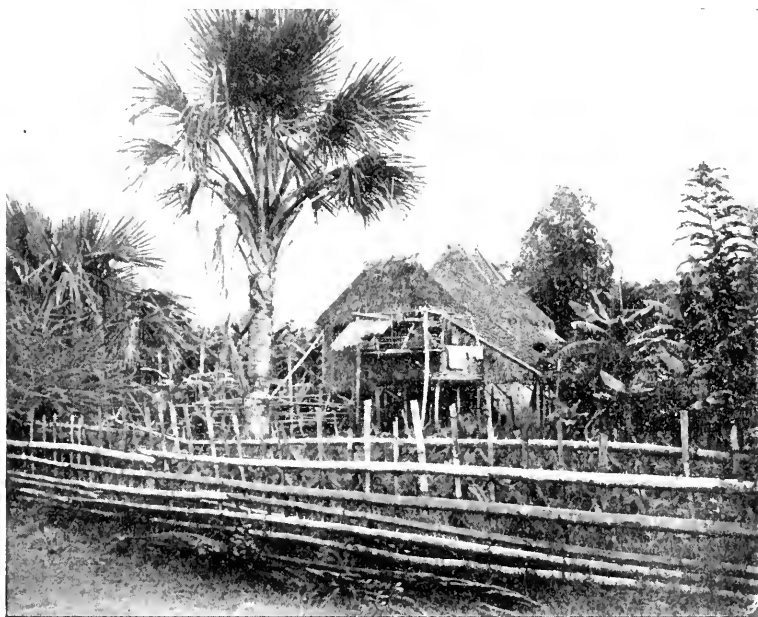


FIG. 3. THE BURRI PALM.

midrib bearing a large number of slender leaflets, is similar in structure and appearance to the leaf of the cocoanut. When the plant is fully grown the leaves are cut and the leaflets stripped from the stem. These leaflets are bent over a piece of bamboo, sewed together with fine strips of rattan, and thus made into small mats or shingles. The nipa mats are laid on the sides and roofs of houses in the same manner as shingles, and are fastened down with strips of bamboo. A house built of this material can be constructed in a few days and, under ordinary conditions, will last from five to seven years. It is cheap, cool and in every way suited to the climatic conditions of the country.

The nipa palm has several other uses. Its fruit is edible and the

flower stem yields an alcoholic beverage known as tuba or nipa wine. Hats, mats, rain coats, sails and various other articles are woven from the leaves.

Burri, Corypha umbraculifera.

Another member of the Palmaceæ that has a great variety of uses in the Philippines is the burri, or talipot palm. This palm grows in abundance in nearly all parts of the archipelago. It is a large ornamental tree crowned with gigantic fan-like leaves. These leaves, like those of the nipa, are composed of numerous slender leaflets. In the burri, however, all of the leaflets radiate from the end of the long stem. Preparatory to use, the leaves are gathered and dried, often for several weeks. They are then split into narrow strips and in this form are woven into hats, mats, bags, baskets, fans and other similar articles.

Local Fiber Plants.

More than four hundred Philippine plants have been reported, the fibers of which have some local economic use. It is difficult to select from among this number the few that may be considered of first importance. The rattans (*Calamus sp.*) which are found throughout the forest regions of the islands are of great value and are used for many different purposes. Malobago, or halibago (*Hibiscus tiliaceus*), is a valuable bast fiber obtained from a tree growing near the seacoasts. Pangdan (*Pandanus sp.*), the plant known in the United States as 'screw pine,' yields a fibrous leaf from which are made hats, mats and sugar-sacks. Idioc, or cabonegro (*Caryota urens*), is a coarse black fiber well known in the commercial world and used in the Philippines for making a coarse resistant cordage. Anabo (*Abroma alata*) is a strong fine bast fiber produced in all parts of the archipelago and largely used as a cordage material.

The Development of the Fiber Industry.

The methods now employed in the production of the leading Philippine fibers are slow, wasteful and a century behind all ideas of modern agricultural development. Certain definite lines of improvement such as the more careful selection of plant varieties, a more thorough system of cultivation, and the extraction of fiber by means of machinery are urgently needed. A development of the fiber industry along these lines, that shall result in carefully managed abacá, maguey and cotton plantations, and in the introduction and general use of fiber-extracting machines, will be a long step towards the fulfillment of the first and greatest need of the Philippine Islands, the establishment of the country on the solid basis of material prosperity.

THE CLIMATE OF THE CENTRAL AMERICAN PLATEAU.

BY GUSTAVE MICHAUD, D.Sc.,

SPRINGFIELD, MASS

A FEW weeks ago the *Springfield Republican* published the following extract from a letter sent by our minister to Costa Rica, Hon. W. L. Merry, to Gen. G. W. Davis, governor of the Panama canal zone:

Six years and a half of residing in San José have made manifest to me its fine and agreeable climate. When this fact will be known to the many American officials and employees coming to the Isthmus of Panama to work under the canal commission, they will take advantage of the opportunity to visit Costa Rica for recreation and for their health. . . . A few weeks stay here would invigorate our men.

The writer spent six years, from 1889 to 1895, on the Central American plateau and gathered some meteorological and physiological data which led him to the conviction that our minister's statement is not exaggerated. The climate of that portion of the upland which extends from the Panama isthmus to the Yucatan peninsula, and which includes the highlands of Costa Rica, Nicaragua, Honduras and San Salvador, has features of its own, not frequently found under the tropics and never outside of them.

The uniformity of temperature throughout the year, which characterizes the tropical climate, an altitude of some 4,000 feet above sea-level, with its corresponding decrease in the density of air, a lower temperature than could be expected for such an altitude in the torrid zone, are the main features of the climate of the Central American plateau. The last of these is the most important. The value of tropical plateaus as health resorts is a subject which has been much discussed recently. That of the Central American upland will be better understood if some of the conclusions which have been reached within the last ten years, as well as some of the experiments which have led to these conclusions, are previously stated.

The density of air decreases rapidly as one rises on a mountain slope. At an altitude of 18,500 feet, a given volume of air contains but one half the quantity of oxygen which it contains at sea-level. Scarcity of oxygen does not seem to be a desirable condition, yet recent experiments have shown that, within certain limits, that very quality of mountain air induces in the human system changes which

are beneficial to the majority of patients. The most important of these can be briefly stated: The number of the blood red corpuscles increases as the air becomes rarer. The main office of the red corpuscles is the absorption of oxygen in the lungs and the carrying of it into the whole body, wherever heat and power are to be generated.



NOON AT THE VILLAGE MARKET, COSTA RICA.

There are over two millions red corpuscles in one drop of the blood of a healthy person. In anæmia and connected states, that number often falls to one half of its value. Life in rarefied air results in the opposite state. After the adaptation period is over, a considerable increase in the number of red corpuscles, coinciding with more frequent and deeper aspirations, causes the paradoxical result, that more oxygen is brought to the organs in the rarefied mountain

air than in the denser medium, at sea-level.

The scientist, Viault, was the first to notice that there was an extraordinary number of red corpuscles in the blood of the inhabitants of the high plateaus of Peru. Careful determinations led him to the conclusion that the average increase was from 5,000,000 per cubic millimeter in the blood of a man living at sea-level, to 8,000,000 after a stay of three weeks at an altitude of some eight thousand feet. In their book, *La vie sur les hauts plateaux*, the Doctors Herrera and Lope, of the city of Mexico, reached a similar conclusion. In Europe, Egger experimented on Monte Rosa (6,201 feet), and found that the red corpuscles increased, on the average, 17 per cent. in two weeks. Karcher, Sutter, Veillon, experimenting on lower altitudes (3,452, 3,232, 2,297 feet), still found a notable increase of the red corpuscles. Wolff and Koeppe noticed it again on the Reyboldsgrun, which is only 2,300 feet high. In 1896, Leuch published in the *Korrespondenzblatt f. Schweizer Aerzte*, the results of a most accurate and painstaking study on the changes undergone by the blood of anæmic school chil-



SHADE AND LIGHT EFFECTS AT A HIGH ALTITUDE, CARPENTERIA MOUNTAIN.

dren after a stay in the mountains. The anæmia disappeared, while the number of red corpuscles increased. It decreased after return to a lower level, but remained higher than before the sojourn on the mountain. These facts were fully confirmed by the researches of Mercier, von Jaruntowsky and Schroder.

The greater consumption of oxygen induced by the increase in the number of red corpuscles has been measured. According to Schumberg and Zuntz, a man brought to an altitude of 12,467 feet consumes 33 per cent. more oxygen than at sea-level. The increase is not instantaneous. Coindet found that foreigners who had but recently arrived on the Mexican plateau inspired 5.5 liters per minute, while those who had spent a longer period in the same localities took in nearly 6.5 liters.

But while the adaptive changes take place readily and regularly under ordinary conditions in healthy persons, many observations at health resorts of high altitude have shown that in a few cases (old age, certain organic diseases of the heart) they do not take place at all, while in the case of anæmic and neurotic patients they take place only at a moderate altitude and when a cool and bracing atmosphere allows of much outdoor exercise without perspiration. A natural inference to be drawn from those facts is that the climates of all tropical plateaus are not equally conducive to health. While all of them allow life outdoors in any season, and, when not extremely high, are absolutely free from the considerable and sudden changes of temperature which are so injurious to consumptives in the temperate zone, yet the value of such resorts depends mainly on the grade of cooling attending the ascent, especially in the case of general debility, constitutional or even symptomatic. Extremely high altitudes do not agree with the majority of patients; if, at a moderate height (from 3,000 to 5,000 feet), the temperature is low enough to invite exercise, the climate is certainly curative. But if the thermometer reaches daily the eighties, the heart will be unduly quickened during exercise, perspiration will become visible, a tired feeling will appear and the hematose as well as the genesis of blood corpuscles will be interfered with. To suffer from the heat while taking exercise is never invigorating, but, in rarefied air, it is an inconvenience which is the more serious in proportion as the altitude at which it manifests itself is greater. It may be said that, other circumstances being equal, the invigorating value of the climate of a tropical plateau depends on the amount of cold bought at the expense of air rarefaction.

This fact gives the climate of the Central American upland its superiority over that of the broader portion of the plateau which extends from Guatemala to California and which includes the whole Mexican tropical highland. The average yearly temperature of San



11,500 FEET. SUMMIT OF VOLCANO IRAZU.
 7,000 FEET. ON THE SIERRA CANDELARIA.
 5,000 FEET. A STREET IN SAN RAFAEL.
 3,800 FEET. A STORM ON THE VOLCANO IRAZU.
 2,500 FEET. RIO BRAZIL.
 SEA LEVEL. A PUBLIC GARDEN IN PORT LIMON.

José is 67.5° ; that of the sea coast is 78.0° . These figures show an average decrease of temperature of 2.8° for every 1,000 feet of altitude. Observations made in other Central American cities, though less reliable, give even higher figures. On the Mexican tropical plateau, the average decrease of temperature resulting of the ascent is only 2.3°

per 1,000 feet. This average is based upon the study of the climate of the cities of Puebla, Mexico, Guadalajara, San Luis Potosi, Pachuca, Zacatecas, Guanajuato, Oaxaca, Queretaro, Aguas Calientes, Leon, Pabellon, San Juan del Rio, Patzcuaro, Tacubaya, the list including all the cities situated on the tropical plateau and for which meteorological records are available. The highest figure (2.7°) is given by the city of Zacatecas, 8,187 feet high; the lowest (1.8°) by the city



FOUR TYPES OF COUNTRY HOUSES ON THE CENTRAL AMERICAN PLATEAU.

of Oaxaca, which, although standing 1,349 feet above San José, has a warmer climate (69.0°) than the latter city.

There are in Central America but two seasons: the rainy season, extending from about the middle of May till the middle of November, and the dry season, covering the rest of the year. In the rainy season, rain falls only for a few hours every day, generally from 2 p. m. till 6 p. m. leaving both mornings and evenings cloudless. Patients suffering from lung troubles find both seasons about equally curative on the highland. Debilitated and neurasthenic invalids recuperate better in the dry than in the rainy term. During the rainy season, the cities situated on the Atlantic slope have a climate somewhat dryer than that of the cities which are located on the Pacific side. The contrary is true during the dry season.

The intensity of light, a result of altitude and latitude combined, is perhaps one of the most important therapeutic elements of the climate

of many tropical uplands. Thanks to the researches of Pettenkofer, Voit, and especially to the heliotropic experiments carried on a large scale by Finsen at the Light Institute of Copenhagen, we begin to realize that the chemical rays of sunlight have as much to do with nerve action and metabolism as with sunburn. So far as the latter phenomenon is concerned, the worst sunburn the writer ever saw . . . and felt . . . was got *through a colored shirt*, in the neighborhood of the city of San José. About 8,000 or 10,000 feet, it is impossible not to notice the extraordinary intensity of solar illumination when the sun is nearing the zenith. At a much lower altitude, in the case of such subjects as 'Noon at the village market,' the photographer soon learns that times of exposure which gave the best results in the United States give overexposed negatives on the Central American plateau.

From one of the scientific periodicals published in the progressive little republic of Costa Rica, *El Boletín del Instituto Físico-Geográfico*, the writer compiled the following summary of the climatic conditions of the city of San José. The *Boletín* is published by the government meteorological observatory, an institution founded in 1889 by that remarkable Costa Rican, Don Mauro Fernandez, who was then Minister of Public Instruction. The observatory has a staff of four scientists and has rendered considerable service to the study of the climatology of that quarter of the world. The data represents the average of observations extending over a period of twelve years.

	Dry Season, December to April, Inclusive.	Rainy Season, May to November, Inclusive.
Temperature 2 a. m.....	62	63
“ 6 a. m.....	60	62
“ 10 a. m.....	72	73
“ 2 p. m.....	77	76
“ 6 p. m.....	68	68
“ 10 p. m.....	64	65
Daily average.....	67	68
Rain, inches.....	4	71
Relative humidity.....	75	84

THE SCIENCE PROBLEMS OF THE TWENTIETH
CENTURY.BY PROFESSOR A. E. DOLBEAR,
TUFTS COLLEGE.

LET us define science as knowledge of the relations of phenomena, and define phenomena as any or all changes that take place, which may be known to mankind. Let us also assume uniformity of action, that is that under assigned conditions the same phenomenon will be reproduced, what is called and what is meant by the term *law*.

We have several bodies of correlated relations which constitute such sciences as astronomy, chemistry, biology and so on. The phenomena exhibited by large bodies at great distances apart we call astronomy. Such as are exhibited by minute bodies near together we call chemistry, and the phenomena among living as distinguished from what we call dead things, we call biology. Among these and other similar sciences, where we have noted the uniformities in the phenomena and find ourselves able to predict occurrences, we say we have definite knowledge, and especially so when the bodies that exhibit the changes are of such magnitude that we may control them. This is what is meant by experimentation. Until phenomena are studied in their relations to other known and established relations they can not be said to be a corporate part of science. There are many isolated facts not yet in established relations, awaiting their proper setting. Facts are always scientific data, they are not science itself. That a body left unsupported will fall to the ground has been known for thousands of years, also that the moon revolves about the earth. The correlation that shows that both belong to the same class and are due to the same agency, gravitation, is science. The man who proved the relation was a scientific man, was doing scientific work. In like manner everybody has known in all times, of mankind and animals on the earth. The correlations that show their relationship is science, and the one who showed it was a scientific man. The two examples are to show that scientific work consists in establishing the relations among phenomena. This is what marks the profound difference between the work of the nineteenth century and all the preceding ones—the establishment of the relations among phenomena.

Prior to the nineteenth century there was a vicious assumption underlying nearly all effort in the domain of knowledge, that was, that there were no necessary relations among the different classes of phe-

nomena. That astronomy, geology, physics, chemistry, physiology and all the rest were independent departments of knowledge and that each could be worked out completely without help or hindrance from others. The great contributions of the nineteenth century showed they were all of one family, and the surprise as one after another were thus linked was only paralleled by the hostility manifested in many quarters to such a claim. Together they show strongly that the knowledge was so unexpected and so new that it was not easily assimilated. Especially was this true when the new implications made it needful to abandon much in philosophy and religion that had been held to be unassailable. Many heated battles were fought, but science was always victorious and never had to surrender a field once entered.

What these triumphs were has often been presented within a year or two, and the recital of them has raised the query in many minds whether there can possibly be left much of importance to be discovered. Alexander conquered the world and wept because there was no more Alexandrine work to do. He must go home and mope the rest of his life. Inactivity is an intolerable idea to an energetic man with but one idea. Heaven saved Alexander from a long endurance of such idleness as he feared, by removing him when his work was done.

Is there no more work for the man of science? Are there no more problems of importance awaiting the investigator? Have we all the knowledge we are likely to get? There are some who, having noted the prodigious product of the nineteenth century, have half feared that science has been worked out.

That this is not true I will endeavor to show.

Beginning with astronomy. We are well assured now that the earth as a part of the solar system has had a long history. That all these bodies have reached their present conditions and relations by a process of growth taking millions of years. The same factors that have been active in the past are still operative, producing changes in magnitude, in distances, in temperature and the like. The moon, once a corporate part of the earth, has left it through tidal action and will move still farther away for something like fifty millions of years, after which it will return. The sun is a mass of gas, which by its contraction through gravitation has become exceedingly hot, and is radiating its energy away at a definite and known rate. As it is limited in size and amount of material, one may without difficulty calculate that the supply of heat from it will last about ten millions of years. It will cease to shine and become cold unless something like a catastrophe shall reendow it with high temperature and larger volume, when it may repeat the history of these millions of years past. The same conditions of contraction and rise in temperature are observable in

thousands of the heavenly bodies, and in all stages from thin gaseous masses to cold non-luminous solid bodies.

Now that we know so much of the past history of the solar system, and in addition that our nearest neighbor is more than 200,000 times the distance to the sun, also that the whole system is itself moving in space at the rate of about 400 millions of miles a year in the direction of the star Vega, we yet need to know whether this motion is a drift or part of an orbit. At present no one knows. The directions and rates of motion of a number of stars have been very well determined, but such measures are not numerous enough to enable us to say whether there is more order in the movements of stars than there is among the molecules of a gas, where molecular collisions are constantly taking place. Such phenomena as that of the new star which suddenly blazed out in Perseus are now explained only by assuming stellar collisions wherein the masses are so large and have such velocity that impact at once reduces them to incandescent gas. This means the possibility of such disaster to the solar system, but it is a present comfort to know that if we were to collide with our nearest neighbor at present rate, 12 miles a second, it will take nearly 50,000 years to reach it.

We have now about a hundred million stars in sight, and astronomers have been surprised that a greater number of the more remote ones are not to be seen. The actual number of stars in our universe is much smaller than had been supposed, and instead of there being an infinite number in an infinite space the present outlook is that there is a boundary to the visible universe; but this remains to be determined, and this problem is engaging attention in several of the great observatories. We all want to know what kind of a universe we live in and the series of events that take place in it. In older times there were supposed to be but seven members of the solar system. The nineteenth century discovered more than five hundred. Eros was discovered only six or eight years ago, while additional moons to both Jupiter and Saturn were seen for the first time within ten years. It is not probable that all have been discovered. Search is yet being made for other planets.

Though limited, one can get some idea of the magnitude of the universe when it appears that some of the remote stars are so far away as to require something like a million years for their light to reach us, though light travels at the rate of 186,000 miles a second—a distance so great that it would take trillions of years to reach them at the rate that we now are moving in space, namely about 400 millions of miles a year. Space seems illimitable, time is long, and if matter be indestructible, yet the solar system as we know it will have gone through all its phases of growth, maturity, old age and death, long enough before the general aspect of the heavens will have been greatly changed

from what they are to-day. This is astronomical work of importance awaiting research.

We desire to know much more concerning the individual planets. Everybody asks, 'Are the planets inhabited?' and no favorable answer has yet been given. If one means by the question, inhabited by such beings as we are structurally, then one can say that if one of us were transported to any of the planets we could not live there a minute. Some, like Jupiter, are too hot; others, like the moon, too cold, or without air to breathe or water to drink, or with too great or too little gravity for our bodies. One does not need to assume such likeness, especially since we know something of the past history of man and animals on the earth, adapted to it in form, size, structure, habits and intelligence all correlated. To assume intelligence of our type is hardly allowable any more than for structures like ours. Vertebrate skeletons are not necessarily the only form in which intelligence of high type may abide. The implements and skill of the astronomers are yet to determine what can be learned about this question. Taking what we know about the development of life on earth, it would seem to be insanely improbable that among the millions of millions of huge bodies in the universe, all apparently made of the same kinds of matter and subject to the same laws, that the earth is the only one among them all to have life and mind developed upon it. But at present we do not know that it may not be true. Let the twentieth century find out.

Geology: The whole of geology was a gift of the nineteenth century. There was nothing that deserved the name before it, yet more than half of the land of the globe has not yet been surveyed, and many geologic problems are yet unsettled, concerning regions that have been studied. The mineralogical relations and precedents among basalts, granites and other rocks, as well as the physical conditions that determined composition, arrangement and distribution, remain to be determined. Volcanic phenomena are not at all well understood. The composition of the interior of the earth is quite unknown; its temperature, and the rate of heat conductivity of the various rocks—questions which, when answered, will have much to say about the age of the earth and especially of the length of time since it has been a habitable body for any living things. At present there are two camps interested in this question, with lower time limits from ten million to a thousand million years. When Asia, Africa and South America have been as well studied as Europe and North America have been, there will probably be found vast stores of metals, coal, oil and valuable minerals, thus adding to the world's stock of needful things. Also the discovery of new varieties of fossils, the ancestors of living species, especially of mankind, missing links, will add to the interest in human affairs. Geologists have for years been trying to find some

definite measure for geologic epochs, to ascertain how long ago the glacial age was, and how long it lasted. At present there are only surmises that the glacial epoch ended from 10,000 to 50,000 years ago. The twentieth century will probably be able to settle this.

Chemistry too as a science was nineteenth century product. There were guesses and ingenious surmises, but there were no known general laws, such as of definite proportions, of atomic weights, of energy in reactions and the like. It became possible to measure approximately the sizes of molecules and atoms, to know definitely their rates of vibration, and molecular structure is, for many compounds, made out about as well as if they could be dissected and their atoms handled like so many parts of an engine or dynamo.

As knowledge grew on the basis of experiment, generalization of course was attempted, and as physical phenomena were inextricably interwoven with the chemical, constant modifications were required. Not a few propositions found their way into books and general use which had to be abandoned. Thus, it was assumed that when molecules of salt, NaCl, were dissolved in water, each molecule retained its identity and moved as a whole in the liquid. We now know this is not true, but each atom becomes practically independent and moves like a gaseous particle in the air, producing pressure in the same way and for the same reason. The new knowledge has made it needful to revise again some of the notions that were held, and so profound is the change required that some years will be needful to bring chemistry as a science into satisfactory relations with physics. That is not all. We have all been taught and have probably had no misgivings in saying that matter is indestructible. Much philosophy is founded on that proposition. But we are now confronted with the well vouched for phenomenon from two independent workers that under certain conditions a certain mass of matter loses weight, not by mechanical removal of some of its molecules, but by the physical changes which take place in it. This is a piece of news that is almost enough to paralyze a scientifically minded man, for stability of atoms, unchanging quantity and quality, seems to be at the basis of logical thinking on almost all matters. In the 'Arabian Nights' one may expect that the unexpected will happen—genii may be summoned to do this or that, matter may be created or annihilated at will—and the conception gives one pleasure though one knows it to be impossible, and one thinks it impossible because one has never known such changes in matter, and because one has been taught that matter is indestructible. The amount of change is slight in the experiments related, yet well within the possibility of measuring, and one may be sure that from now on the most expert and careful and patient experimenters will attack this question and verify or disprove it. If it be disproved, we shall be philosophically where we have so long been. If it be proved,

it will be the most stunning fact that has come into science for a hundred years. The nebula theory, the doctrine of evolution, and the antiquity of man will be trifles compared with its significance.

Chemistry, though, with or without that fact, has a wonderful field where one may work intelligently in a constructive way. Compounds both inorganic and organic have been produced in great variety, and some chemists are at work trying to make artificially many things which one has to depend upon nature for now—thus quinine, now used in such great quantity; others are sugar or albumen for food, or nitrates for fertilizers, and so on. All these products, if produced on a commercial scale, would be of enormous worth to the world. Aside from these the chemical preparation of antitoxins for the relief and cure of many diseases, cholera, plague, yellow-fever, typhoid fever, are all being sought for with a great probability that they will be discovered and the life of men be saved for many years. I wish I could say that if life be saved and kept by such artificial means that mankind would not seek other ways of decimating its ranks. The average life of the Jews is upwards of seventy years. If all men had the same degree of vitality the world would be so crowded in a hundred or two hundred years that only the loss of fertility would save the necessity for famine, war and pestilence. Chemistry may give us a boon and leave nature to find some other resource for reducing numbers. That such resource would be radically different from her past methods is not very probable.

Physics is that science which is concerned with transformable energy and its transformations under all kinds of conditions. The energy may be mechanical, chemical, thermal, electrical, gravitational, physiological or mental. So long as they are transformable they are all departments of physics. The nineteenth century correlated them all and showed the conditions for transformation and the nature of several forms, thus heat, as vibratory atomic and molecular motion, radiant energy a wave motion in the ether. The discovery of the ether and many of its phenomena belongs also to it. The development of many arts and industries followed the new knowledge, so we have now, for instance, the electrical industries in many ways, the spectroscope and its astronomical revelations, the telescope grown from a four inch objective to a four foot objective.

The old ideas of the nature of matter or of atoms have all been abandoned and we have come to the conclusion that matter is not inert but is loaded with energy, that indeed the ether is saturated with it, though it is available to us only through the agency of matter, which acts as a transformer and a distributor of it. Yet we need to know much more of it. There is more to be learned about chemistry in its relation to physics than any seems to have considered hitherto. It is the form of energy which is present in atoms. Thus when hydrogen

and oxygen unite they give out a surprising amount of energy in the form of heat. A single pound of this combination, taken at ordinary temperature, will give out an amount of heat equal to seven million foot pounds of work, or sufficient to raise a ton one half mile high. We know that heat is a vibratory kind of atomic and molecular motion and the rate of this vibratory motion is the measure of the temperature. The question is as to the antecedent of the heat which thus appears. In what form does energy exist in atoms? Up to this time we have been able to trace energy through its various forms until we come to atoms; there it has eluded us. We say 'chemical energy,' but we have no idea how it differs from heat or from gravitative energy. It is a mystery. What form of motion or stress can be thus embodied? In some way it is related to the ether. It seems as if in some unique manner atoms drew from the ether as from a common reservoir, each particular atom capable of holding so much of that kind and no more, like pint cups and quart cups, and this at once transformed into heat at the instant of combination. When combinations of atoms such as water are decomposed, they again absorb the energy spent to separate them, and an atom therefore possesses more available energy than any combination of atoms. It seems as if atoms acted as transformers of ether energy into the ordinary and familiar forms, such as heat and electricity, and *vice versa*, transforming the latter into ether energy. When we learn this secret we may likely enough be able to artificially extract from the *ether* as much energy as we need for any purpose, for as I have said, it is inexhaustible, and every cubic inch of space has enough for all the needs of a man for many days. This seems fairly probable, and when the source of atomic energy is discovered, it will rank with the greatest scientific achievements of all time. We shall know more of the ether, of the structure of matter, of the antecedents of most of the energy we are familiar with, as this phenomenon underlies most if not all of the phenomena in all the sciences.

It is yet regarded as a mechanical paradox that a medium without friction should have waves set up in it by molecular vibration, and little is known of the physical relations existing between matter and ether by which electrical and magnetic phenomena are produced, and one may say that of the nature of ether we know nothing. Think of the amazing extent of it. As limitless as space itself, with no break or separation of its parts, not made up of particles like matter, but completely filling space and so constituted that any movement of a particle of matter in some way affects the whole body of it to the remotest part of the visible universe.

The nature of gravitation is as unknown as the nature of life itself. We know how it acts, and that this action is millions of times

quicker than light, but that is all, and the one who unravels the mystery will deserve to rank with the greatest of discoverers.

In like degree are we ignorant of electrical and magnetic phenomena which depend upon the ether. When the ether is understood we shall be able to understand in a mechanical sense how moving a magnet disturbs every other magnet wherever it may be, why chemical compounds are possible, why crystals assume geometric forms, and why cellular structure in plants and animals can embody what we call life. To discover the nature and mode of operation of this ether is the work of the twentieth century, and we may be sure that he who accomplishes this will deserve to rank with the highest; indeed it may fairly be said that in importance it is not secondary to anything known, for it is apparently concerned in all phenomena from atoms to masses as big as the sun.

The biologists have great problems on hand for solution. The nineteenth century work made it clear that all the forms of vegetable and animal life of to-day are the product of slow changes in form and functions of living things reaching back millions of years. The successions of some forms were well worked out and the principle established. We call it evolution and everybody nearly believes that this represents the truth in the matter, but how these changes occur and what necessitates them remain as mysterious as ever. Darwin spoke of natural selection. There were all sorts of variations in progeny, and the ones best fitted to the environments survived, but he gave no reason *why* there should be variations, and this is the great question to-day. Many are at work to discover this, and some who have worked in this line have stumbled upon some very unsuspected facts. There has been assumed that like would produce like, and that heredity could and would account for abnormal structures when parents for any reason through new environment had acquired new habits or new structures of any kind. Now it has been shown that such changes of structure or of habit seldom if ever appear in the progeny. For instance, no matter how many generations of mice have their tails cut off each new mouse has the same old length of tail. Each lamb has as many tail vertebræ as did those of hundreds of years ago, though all lambs have their tails cut off when young. Such acquired character is not inherited. Nature pays no attention to any changes save such as she herself initiates, and the conditions she herself adopts remain to be found out. Sometimes she makes monsters and sometimes geniuses, but never by external environment, always *de novo*. This throws overboard the principle good and thoughtful men have so long cherished, that the good habits of one generation would be a hereditary possession of the next. The conditions for heredity are now a most absorbing study among some of the foremost biologists. It is suggestive that at this late day such a reversal of opinion on this ques-

tion has come about and that the question has been run down to cellular structure and molecular arrangement. It will hardly be gainsaid that a knowledge of the proper conditions for changing forms, functions, habits and motives of living beings will be of priceless value to the race, and this work comes to the twentieth century.

Another piece of work, bringing great surprise among biologists as well as the rest of the thinking world, has been given to us within a year or two, namely, that unfertilized eggs have been made to develop in a normal way by subjecting them to certain inorganic chemical substances, such as magnesium chloride. It has been repeated by so many there is no doubt about it now, but its significance is that life itself is a chemical process and does not necessarily depend upon antecedent life any further than such structure contains chemical combinations of proper sort, and that if these be provided in other ways life and growth will result. This research has no more than begun and we may be on the lookout for surprises. A French biologist reports that if an egg be properly cut into as many as sixteen pieces it will develop into sixteen individuals, differing only in size from the normal individual. This opens out a new field, the philosophical importance of which exceeds its biological importance, as can be seen in a minute's thinking. What the outcome will be no one can tell now, but we may envy the biologists who devote their time to such investigations.

A few years ago two German scientific men discovered that a minute drop of a mixture of oil and a salt of potash acted like a microscopic living thing in several ways. It would move about spontaneously, change its form, had a circulation in itself, would gather to itself particles of other matter in its neighborhood, and was sensitive to stimulus from the outside. It comported itself like a thing of life in all ways but one, it could not reproduce its like. The material itself was called artificial protoplasm. The work is still being investigated, both abroad and at home, with the hypothesis that if the proper chemical constituents can be found and added it will then be a real artificial living thing. As it already possesses four of the five distinguishing characteristics of a living thing, ingenuity and persistence will enable some one to find and endow it with the fifth. It will not be safe for one to predict that this can not be done, for it may be done to-morrow, and the twentieth century starts with a pretty problem considered as a physico-chemical problem but the one who solves it, if it should be done, will have reason to be thankful he is not living in any preceding century, for his life would be made a burden to him, if he was not made a martyr.

I have been told by many good people that this question or that question was quite outside of the domain of science and presumptuous in one to inquire into. Astronomy and geology and chemistry are graciously permitted to be in the hands of the man of science, but life

and mind phenomena are declared to be outside the province of physical science, yet the same was said about astronomy and geology and chemistry not many generations ago. Was not Newton condemned for dethroning the Almighty by proposing the law of gravitation for keeping the planets in their orbits? Was not war made upon those who undertook to show that the earth was more than 6,000 years old, and were not the chemists who showed how organic compounds could be formed believed to be enemies of the truth and bent on misleading mankind? Isn't it curious to contemplate that those who know least about a given science should be the ones to set its limits, who know what can not be done or hoped for so much better than those who devote their lives and their best endeavors to discover what is true and what seems probable? To-day men's lives are not endangered as they used to be for their attempts to find an answer to puzzling questions, so the work goes on, and the things discovered are never like what was anticipated by the good and conservative people who know beforehand what can and what can not be known, and it is a bit sad that the latter must die that a new generation may arise to possess the new truth. It took more than two generations to convince the world of the truth of the nebular theory, that the earth was millions of years old, that mankind had occupied the earth for hundreds of thousands of years, and the doctrine of evolution is hardly forty years old, yet are there not many who give it no credence? Perhaps one of the good things which the twentieth century will be able to accomplish will be effectually to warn everybody of the danger of setting any limits to knowledge, also that any opinion mankind has held that has not been through the crucible of science is probably wrong, but the only reason for holding this is that so far every one so tested has been found to be erroneous.

The study of nerves, their connections and activities, has been begun in earnest only within the past few years, but what has been learned seems to lead to as many surprises as has any other branch of science. Only here and there is there now an investigator in this branch, but these have already found out that all nervous action is spent upon the muscles. That all are in one way or another connected with them, that each particular nerve cell has a specific function and substitution seems no more possible among them than can the eye be substituted for hearing or for tasting. At present work is being carried on to determine the functions of various parts of the brain, especially for the effects of use and disuse, the nature of exhaustion, the rate of recuperation, the source of energy and of automatic activity, what happens in sleep, in the hypnotic state, in disease, insanity and in unconsciousness. Dr. Hall has said that the nerves are the most wonderful things in the world, and we know so little about them. Mind and thinking, conditioned by their presence

and activity, on the one hand, and all expressions of them through muscular action as exhibited by motions and emotions.

There are many reasons for expecting most important disclosures from this direction, which may make needful many changes in common beliefs in educational theories and efforts, of responsibility in crime and the proper management of defectives of all sorts. It is not unlikely as great changes as took place during the last century in the beliefs on many important subjects will be required for the work of the twentieth century.

So far I have been speaking of science as related knowledge. Knowledge of such a kind as to react upon our opinions of men, of institutions, society, and the universe as a whole, but science is more popularly conceived as improved ways of doing things, of new products and new possibilities in life, of the arts as managed for economy of effort, enhancing comfort and removing the stress of living. These, however, are not science, but the products of science, and every one is properly concerned to know what changes are likely to come from such a source. The mechanic arts of the last century worked a wonderful change in the modes of living, in the variety and kinds of wants. If we could be deprived suddenly of all save such things as could be had a hundred years ago, we should all be made as miserable as one can think, yet those who lived a hundred years ago were no more miserable than we are. They got as much out of their lives as we do out of ours, and never suffered from thinking they did not have railways, telegraphs, telephones, steamships, automobiles and weather forecasts. These things could never be missed as no one had ever had them, and perhaps most people would have thought a prophet of them to be a romancer.

Many lessons have been drawn from history with the expectation that we may the better order our lives. How many historians there have been, and how few are those whose interpretations have not been wrong! One may recall that squib by Bishop Stubbs, of Oxford, whose contempt for Froude was profound. Canon Kingsley had resigned the chair of history at the university, assigning as reason that what had been understood to be history was unfounded.

While Froude instructs the Scottish youth
That parsons never tell the truth,
The Reverend Canon Kingsley cries
That history is a pack of lies.

These strange results who shall combine?
One plain reflection solves the mystery,
That Froude thinks Kingsley a divine
While Kingsley goes to Froude for history.

One might once fairly have inferred that leisure was what all man-

kind desired. The invention of labor-saving devices, so-called, the cotton gin, the factory loom, the sewing machine *et al.* has turned out sociologically to be very different from that, for the time saved from the old methods has been fully occupied in doing more work, raising more cotton, weaving more cloth, making more clothes. Men have not more leisure because they want something else more than they want leisure. Tastier food and personal adornment are the things that bring the chief stress upon life.

Leisure and idleness are not identical. Leisure is the relief from the stress for maintaining life. There is no leisure for one whose whole time is required to supply food, clothing and shelter for himself and others. When these demands can be met in less than the whole time, the remainder may be called his leisure time and this may be spent in idleness, that is, doing nothing, or it may be spent in doing something else in accordance with one's tastes, aptitudes and opportunities. One may read or study or write or travel, or one may add to one's income by working overtime or at other occupations. Such an one has leisure which he employs in ways that give him a measure of satisfaction. What is called a higher standard of living is almost always the immediate result of leisure—more palatable food, better clothes and houses. If one spends all his income to provide himself with better things than are really needful to keep him healthy, he can not say he has no leisure, for there is no limit to what may be called better things which one may possess and be no healthier or happier. Do not the so-called poor outlive the rich? Whence the centenarians of all countries, Indians, Mexicans, Negroes? Does not nature take as loving care of tramps as she does of the so-called good citizens, who faithfully work and save and build?

To be beyond compulsion to do anything is desirable, of course, for whoever is compelled is so far a slave. During the nineteenth century we were all urged by advice, example and mottoes that thrift was the chief thing. One who did not respond to the pressure was stigmatized as lazy. The hustler was the admired type from pupil to preacher. High speed has been demanded in living as well as on railroads, and he who could not or would not keep up has often had a hard time to live at all. The assumption in all this was that life *should* be strenuous. Our energetic President has publicly urged this. But there are many reasons for holding that it is all wasteful, loading life with miseries and not at all in accordance with Nature's plan. Nature is never in a hurry. She takes ten thousand years to make Niagara Falls and a hundred thousand years to make man, and she spares neither her own work nor man's, as if neither is worth the keeping. In Babylon of old were there not Morgans and Rockefellers, many storied buildings and great armies? Nature has transformed men and armies into gas and shrubbery, the buildings into tumuli, and made a

desert of the gardens. How much better to-day is the world for their energy, their strenuousness and their power? Are we any more lovable or stronger or wiser?

I have sometimes amused myself wondering what question I would ask an inhabitant of Mars, if communication with that planet could be established. If but one question could be answered, what should that question be? Is there any one question which everybody would be willing to have asked and forego every other one? Would it be a question of astronomy or of biology or of philosophy? Each one should settle for himself what that question ought to be, if its answer was to be of interest to all mankind. If it were of a religious or philosophical kind, think what happiness or misery would befall the most of us when the answer came. It would be almost like a judgment day and half the world or more would be thrown into a suicide mood. Ignoring momentous questions, what others are we really most concerned to have answered? Do we not all want to know of the nature of life, of mind, and of all the activities of nature displayed in phenomena? Does not everybody ask, 'What is electricity?' 'What is life?' I do not remember ever to have heard the question 'What is gravitation?' though it is certainly one of the most obscure of all the great activities of nature. Not a particle of matter escapes its hold, and the law of inverse squares we have all learned so glibly, we take on the basis of uniform experience. How can such action be the outcome of inherent properties of matter, and what must be the texture and distribution in the ether so compelling?

Surmises by the score have been made, but none are satisfied with any attempt to find a reason or the antecedents of the phenomenon. It conditions every phenomenon of every kind that comes to our knowledge in a gravitative way, but hitherto it has quite eluded the most ingenious of guessers, and most persons who have been concerned with its problems have either abandoned attempts at its solution or have unwarrantably concluded it is insoluble. There is no good reason why it should be thought of as an ultimate problem, and its solution belongs to the twentieth century or some of its successors. In my judgment its rationale will be found some time.

When, a hundred years ago, men said that heat was caloric, it is plain on a little thinking that such an answer brought us no nearer the real solution. Giving the thing a new name was not an explanation. We have been taught for a generation that heat is a mode of motion, and when we now think of the phenomena we think of brisk changes of position of the minute particles of a body, and that idea reveals heat as a *condition of matter*, not a thing in itself any more than the spin of a top is to be thought of as a thing to be described apart from the top.

A hundred years ago light was thought to be a kind of corpuscle

and now we call it a wave motion in the ether, and say there is no such *thing* as light, it is merely a condition of the ether in the same sense as heat is a condition of matter; and there are some physicists who go farther and declare it to be only an optical illusion, a physiological phenomenon and does not exist apart from the mechanism of the eye. Such have proposed we discard the word light from physical science, seeing it is only a condition of the optical apparatus. At any rate, the nature of light is now so well known and understood that no one thinks of asking the question 'What is light,' but the answer we give is a long remove from the answer expected a hundred years ago.

Here on the threshold of the new century we are confronted with the question 'What is electricity?' and the answer implied by the question seems to demand a something which could be described by one who knew enough, as one would describe some new mineral or gas or thing. Some eminent scientific men are befogged by the question, say it is some ultimate unknowable thing, and hopeless as an inquiry. If it be a something it must be described by its constant properties as other things are. If it be unlike everything else then it can not be described by terms that apply to anything else. All material things have some common properties. A glowing coal is an incandescent solid, a flame is an incandescent gas, but neither glow nor flame exists apart from the matter that exhibits the phenomena. Both are conditions of particular kinds of matter.

If electric phenomena are different from gravitative or thermal or luminous phenomena it does not follow that electricity is miraculous or that it is a substance. We know pretty thoroughly what to expect from it, for it is as quantitatively related to mechanical and thermal and luminous phenomena as they are to each other; so if they are conditions of matter, the presumption would be strongly in favor of electricity being a condition or property of matter, and the question 'What is electricity?' would then be answered in a way by saying so, but such an answer would not be the answer apparently expected to the question. To say it was a property of matter would be not much more intelligible than to say the same of gravitation. At best it would add another property to the list of properties we already credit it with, as elasticity, attraction and so on. In any case the nature of electricity remains to be discovered and stated in terms common to other forms of phenomena, and it is to be hoped that long before this new century shall have been completed, mankind will be able to form as adequate an idea of electricity as it now has of heat.

What thoughtful person has not asked 'What is life?' Many and long answers have been given to this question. One has said 'Electricity is life.' Another 'Life is the continuous adjustment of the internal relations to the external relations.' Which definition tells rather what life does than what it is. Some have imagined it to be

a kind of force, called vital force which presides over the phenomena of living things which may be now in and now out of the matter of the living thing. Vital force as such was mostly discarded as a physiological factor a good many years ago, and in its place was put physical and chemical forces, and to-day most physiologists say that life is reducible to physical and chemical agencies; if it be true, it is not much of an answer to the question 'What is life?' for it leaves us still the question to be intelligibly answered as is the question as to the nature of heat. If one recalls how it has fared with the other queries where more knowledge has given a new and unexpected answer to each, one would be led to anticipate an answer quite different from the one somehow imagined. However it may turn out, there is evidently much work to be done and the twentieth century has the problem plainly before it.

Once more the relation of mind to body waits an answer. Is mind to be thought of as a somewhat, resident in a body, but not necessarily a part of it? If one calls it soul or spirit and thinks of it as separated from body, yet with the same attributes, capable of being now here and now there by an act of volition, unrestrained by physical factors as gravity or heat or the rest, he evidently gets the idea from his philosophy of things in which he assumes limits to the properties of matter before he has exhausted its possibilities and functions. It can not be denied that the physiological psychologists have lately been finding mind all through the bodily structure and giving an entirely different conception of soul from that usually held. However it be in reality, the problem is clearly before the twentieth century workers, and one must rest in agnosticism about it until the knowledge comes.

It seems clear that we have much to learn as to the nature of all the forms of energy, and one appears to be as mysterious as any other, though some of them, like gravitation, are so common and so constant that they awaken no curiosity in most persons and seem to be quite unrelated to personality or to philosophical and religious matters. It seems probable that whoever shall find the meaning of any of these factors will have at hand means for the disentanglement of the whole. With all these problems to be solved is there not enough for the work of the century? and whoever shall catalogue the triumphs of the twentieth century, if he can point to all these or a good part of them will have reason for holding that this century has accomplished as much and as important work as did its predecessor, the nineteenth.

HUMAN AND OTHER FORMS OF CONSCIOUSNESS.

BY DR. HENRY RUTGERS MARSHALL,
NEW YORK.

WHEN we are trying to think clearly we are wont to be disturbed if our friends accuse us of wandering from the sure grounds of science and entering the jungle of metaphysics.

Nevertheless, it must be acknowledged that, without realizing it, all men do really devote a fair proportion of their thought to problems which, strictly speaking, are of a metaphysical nature: and the question as to the relation of 'mind to body,' which has an entrancing interest for so large a body of thoughtful people, is clearly one in reference to which no one can take a definite position without at the same time assuming an attitude in relation to fundamental metaphysical principles.

We turn to the skilled biologist in these days for expert opinion in this matter, only to find him tarred with the same brush; for as a biologist the problem before him has properly no significance. As a biologist he is concerned with forms of 'animal behavior,' to use Lloyd Morgan's happy phrase. If he takes into consideration in any way the consciousness of animals, in that fact he assumes the attitude of the metaphysician. It is clearly because he takes this step into the metaphysical domain, without realizing it, that we find among those psychological biologists who consider the consciousness of animals so wide a divergence of opinion as to the conditions under which such consciousness exists.

But, as I have said, this matter is of great interest to all of us, and is looked upon as deserving our serious consideration. It is quite worth our while then to acknowledge frankly that we are dealing with a metaphysical problem, and at the start to make a rather deep plunge, laying aside for the moment all thought of the consciousness of animals, and asking ourselves what ground we have for our every-day assumption that other men are conscious as we ourselves are.

The ready answer seems to be that they tell us of their conscious states. But evidently this reply does not suffice us, for it becomes very clear upon consideration that no amount of hearsay evidence would serve to convince us of the fact that these other men are conscious did we not note that our activities, which are very like their activities, are accompanied in our experience by modifications in our

conscious life. This very speech of others is a type of activity which we interpret by reference to the modifications of consciousness which go with our own similar speech activities. When, for instance, I say 'yes,' I hear the sound of my own voice and at the same time experience a modification of consciousness which I describe as the state of assent. When my friend says 'yes' I hear the same sounds which a moment ago proceeded from my own body, and I assume that my friend experiences the same conscious state that I describe as assent. In other words, we introject into other men, as it were, conscious states similar to our own conscious states, when they and we ourselves act in the same way, or are subjected to the same stimulations from the environment.

Even when we come to an agreement that consciousness exists in each of us we depend upon this interpretation—this argument by analogy—for our simplest knowledge of the mental states of other men. You and I agree to call the conscious states accompanying stimulations of the eye, light sensations; but in the fact that stimuli of the same nature reach my eye and your eye I have no evidence that what you call light sensations are what I call light sensations, apart from the fact that I judge by analogy that, as you are very like me, you are to be credited when you say that you have a consciousness very like mine; and that as your eye is very like mine, its stimulation by light must correspond with modifications of your consciousness very similar to the modifications in my consciousness that correspond with the stimulation of my eye under the same light conditions.

That this argument by analogy is the basis of our assumption of the existence of consciousness in other men becomes indeed very clear in the fact that we do not hesitate for a moment to pass beyond humankind and ascribe consciousness to the higher animals other than man, although they are entirely incapable of describing their mental states to us.

I have, of course, no fault to find with this manner of our thought; I wish, however, in the very beginning to emphasize this fact, for in what follows I shall attempt to show that in connection with certain generally accepted modern views we are led to follow out this argument by analogy much farther than it is commonly carried, and to results which are of very great interest.

I. *Of Consciousnesses Simpler than Human Consciousness.*

As we have noted, the existence of conscious states in connection with animal activities is naturally inferred by each of us. It is also very generally agreed that the mental life of even the highest of animals is simpler than our own. These conclusions were reached long before men had gained any knowledge of the nature of the human

nervous system or of the fact that all these bodily activities which are accompanied by modifications of his consciousness seem to be dependent upon modifications of the activities of this nervous system.

But coincidentally with the advance of knowledge in reference to the structure of the nervous system modern psychologists have quite independently reached the conclusion that human consciousness itself is systemic in its nature. As the nervous system of a given man is looked upon as a closed or definitely bounded physical system; so is his consciousness looked upon as a closed or definitely bounded psychic system.

Furthermore, we have learned that in a general way the consciousness of a given human individual increases in complexity and coordination *pari passu* with the increase of complexity and coordination in his nervous system, in the course of his development from birth to the life of full intelligence.

It is natural for us then to conclude that wherever we find in an animal a closed nervous system of greater or less complexity we have good ground for the assumption of the existence of some form of consciousness of a corresponding greater or less complexity; and this accords, as we have seen, with the every-day assumption of the common man. It is true, as we have said above, that many of our biologists hesitate to accept this commonly accepted view: but it is also true that they fail altogether to furnish to us any valid reasons for rejecting it, being utterly at a loss to give us any satisfactory mark by which to distinguish between animals which are certainly conscious and those which certainly are not.

Modern students of neurology have discovered a further fact of importance to our consideration, viz., the fact that among all animals subject to our study, excepting possibly the very lowest forms in which nervous systems exist, each nervous system is really a more or less complex system of minor nervous systems. The sympathetic nervous system in man, for instance, has a distinct individuality of its own, although it is at the same time a part of the whole broad system: and more or less of such individuality is traceable in connection with many other minor systems within the whole nervous system.

It is interesting then to note that the psychologist also finds himself compelled to look upon human consciousness not only as a psychic system, but as a broad system of minor psychic systems. For instance, our ocular sensations and their resultants are in themselves systematized; and our aural sensations and their resultants are also, although differently, systematized; while at the same time they are both parts of the whole psychic system which we call consciousness. Each group has a measure of individuality, each forms a minor system within the broader conscious system.

Now some of these minor nervous systems in the higher animals display characteristics which enable us to compare them somewhat accurately with the whole fully developed nervous systems of certain of the lower animals which on the basis of our argument by analogy we must, and in fact usually do, agree to have corresponding with them certain lower than human forms of consciousness.

This being true, it surely follows that if any of these minor nervous systems of ours could be separated from the preeminent part of the nervous system—*i. e.*, the brain—and still live, then these separated minor nervous systems within our bodies would have corresponding with them consciousnesses of low grade, which would be separated from what we may call the preeminent or brain consciousness, but which would nevertheless still be consciousnesses, and within the human body.

We are led then to ask whether thoroughly disconnected living minor nervous systems can under any conditions exist within the human body, and to this question we find that we must give an affirmative reply.

Suppose you were shown a frog with its head covered so that it could not be disturbed by your movements, and fastened with tapes to a board, but with both legs free.

Now if I put a drop of weak acid, say on its right knee, it would promptly rub the acid off with the back of the right foot. But suppose I fastened this right foot down with tapes, or disabled it permanently, and then again touched the right knee with acid; the right leg would struggle in the attempt to rub off the acid as it did before; but being unsuccessful because of the binding tapes or injury, after a moment of quiescence or hesitation, it would rub the acid off with the foot on the other side, *i. e.*, the left foot. The common man would be likely to say, offhand, that the frog displayed a good deal of intelligence in this.

But now suppose I remove the head bandage and show you that the frog's head, and with it its brain, had been entirely removed. Experiments show that the frog will act in exactly the way above described if its brain is extirpated.

Now when you discovered this fact, if you made any remark, you might *properly* say: 'What a high degree of intelligence is involved with the mere activities of the spinal cord.' The average biologist, to be sure, usually says not this, but, rather, 'unconscious reflexes simulate the actions due to intelligence'; but I submit that he does this solely because of his preconception that the activities of the cortex of the brain are alone concerned with our conscious states.

The very argument by analogy which leads you to say that other men have consciousnesses because they act thus and so, also leads you

to hold that the live and healthy frog with its brain intact has a consciousness; and if this argument is worth anything at all it must surely lead you also to say that the frog's spinal cord activities have psychic correspondents. And if this is true of the frog why is it not true of man?

In my normal life these psychic correspondents of the spinal cord activities, if they exist, are minor psychic systems within the whole psychic system that I call consciousness. And these minor systems are usually unable to affect attention, although occasionally some of them do so when we are quiescent. We do not note the heart throb now, but we may as we are falling asleep.

We are clearly led thus to see that if disconnection of minor nervous systems from the broad nervous system as a whole can occur, then we may properly assume the existence of minor consciousnesses within the human body.

This view has been suggested long since, but is rejected, and often with derision, by many of our biologists. But in consideration of the facts above referred to it seems difficult to deny its validity, and in the opinion of the writer its rejection is due merely to an unwarranted hesitation to carry our every-day reasoning to its legitimate conclusion. The preeminent nervous system expresses itself by bodily activities of one kind or another, and notably by certain contractions of the throat and respiratory organs, and movements of the lips which produce speech. The sympathetic system, and other practically, or actually, separated minor nervous systems, express themselves by bodily activities of one kind or another exclusive of these activities of speech. While it is perfectly clear that the consciousness which expresses itself in speech, as well as in various other bodily activities, is the preeminent human consciousness, it seems equally clear that there must exist minor consciousnesses which correspond with the activities of minor nervous systems within our own bodies, provided these are, as is the case at times practically, or in some instances actually, disconnected from the main system of nervous systems.

Such disconnection as is necessary for the separate existence of such minor consciousnesses within our bodies may evidently result from pathological lesion, or may be due to the use of the surgeon's knife. But it seems probable that this disconnection may occur in a quite different way, and that if we appreciate this fact we are led to understand the nature of certain phenomena of consciousness which are usually thought to be most mysterious.

In the physical world we note disconnections between systems of activity due to the incommensurability of their rhythm. It is highly probable then that certain active minor nervous systems may become disconnected from others as the result of what we may also call an

incommensurability of rhythm; and we may surmise that the same thing is true of the corresponding psychic minor systems in consciousness which in like manner may be said to be incommensurable.

We have thus a very simple explanation of such facts as the familiar one that the soldier in the wild excitement of battle does not note the painful sensations of the wound in his leg. The brain consciousness is then so intensely active in its relation to the mental states initiated by his sensations of sight and hearing, that these activities are incommensurable with those in the less active minor psychic systems affected by the wound.

But especially does this conception throw light, in cases of so-called 'double personality,' upon the failure of recall by the one personality, of the occurrences in the conscious life of the other personality; and also of the failure of recall by the hypnotic patient, in his normal life, of his mental states during his trance. Here we may assume that two diverse great minor psychic systems, which are utterly incommensurable in rhythm, alternately take possession, as it were, of the body of man, and control his expressions. Being thus incommensurable, the two systems are almost exactly as much disconnected as are two individual men, and of course under such circumstances the mental states of one psychic system can not in any way be revived in the conscious life of the other psychic system.

We may now turn to another important point. We have stepped from the complex fully developed human consciousness to the simpler consciousnesses of the animals. We have further seen that under certain conditions there may be in our own bodies simpler consciousnesses than what we may call, for the sake of brevity, the 'brain consciousness.' But can we not—in fact, ought we not—take a further step, and hold that psychic elements may exist?

Apparently, if we are to be logical, we must take this step. We must assume that if we could isolate a neural element, a psychic element would correspond with its activities. It is true that the neurologist has never been able to discover a disconnected, isolated, living neural element; and it is true also that we can not isolate any psychic element, and even if we could do so, it as an element could not be emphatic *in consciousness* which is necessarily systemic and not elemental.

But now we may note that if disconnected minor neural *systems* may exist in our animal body there seems to be no reason why living neural *elements* may not from time to time become disconnected from, and then again reconnected with, one or another minor nervous system: and correspondingly no reason why psychic elements may not from time to time be disconnected from, and then reconnected with, one

or another minor psychic system within consciousness; some being now cut off, some being now added on, to go to make unanalyzable differences from time to time in what we call our personalities.

If we accept this conclusion, we are led to take one further step which has importance in connection with the consideration of the next division of this article.

We commonly assume that so special a significance is to be given to action within the nervous system in man's organism that it alone can be considered of moment in the relations of correspondence with consciousness. Our modern biologists, however, are coming to see that all protoplasmic substance has powers of interaction—of 'conduction'—similar to those observed in nervous tissue; and that masses of protoplasm may form systems of active life without the existence of anything like nervous systems; nervous matter, indeed, appears to be but a specially differentiated kind of protoplasm which serves as a peculiarly quick and sensitive 'conductor' from part to part of the organism.*

It seems possible therefore to hold that while the form of consciousness with which we are familiar is practically correspondent only with transfers of energy within the vastly complex human nervous system; nevertheless it may be true that any transfer of energy in protoplasmic matter may have a coincident psychic effect; and that consciousnesses of a certain grade may exist in living bodies which are systematized and yet without nervous systems.

If such a view be possible, then we must hold that human consciousness is in all probability complicated by the existence of psychic correspondents of transfers of energy in other protoplasmic masses than those which we designate as the nervous system; although it must of course be granted that the very superior 'conductivity' of the nervous masses makes the part of human consciousness which, under such a view, corresponds with activity of the nervous system vastly more important in the whole of man's consciousness than all the rest of the psychic effects corresponding with transfers of energy in protoplasmic masses other than the nervous tissues.

One more point of a good deal of importance must be noted in this connection.

If we once agree that all transfers of energy in protoplasmic substance have their psychic correspondences, then of course we must

* Confer Loeb, 'Physiology of the Brain,' p. 60 and elsewhere. Professor Loeb scouts the very idea that this, or any other fact, points to the conclusions which we here suggest; but I judge that this is because 'consciousness' for him means something much narrower than it does for us here.

allow that there are consciousnesses of a lowly and sluggish nature in connection with the lowly and sluggish life of the plants. This, it will be remembered, was a point defended on other grounds by the great psychologist Fechner, and which has since been upheld by not a few, among whom we may mention a man of as high position as Paulsen.

But this point we must pass over with this mere mention, for we have problems of greater interest to consider.

The final test of any theory lies in the explanation it gives of the mysterious; and it is a very cogent argument in favor of the broad view of the nature of consciousness thus taken that in connection with these conceptions we have a completely satisfactory answer to the old time puzzle as to the moment of the beginning of the individual soul life.

Perhaps it may be well at this juncture to recall two points made above.

1. That a fully developed human consciousness is a complex system of minor psychic systems—a system of minor, less developed consciousnesses; and that consciousness under the broader conception just reached corresponds with the activities in a fully developed *physical* system which is a system of minor less developed *physical* systems, of which the nervous system is of preeminent importance indeed, but not alone of significance.

2. That if any one of these minor *physical* systems is cut off from the whole *physical* system a minor consciousness may be held to correspond with the activities in this cut off minor system.

In the human species, to which in this connection we may confine our attention, the unfructified germ cell is a living protoplasmic particle which is cast off from the body of the female; and, under such a view as we have above been led to hold, so long as it is a living particle, it has corresponding with its exceedingly lowly activities, an exceedingly lowly form of psychic existence.

While it was part of the body of the female it had its little part in forming the totality of those systemic physical activities to which corresponded the female's consciousness.

If the germ cell happens to be fructified, and attaches itself to the internal tissues of the body of the female, notwithstanding that this attachment is only of such nature that our biologists call it parasitic; nevertheless, under the view here taken the cell again becomes part of the whole bodily system of the mother, and its activities again play their lowly part in the production of the systemic action of the whole body, which has its correspondent in the whole of the consciousness of the adult female.

This germ cell under these conditions, within the female, and in connection with her body, develops very rapidly into the embryo. It is true that the relation of the embryo to the mother continues to be almost parasitic in its nature during its development up to the time of birth, as it also remains for a considerable time after birth. Nevertheless, it draws its nourishment from, and is in a broad sense systemically related to, her body. For as part of her bodily system no activity in any part of the embryo can be without *some* direct or indirect effect upon each and every part of the body of the mother; and no activity in any of these parts of the mother can be *totally* without direct or indirect effect upon it.

The psychic coincidents of the activities in the embryo are thus part and parcel of the mother's consciousness, if this is considered in the broad way presented in the preceding section.

As the embryo grows, within it develops a nervous system of its own, and if our view is correct a minor form of consciousness must exist in connection with the activities of this rudimentary nervous system.

It is true that, so far as we know, the nervous system of the embryo never has a direct connection with the nervous system of the mother: nevertheless as there is a reciprocity of reaction between the physical body of the mother and its embryonic parasite, the relation of the embryonic nervous system to the nervous system of the mother is not very far removed from the relation of the preeminent part of the nervous system of a man to some minor nervous system within his body which is to a marked extent disassociated from the whole neural mass.

Correspondingly then, and within the consciousness of the mother, there develops a new little minor consciousness which, although but lightly integrated with the mass of her consciousness, nevertheless has its part in her consciousness taken as a whole, much as the psychic correspondents of the action of the nerves which govern the secretions of the glands of her body have their part in her consciousness taken as a whole.

It is very much as if the optic ganglia developed fully in themselves, without any closer connection with the rest of the brain than existed at their first appearance. They would form a little complex nervous system almost but not quite apart from the brain system; and it would be difficult to deny them a consciousness of their own; which would indeed form part of the whole consciousness of the individual, but which would be in a measure self-dependent. Should the optic ganglia when fully developed be separated away from the brain; then what was once a minor system within the whole brain system would become a new individual with an optic consciousness all its own.

Now something not unlike this happens at birth. Before birth the minor physical system, *i. e.*, the embryo, though lightly attached to, is nevertheless part of the physical system of the mother: and the psychic correspondents of its activities form part of a complex consciousness which is that of the mother and embryo together; the psychic correspondents of the activities of the mother, as exclusive of those of the embryonic parasite, being of course preeminent in such a complex psychic system.

At birth we have a disruption of the less developed, from the more developed, physical system; and corresponding therewith we have a minor consciousness of low development 'split off' from the more highly developed preeminent consciousness of the mother which remains to all intents and purposes intact. The new 'split off' minor consciousness then begins its existence as an individual entity, and as time goes on develops into a full formed human individual consciousness.

II. *Of Consciousnesses more Complex than Human Consciousness.*

We may now turn to the question whether there are other forms of consciousness still more complex than those forms of human consciousness with which we are familiar in our own life of reflection.

The fact that each human consciousness is a psychic system which is a complex of minor psychic systems, which are themselves highly complex systems of psychic elements, leads us to see that it is by no means impossible that our own complex psychic systems, taken as wholes, *i. e.*, our own consciousnesses, may be joined with other complex psychic systems, *i. e.*, other consciousnesses, in the formation of consciousnesses of still higher grades of complexity.

We are led thus in the first place to consider whether there is any possibility of the formation of such higher systems—of such higher consciousnesses—from the combination of the consciousnesses of human beings aggregated in social masses: whether, in other words, there can be any such thing as a 'social consciousness'; and whether coincidentally the aggregates of individuals in social bodies may rightly be looked upon as a 'social organism.'

The first thought which suggests itself to us in this connection seems to argue against such a notion, for we are accustomed to hold that the neural systems with which the consciousnesses of men are correlated are what we call closed systems, and as such are physically disconnected completely from one another; and if such is the case it would seem impossible to imagine the coincident consciousnesses united into a unified system.

Upon second thought, however, we are led to ask wherein consists the bond between the minor neural systems, within the great neural

system, in any individual man; and when we ask this question we find ourselves bound to acknowledge our dense ignorance. It is easy to speak of the 'integration' of these systems; but difficult to explain in what this 'integration' consists. All that we are able to assert is that the minor systems are contiguous, and so connected that together they act as a unit. But evidently this contiguity and connectedness within the neural systems of individual men are of various grades, as the unification of the activity between the several minor systems is of different grades.

We are led to note furthermore that when, for instance, any of us touches the hand of a fellow man, the nerve terminals of his neural system are contiguous with, and active at the same time with, the corresponding nerve terminals of that fellow man; and that his neural system and his neighbor's neural system at such a moment form in a sense one still more complex neural system, in which there are two great minor systems in either of which may occur the inception of changes in grade of activity, but in which this inception of activity must affect both parts of, that is the whole of, what we may call the duplex system. No action in the nervous system of one (*A*) of the two men (*A* and *B*), under such conditions of contact, can be without some effect upon the activity of the nervous system of the other man (*B*); nor can this action in the one man (*A*) fail to be influenced by the existing conditions of activity in the nervous system of that other man (*B*).

Taking one step further we note that the nervous systems of two or more individuals living in the same physical environment may be connected by common stimulations the most important of which are those of ocular, or of aural, nerve terminals—and by those signs and symbols in language, spoken and written, which are substituted for these stimulations—just as well as by the common stimulations of touch nerve terminals of which we have just spoken; and we are thus led to see that after all it is not at all impossible to surmise that the individuals of social groups who are similarly constituted, and who are affected at the same time by the same stimuli from the environment, may be organically interrelated elements of a social body to which must be coincident a social consciousness.

We find then that our consciousnesses may not improbably be minor psychic systems which are parts of a greater social psychic system; that we are warranted in assuming that there may be social consciousnesses of which our individual consciousnesses are elementary parts. But we can not accept such a position without making certain reservations to avoid misunderstanding.*

* For a fuller discussion of this subject confer my 'Instinct and Reason,' p. 189 ff.

In the first place it seems clear that it is improper to speak of the opinions of aggregates of men, as we comprehend them, as a 'social consciousness,' as our extreme sociologists are wont to do. If such a social consciousness exists, our thoughts are elements of it, in very much the same sense that our sensations are elements in our individual consciousnesses. As our individual sensations do not, and as no mere massing of such sensations could, make our consciousnesses what they are; so the mere massing, so to speak, of the thoughts of men can not make a social consciousness. If it exist, it must be something beyond our ken; something that we, as parts of it, can no more expect to grasp than we could expect our sensations to grasp the nature of our consciousness as a whole.

If there be a social consciousness of sufficiently high grade corresponding in general form to our individual consciousness, it may know our thoughts, much as we appreciate the existence of our own sensations and their elementary qualities; and it may have means of expression that are effective for other consciousnesses of its own order; but we as elements of this wider consciousness can surely not be able to grasp even dimly the intimate nature of that higher consciousness which, if it exist, must be determined by the pulse of thought of many interrelated individual consciousnesses. What sociologists are often tempted to speak of as the 'social consciousness' should therefore properly be spoken of merely as the related consciousnesses of the individuals composing social groups.

In all that has preceded this we have given our attention solely to the study of animal and vegetable life, and have left entirely unconsidered the possibility of the existence of anything of a psychic nature in correspondence with inorganic matter.

But, if we allow ourselves to consider such a view as that presented above, we are led further to surmise, as many thinkers have already done, that not merely such transfers of energy as occur in protoplasmic matter may involve correspondent psychic effects, but that all transfers of energy, whether in living or non-living bodies, may involve correspondent psychic effects, even though they be of a nature which we can but little comprehend.

This view which Paulsen* refers back to Plato and Aristotle, and traces in the thought of Spinoza and Leibnitz. Schelling and Schopenhauer and Lotze, and which was so clearly stated by Fechner, is in line with the ever-diminishing distinction between organic and non-organic bodies with which the scientist is making us so familiar. It is a view which has been considered by the large body of conservative thinkers in the past as exceedingly imaginative, and not one to

* 'Einleitung in die Philosophie,' p. 97.

be taken too seriously. In the light of the results of modern investigation, however, it surely appears that this view must be given careful consideration.

One of the distinguishing characteristics of living organisms lies in the fact that they are composed of a unified aggregate of elements, which are so related in a system that no element can be modified without the production of some modification in all the other elements, and in the system as a whole; and so related that the system as a whole can only be modified through the modification of its elements.

Now we have reason to believe that mere physical elements within the universe are so related together that they form systems of various degrees of complexity, and of this very same nature; that is, that elements within the physical universe are bound together in systems of greater or less complexity; in which systems the elements are so related that no one of them can be modified without the production of some measure of modification in all other elements of the system, and in the system as a whole; and so related that the system as a whole can only be modified through the modification in some measure of each of its component elements. It thus appears that systems which by a slight stretch of language we may speak of as *quasi* organic may exist in aggregates of physical elements which are usually spoken of as inanimate and inorganic.

If then an organism can be said to exist in any aggregate of physical elements whenever there exists a reciprocity of reaction between the elements of the aggregate; and if there is a thoroughgoing correspondence between psychic forms and transfers of physical energy, then there must be some type of consciousnesses corresponding with the types of inanimate systems above depicted. These consciousnesses must indeed be of forms very different from human consciousness as we know it; and, in most cases likely to be considered, must be of forms which we would be likely to consider as of a very low degree of 'integration' in comparison with human consciousness.

If now we consider the universe as a whole, as inclusive of all of what we usually speak of as organic, and as inorganic; and if we look upon it in a broad way, we perceive that it as a whole must be looked upon as a vast organic system. In it are various parts which are more or less complex systems within systems; and, broadly speaking, all parts of this vast system are in some measure related by a direct or derivative contiguity, and are subject to reciprocity of reaction, so that no element can react without in some measure affecting the activities of all the other parts of the vast organic system, and so that the reaction of any element is affected necessarily by the reactions of each and every one of the other innumerable parts of the whole vast system of the whole universe.

If the suggestions of previous paragraphs are valid, correspondent with this vast organic universe we are compelled to imagine the existence of a universal consciousness in which each psychic element affects every other, and is affected by every other.

As I have said above, this conception, or conceptions closely allied thereto, have been reached by many thinkers who approach the subject from the most diverse standpoints. Let me quote two passages from lately published works by writers of eminence, in which this is exemplified.

In his 'World and the Individual'* Professor Josiah Royce tells us that

We have no right whatever to speak of really unconscious nature, but only of uncommunicative nature, or of nature whose mental processes go on at such different time-rates from ours that we can not adjust ourselves to a live appreciation of their inward fluency, although our consciousness does make us aware of their presence. My [Professor Royce's] hypothesis is that, in case of nature in general, as in the case of the particular portions of nature known as our fellowmen, we are dealing with phenomena of a vast conscious process, whose relation to time varies vastly, but whose general characteristics are throughout the same. From this point of view, evolution would be a series of processes suggesting to us various degrees and types of conscious processes. The processes, in case of so-called inorganic matter are very remote, from us; while in the case of the processes which appear to us as the expressive movements of the bodies of our human fellows, they are so near to our own inner processes that we understand what they mean. I suppose then that when you deal with nature you deal with a vast realm of finite consciousness of which your own is at once a part and an example.

And in Dr. Stout's 'Manual of Psychology'† we find the following words:

If the doctrine of psychophysical parallelism is true the reason of the connexion between conscious process and correlated nervous process is not to be found in the nervous and consciousness processes themselves. Both must be regarded as belonging to a more comprehensive system of conditions; . . . In particular the individual's consciousness, as we know it, must be regarded as a fragment of a wider whole, by which its origin and its changes are determined. As the brain forms only a fragmentary portion of the total system of material phenomena, so we must assume the stream of individual consciousness to be in like manner part of an immaterial system. We must further assume that this immaterial system in its totality is related to the material world in its totality as the individual consciousness is related to nervous processes taking place in the cortex of the brain.

If the notions presented in the previous sections are warranted, then it appears clear that there must be in this universe an enormous variety of consciousnesses corresponding with the enormous variety of types of systematization in this universe. These consciousnesses must vary in breadth and complexity; and as certain minor systems within the whole vast physical system must be more closely systematized than others, so certain of these consciousnesses must be more closely systematized—more nearly closed systems—more self-contained—more individual—than others. Human consciousnesses would in this view be

* Vol. II., p. 225 ff.

† Ch. III., Sec. 4, p. 51 ff.

special forms of such closely systematized—self-contained—individual—psychic systems.

It appears possible then to conceive that in this universe there are innumerable grades of consciousnesses, other than human consciousnesses. At times human consciousnesses may become inherent parts of such other forms of consciousness: and their existence might affect us by resulting in an alteration of what James might call our 'feel.'

We often seem to appreciate that we are swayed by some far-reaching but ill-defined influence of this nature, the effects of which we experience mainly in a negative way when we break away from it.

Lowell has expressed this experience in some beautiful lines in his 'Under the Willows':

My soul was lost,
Gone from me like an ache, and what remained
Became a part of the universal joy.
My soul went forth, and, mingling with the tree,
Danced in the leaves; or, floating in the cloud,
Saw its white double in the stream below;
Or else, sublimed to purer ecstasy,
Dilated in the broad blue over all.
I was the wind that dappled the lush grass,
The tide that crept with coolness to its roots,
The thin-winged swallow skating on the air;
The life that gladdened *everything* was *mine*.

But suddenly the sound of human voice
Or footfall, like the drop a chemist pours,
Doth in opacious cloud precipitate
The consciousness that seemed but now dissolved
Into an essence rarer than its own:—
And I am *narrowed* to myself once more.

If such other forms of consciousness exist in the universe, not only may we at times, as we have just seen, become inherent parts of some of those of higher grade than ours; but it is also possible that at other times such diverse consciousnesses may merely attach themselves to ours, as it were, leaving our own consciousnesses essentially intact; but in such cases the other consciousnesses may serve to produce noticeable modifications in our own consciousnesses, which may point to influences from outside of such human consciousnesses as are familiar to us.

All readers of this article are familiar with the voluminous records of facts made by Hodgson and others in connection with the Society of Psychical Research, and brought into prominence in Frederick Myers's lately published work; facts which are more or less mysterious, and which not a few people think of as corroborative of that most vague of hypotheses, the spiritualistic, or spiritistic, hypothesis as it is now called.

Had these records been made twenty-five years ago they would have been immensely more voluminous, because they would have included accounts of what were then the most convincing pieces of

evidence of this hypothesis, but what are now described as phenomena of multiple personality, automatic writing, etc., which if not thoroughly understood, have surely been shown to bear no such interpretation as that involved with the spiritistic hypothesis.

So it seems probable that in twenty-five years from now many more of these recorded facts above spoken of will appear similarly explicable without resort to this spiritistic hypothesis.

Of such of these facts as then remain unexplained, a very small part may be interpreted as fraudulent, but a very large part indeed as due to perfectly honest but false judgments, or to illusions of forgetfulness, and especially to illusions of memory.

The small remnant of these facts which still remain unexplained on well established psychological principles, if they seem tangible enough to point to anything at all, will surely not point to the existence of disembodied human spirits; but rather to the existence of consciousnesses other than human consciousnesses similar to those of which we have just spoken; consciousnesses, as we have said of forms very different from those known to us in our own experience, but which may occasionally attach themselves to ours in such a way as to produce modifications of our consciousnesses which seem to point to influences from outside of such human forms of consciousness as are familiar to us.

If they are found to point to anything, they will surely not point to the existence of disembodied human consciousnesses as I have just said; nor to the existence of disembodied consciousnesses at all: but rather to the existence of consciousnesses so differently embodied that, in Royce's words above quoted, 'we can not adjust ourselves to a live appreciation of their inward fluency, although our consciousnesses do make us aware of their presence.'

I do not hesitate to agree that such influences very probably do affect us, and as evidence in favor of such a view I shall close by quoting the mature convictions of Professor Wm. James, who will be acknowledged to be one of the most acute of introspectionists the world has known.

Referring to certain early experiments of his he says:*

One conclusion was forced upon my mind at that time, and my impression of its truth has ever since remained unshaken. It is that our normal waking consciousness, rational consciousness as we call it, is but one special type of consciousness; whilst all about it, parted from it by the filmiest of screens, there lie potential forms of consciousness entirely different. We may go through life without suspecting their existence; but apply the requisite stimulus, and at a touch they are there in all their completeness, definite types of mentality and adaptation. No account of the universe in its totality can be final which leaves these other forms of consciousness quite disregarded.

* 'Varieties of Religious Experience,' p. 388.

THE PREPARATION AND PROPERTIES OF COLLOIDAL MIXTURES.*

BY PROFESSOR ARTHUR A. NOYES,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

IT was by the well-known investigations of the English physicist, Graham, published in the seventh decade of the last century, that the general attention of scientists was first drawn to the existence of a class of homogeneous mixtures, differing materially in their properties from ordinary solutions, such as those of salt and sugar. Impressed by the fact that the dissolved substance as a rule separates from the one class of solutions in the amorphous and often gelatinous state, and from the other in the form of crystals, he designated the former substances colloids and the latter crystalloids, and their solutions have since been commonly known, respectively, as colloidal and as crystalloidal or ordinary solutions. During the period immediately following Graham's classical researches, the subject of colloidal solutions received comparatively little attention. Within the last fifteen years, however, this field has become a favorite hunting ground of both physical chemists and physiologists in their searches after new truths, and greatly has the store of our knowledge in regard to this important state of aggregation been thereby increased. Yet the difficulty in reaching general conclusions as to the properties of these solutions has proved to be a very great one, owing to the complexity of the phenomena and to the apparent contradictions between many of the results obtained with different colloids and by different investigators. Moreover, the original literature of the subject has become so extensive and so detailed as to be almost overwhelming to one who, with limited time to devote to it, desires to obtain a general survey of this field of work. A brief review of some of the more important principles thus far established may, therefore, be of general interest.

It seems appropriate to begin the consideration of the subject with a definition of the class of substances to which our attention is to be devoted. In accordance with the general use of the term, colloidal mixtures are most simply defined as liquid (or solid) mixtures of two (or more) substances which are not separated from one another by the

* This article is based upon a presidential address delivered by the author at the Philadelphia Meeting of the American Chemical Society, December 29, 1904.

action of gravity, however long continued, nor by filtration through paper, but which are so separated when the liquid is forced through animal membranes, the substance then remaining behind being designated the *colloid*. This distinguishes them, on the one hand, from suspensions of fine visible particles, and, on the other, from ordinary solutions, and it implies that the colloidal particles are intermediate in size between the particles of such suspensions and the molecules which are present in ordinary solutions.

It is obvious, however, that this definition is not based upon a really fundamental distinction either in the properties exhibited by the various mixtures or in the character of their particles. It would, therefore, not be surprising to discover that the so-defined group of colloids include substances having very different properties in other respects than that just considered. And the first result of the researches upon colloids which should be emphasized is that there are in fact at least two kinds of dissolved or suspended substances retained by animal membranes, which differ so radically in their other properties that their inclusion in the same class is sure to lead to serious confusion, unless special pains be taken to discriminate between them. As types of these two classes of colloidal mixtures may be taken an aqueous solution of gelatine and one of colloidal arsenious sulphide. The former possesses a much greater viscosity than that of water; the latter does not appreciably differ from it in this respect. The former gelatinizes upon cooling or upon evaporation, and passes again into solution upon heating or addition of the solvent; the latter does not gelatinize upon cooling, and if gelatinized by other means it does not redissolve upon heating. The former is not coagulated by the addition of salts (unless in excessive amount); the latter immediately gives an abundant precipitate. This difference may be readily shown by adding to a tube containing a one per cent. gelatine solution and to one containing a colloidal suspension of arsenious sulphide a little strong magnesium chloride solution, when no effect will be observed in the first tube; while a voluminous yellow precipitate will result in the second. We have, therefore, to distinguish the viscous, gelatinizing, colloidal mixtures, not coagulated by salts, from the non-viscous, non-gelatinizing, but readily coagulable, mixtures. The former class may be designated *colloidal solutions*, the latter, *colloidal suspensions*. This nomenclature is based upon the belief that a more fundamental distinction between the two classes of mixtures is the possession by the former of the characteristic properties of true solutions—osmotic pressure, diffusibility, and usually a limited solubility of the colloid at some temperature, and the absence of these properties in the members of the latter class and the manifestation by them of many similarities to macroscopic and microscopic suspensions. Even though

this may not be a sharp line of division, it is highly probable that typical members of two classes exhibit these properties of true solutions in such a different degree as to make the differentiation an important one. Unfortunately, however, colloidal mixtures have not yet been satisfactorily enough investigated with respect to these properties to enable a classification to be based exclusively upon them.

COLLOIDAL SOLUTIONS.

Let us now consider the characteristics of the two classes as manifested by typical representatives, beginning with the colloidal solutions. These substances are, for the most part, obtained directly from animal or vegetable sources and are purified by dialysis. Among the most important are gelatine, agar-agar, unheated albumen, caramel, starch, dextrine, and many natural gums.

A number of the important properties of these colloidal solutions have already been alluded to, but some of them deserve further consideration. The contrasts and similarities between them and ordinary solutions may first be mentioned. Such colloids possess a much slower rate of diffusion, a much smaller osmotic pressure, and a much slighter influence on the vapor-pressure, freezing-point, and boiling-point of the solvent than do corresponding weights of crystalline substances. So small are these effects that whether they exist at all is a question to which much investigation and discussion have been devoted. The now existing experimental data seem to show, however, that the gelatinizing non-coagulable colloids do possess these properties and influences in an appreciable degree. The results of the osmotic pressure determinations in the cases where it has been measured against a parchment or animal membrane, which would not retain the mineral impurities, are especially significant. Thus by this method it has been found that a 6 per cent. glue solution exerts a pressure of about one third of an atmosphere, and that a 10 per cent. solution of the colloids of blood-serum produces one of 40 mm. of mercury. Further investigations in this direction would be of great value. The results of Graham, too, seem to leave no doubt as to the existence of diffusion; he found, for example, that albumen diffused one seventh as fast, and caramel one fourteenth as fast as cane-sugar. Thus, these colloids exhibit the same properties as ordinary dissolved substances, but in a lesser degree—a fact which is explained in accordance with the modern theory of solutions by the simple assumption that they are true solutions, but that their molecules consist of aggregates of the ultimate chemical molecules and are, therefore, of much greater weight and complexity than those of non-colloidal substances.

This assumption seems, however, of itself alone, scarcely sufficient to account for the abnormal viscosity of these colloids, their power of

gelatinization, and their property of permitting the free passage through them of non-colloidal substances, but preventing entirely that of other colloids of either of the two classes. This last property is the same one that is involved in the permeability of animal membranes for crystalloids and their impermeability for colloids, since such membranes are themselves nothing more than gelatinized colloids. Yet it deserves, on account of its great importance, a somewhat fuller consideration. This difference in behavior towards crystalloids and colloids may be readily illustrated by immersing sticks of gelatine or agar jelly in one experiment in a colored salt solution and in another in a colored colloidal suspension, and allowing them to remain for a day or more. Such comparative experiments may be made in a striking way with a solution of copper sulphate and ammonia and with a colloidal suspension of ferric ferrocyanide or Prussian blue made by mixing equal volumes of dilute solutions of ferric chloride and potassium ferrocyanide. Upon removing the sticks after some hours and cutting them in two, it will be noticed that the ammoniated copper sulphate has permeated the stick uniformly to its center, while the Prussian blue has not entered it at all.

Not only are gelatinized colloids permeable to salts, but, remarkably enough, they offer only a very slight, often scarcely appreciable, hindrance to the passage of these substances through them. Thus, accurate experiments have shown that the rate of diffusion of salts and mineral acids is the same, at any rate within one per cent., in a solid jelly containing 3 to 5 per cent. of agar-agar as it is in one containing only 1 per cent. of agar-agar, and it is, therefore, presumably the same as in water itself, though the accuracy with which this latter conclusion has yet been directly tested is much less. It has also been shown that the electrical conductivity of salts in a gelatine jelly is only a few per cent. different from that in pure water, and that there is no sudden change in its value when the jelly sets. This property is, however, dependent on the rate of motion of the ionized molecules of the salt through the medium between the electrodes, and the slight variation in it caused by the presence of colloids, even in quantity sufficient to produce gelatinization, proves that the flow of such molecules is but little impeded by the colloid.

Returning now for a moment to the other side of the phenomenon—the impermeability of one colloid by another—attention may be called to an apparently related fact of much importance, namely, to the fact that the presence of a gelatinizing colloid in a liquid in fairly small quantity prevents the coagulation of colloidal suspensions by salts, and, therefore, usually prevents the formation of a coagulated precipitate when the solutions of two chemical substances are mixed which, under ordinary conditions, give rise to such a precipitate. Thus when aque-

ous solutions of silver nitrate and sodium chloride are mixed, an abundant curdy precipitate is produced, but, if a little gelatine solution be first added to one of the salt solutions, only an opalescence results, and the silver chloride formed by the metathesis remains indefinitely in the state of a colloidal suspension. Glycerine, sugar and even ether in some cases have a similar influence. This result may arise from the fact that in the presence of the gelatine the particles of silver chloride after attaining a certain size are not capable of diffusing, and hence of coming into contact with one another. It is probable, however, that, at any rate in many cases, the gelatine prevents the coagulation by forming an envelope around the solid particle. Whatever may be the explanation of the phenomenon, it is one of great technical importance, especially in relation to photography; for upon it is based the preparation of the so-called emulsions of silver salts in gelatine, colloidion or albumen with which dry plates, films and printing-out paper are coated.

Recent investigations have proved that the gelatinization of these colloidal solutions arises from the separation of a portion of the colloid in the solid state in more or less continuous masses. The resulting jelly, or gel, as it is technically called, has been shown to have an irregular sponge-like structure, the web consisting of a solid mixture of the two substances and the interstices being filled with a liquid solution of them. This has been proved in some cases by direct microscopic observation, and in others by separating the liquid from the solid portion by pressure and by analyzing these portions, which were thus shown to have a very different composition with respect to the proportions of the two constituents. Thus one of the investigators of this subject, Hardy, states that when a solution of 13.5 grams of gelatine in a mixture of 50 c.c. of alcohol and 50 c.c. of water is gradually cooled, it remains homogeneous until a temperature of 17° centigrade is reached. Then it separates into two liquid phases, and is seen to consist of small microscopic droplets suspended in a fluid matrix. As the temperature falls, these droplets cohere to one another and at 12° they have become solid, forming a framework built of little spherical masses. The mixture as a whole has then become a jelly. At 14° the droplets were separated and found to contain 18 per cent. of gelatine while the matrix contained only 5.5 per cent. The important statement is also made that the first appearance of the droplets is attended by a great increase in viscosity, while the subsequent increase is a continuous one. The abnormal viscosity of such colloidal mixtures is, therefore, probably always due to a physical heterogeneity of this kind. The investigations made with other gelatinizing colloids, such as agar, albumen, starch and even silicic acid, have led to a similar conclusion in regard to the structure of the jelly.

COLLOIDAL SUSPENSIONS.

Methods of Preparation.—The mixtures of this class have been, for the most part, prepared artificially. The principles of some of the methods which have been employed for this purpose may, therefore, be first described.

Of these principles the most important one is, that when an insoluble substance is produced *in the absence of electrolytes* by a reaction between two chemical compounds, it almost invariably separates in the state of a colloidal suspension. By the term electrolyte is here meant any dissolved substance which is a good conductor of electricity, one, therefore, whose molecules are, according to the ionic theory, largely dissociated into electrically charged atoms or atom groups called ions. Most salts and strong acids or bases are such electrolytes; but water, neutral organic substances like alcohol or sugar, and very weak acids or bases, are not. Electrolytes must not be present in considerable quantity, for the reason that ions coagulate these suspensions. Thus, when a saturated solution of hydrogen sulphide, a slightly ionized substance, is added to one of arsenious oxide, also slightly ionized, no coagulated precipitate of arsenious sulphide results, but only a turbid yellow liquid, which, when poured through filter-paper, leaves nothing behind. It will be noted that in this case the other product of the reaction is water, an un-ionized compound. If this reaction be carried out with a solution of arsenious chloride, instead of with one of the oxide, the ordinary precipitate of arsenious sulphide is obtained; for, in this case, the hydrochloric acid produced by the reaction, being largely dissociated into hydrogen and chlorine ions, coagulates the colloidal suspension. So, also, upon adding hydrochloric acid to the colloidal mixture resulting from the former experiment, a large precipitate is immediately produced. As a second illustration of this method, hydrogen sulphide water may be added to a solution of mercuric cyanide. In this case also a black opaque colloidal suspension of the sulphide results; for the three substances involved in the reaction, hydrogen sulphide, mercuric cyanide, and hydrocyanic acid, are non-electrolytes; but, upon the addition of hydrochloric acid, or, still better, of magnesium chloride, to this solution, the precipitate immediately coagulates. It is not necessary, of course, that electrolytes be entirely excluded, but only that they be not present at any point at such a concentration as will produce coagulation. The method is, therefore, of fairly general applicability. Thus, a colloidal suspension of Prussian blue can be prepared by mixing dilute solutions of nearly equivalent quantities of ferric chloride and potassium ferrocyanide; for the other product of the reaction, potassium chloride, has a coagulating effect only at higher concentrations.

A second method which has until recently been even more com-

monly employed than that just described, consists in the dialysis of a salt solution in which a colloidal base or acid is present, either owing to natural hydrolysis or to the previous addition of an alkali or acid. Thus colloidal silicic acid may be prepared by dialyzing either a solution of sodium silicate alone, or one to which hydrochloric acid has been previously added. A dark red but perfectly clear colloidal suspension of ferric hydroxide is obtained by the dialysis of a ferric chloride solution which has been treated with ammonium carbonate until a permanent precipitate begins to form. This process of dialysis is commonly resorted to also for freeing colloidal solutions or suspensions prepared in other ways from mineral impurities. It is most conveniently carried out in parchment tubes, which are now an article of commerce. As the surface exposed by these is large, the process is a comparatively rapid one. The solution to be dialyzed is placed within such tubes, and these are immersed first in running tap water and afterwards in distilled water which is frequently renewed.

There is one other method of sufficient importance to deserve mention, and this is the process recently described of preparing colloidal suspensions of metals by producing an electric arc under water between electrodes of the metal in question. This is most readily carried out with the non-oxidizable metals, such as gold or platinum. When gold is used, red clouds of colloidal gold are formed near the arc, and in half a minute the whole liquid assumes a red color. The method depends on the fact that the metal is volatilized into the arc or spattered into it in an extremely finely divided form, and is then condensed or absorbed by the water, which, owing to the absence of electrolytes, has little tendency to cause aggregation of the particles.

Besides these colloidal suspensions artificially prepared from mineral substances, others can be obtained by dialysis and other treatments from animal and vegetable sources. Among the most fully investigated of these are heated albumen and gum mastic.

Properties indicating Heterogeneity.—Turning now to the properties of such colloidal suspensions, it seems appropriate first to refer to those which indicate that these mixtures really are suspensions of minute particles and not true solutions. The fact that the components of the mixture are separated by filtration through animal membranes or close-grained porcelain filters is not of itself an evidence of physical heterogeneity; for by copper ferrocyanide membranes, prepared by depositing a precipitate of this substance in an unglazed porcelain cylinder, sugar and even salts can be separated from true solutions. In some cases, the presence of particles in suspension in so-called colloidal mixtures has been proved directly by microscopic observation; thus this is the case with the colloidal mercuric sulphide and with colloidal arsenious sulphide when prepared under certain conditions, but not

under others; the same is true of blue colloidal gold, which can be produced in a variety of ways, for example, by the reduction of gold chloride solution by hydrazine. In most cases, however, the colloidal particles can not be seen even under the best conditions; they are, therefore, smaller than one seventh of a micron ($1/7000$ mm.), which is about the limit of microscopic visibility. It will be of interest to determine whether they can not be detected in many other cases with the help of the new Zeiss microscope, which, by employing quartz lenses and ultraviolet light (having a much shorter wave-length than ordinary light) and obtaining the image photographically, extends the limit of visible diameters to about one half of its present value. With such an 'ultramicroscope' a German investigator, Raehlmann, has already observed the suspended particles in an albumen solution. By the optical method of Sidentopf and Zsigmondy, in which the colloidal mixture is intensely illuminated by a thin beam of light, and the diffused light reflected from the suspended particles at right angles to the beam is viewed with a powerful microscope, the presence of still smaller particles having a diameter of $1/100$ micron has been detected in red-gold suspensions and in other colloidal mixtures.

A strong indication of the heterogeneity of colloidal suspensions is furnished also by the familiar optical phenomenon, which is often called the Tyndall effect, and is observed when a beam of light is passed through any medium containing particles in suspension. The beam becomes visible, as does a sunbeam in dusty air, owing to a diffuse reflection of light from the particles. This can readily be shown to occur with colloidal suspensions of gold and of arsenious sulphide. Moreover, in every case where reflection takes place from non-metallic surfaces the reflected light is polarized, and this is found, in fact, to be true of the rays diffusely reflected from a colloidal suspension by examining them with a rotated Nicol prism. It has been shown, to be sure, that not only colloidal solutions (colloidal mixtures of the first class), but also ordinary solutions of some substances with complex molecules like sugar, exhibit this phenomenon, so that it is not a decisive criterion of a suspension. They do so, however, in an incomparably less degree than do typical colloidal suspensions, so that it at least furnishes evidence that the particles in the latter mixtures are of much larger size than are those in the former.

Whether the well-defined colloidal suspensions possess in appreciable degree what may well be regarded as the best single criterion of a true solution—a measurable osmotic pressure—does not, in spite of its importance, seem to have been the subject of investigation by the direct osmotic method. Nor is there conclusive evidence that they show the closely related phenomenon of diffusion. If the existence of these properties to an extent corresponding at all to the size and number of the particles should be demonstrated, it would, of course, prove

that the distinction between colloidal solutions and suspensions is not one of quality, but only one of degree.

Properties related to the Electrification of the Particles.—A quite distinct class of properties may be next considered, which depend not on the size of the colloidal particles, but apparently upon the presence of electric charges upon them.

The most direct evidence of this electrification is furnished by the migration of the colloidal particles through the liquid under the influence of an applied electromotive force. This effect may be well illustrated with colloidal suspensions of arsenious sulphide and ferric hydroxide contained in two U-tubes. The tops of the U-tubes are covered with goldbeaters' skin and are surrounded by wider tubes containing pure water in which platinum electrodes are placed, so that the products of electrolysis collecting around them may not influence the colloid. These tubes are then connected in parallel with the terminals of a 110-volt circuit in such a way that the current will flow through each of them in the direction from left to right. It is some minutes before any result is observed. Then it is seen that the ferric hydroxide has moved down with a sharp surface of demarkation on the side where the current enters, leaving a clear layer of water above, and that the arsenious sulphide has done the same, but on the opposite side of the tube. In other words, the ferric hydroxide particles are moving with the positive current towards the cathode, the arsenious sulphide with the negative current towards the anode. The former are, therefore, positively, and the latter negatively, charged. These results are typical ones: such movement, or migration, as it is commonly called, is exhibited by all colloidal suspensions, and, it may be added, also by fine microscopic suspensions, like those of quartz, kaolin and lampblack. Other basic hydroxides, like those of aluminum, chromium and thorium, and certain dyestuffs, migrate to the cathode just as does the hydroxide of iron. The suspended particles of almost all other substances, whether colloidal or microscopic, migrate to the anode. This is true, for example, of silicic acid, stannic acid, metallic sulphides, salts like silver iodide and Prussian blue, and metals like gold and platinum. Of special interest with reference to the explanation of the phenomenon is the recently discovered fact that an egg-albumen suspension migrates towards the cathode in an acid liquid and towards the anode in an alkaline one.

In regard to the cause and character of the electrification two assumptions deserve consideration: one is that it is simply an example of contact electricity, the colloid particle assuming a charge of one sign and the surrounding water that of the other. This correlates this phenomenon of migration with that of electrical endosmose; for the motion of suspended kaolin, for example, through water against the

positive current is obviously the converse of the flow of water through a porous clay diaphragm with the current. It does not, however, give an obvious explanation of the facts that the basic colloidal particles become positively charged and the acidic and neutral ones negatively charged, or of the peculiar behavior of albumen. The other assumption accounts for these facts. According to it the phenomenon is a simple case of ionization, the character of which may be best illustrated by specific examples. Thus, each aggregate of ferric hydroxide molecules may dissociate into one or more ordinary hydroxyl ions and a residual, positively charged colloidal particle, and each aggregate of silicic or stannic acid molecules into one or more hydrogen ions and a residual negatively charged colloidal particle. Albumen, which is known to be capable of forming salts with both acids and bases, would, acting as a salt, dissociate into an ordinary positive ion and a colloidal negative one in alkaline solution, and into an ordinary negative ion and a colloidal positive one in acid solution. To explain the behavior of neutral substances like gold or quartz by this hypothesis, it is necessary to supplement it by the assumption that in these cases it is the water or other electrolyte combined with or adsorbed by the colloidal particles which undergoes ionization. It seems not improbable that there may be truth in each of these hypotheses, contact electrification occurring in the case of the coarser suspensions, and ionization in the case of those which approximate more nearly to colloidal solutions. It should be noticed that these hypotheses do not differ as to the charge on the colloidal particle itself, the existence of which is in fact experimentally demonstrated, but only as to the location of the accompanying charge of opposite sign, namely, as to whether it is on the water itself or on ordinary ions dissolved in it. This matter is not essential to our further considerations.

Let us turn now to the extremely important phenomenon of the coagulation of colloidal suspensions. It will be seen that this phenomenon is certainly closely related to the electric charges on the colloidal particles. Indeed, it seems highly probable that they remain in suspension because of their electrification. Thus it has been found that egg-albumen, whose particles are shown by their migration to be positively charged in acid solution and negatively in alkaline solution, immediately coagulates when the solution is made neutral. Attention may also be called to another interesting fact having, apparently, the same significance; namely, to the fact that when two colloidal suspensions, whose particles have an electric charge of the same sign, are mixed, they have no influence upon each other, but when two suspensions, with particles oppositely electrified, are brought together, the two colloids combine with each other, and with proper proportions a complete coagulation results. Thus, upon mixing suspensions of col-

loidal gold and of arsenious sulphide, no coagulation occurs, but when the suspensions of ferric hydroxide and arsenious sulphide, which we have seen from their behavior on migration have opposite electric charges, are poured together, there is immediate coagulation, and in a few minutes the precipitate settles, leaving the liquid clear above.

Crystalloid substances are also to be divided into two classes with respect to their effect in coagulating colloids. Non-electrolytes, whether organic or inorganic, have no tendency to produce coagulation; indeed, we have seen that organic substances, like ether, glycerine or sugar, often increase the stability of the suspension. On the other hand, strong electrolytes, that is, substances which are themselves largely dissociated into electrically charged particles or ions, cause coagulation, when their concentration in the solution becomes sufficiently great. Although complete coagulation does not occur suddenly as the quantity of electrolyte is increased, yet the interval between the concentration at which, in a given time, the turbidity becomes visibly greater and that at which the particles have become large enough to settle out or to be retained by a filter is usually so small that a fairly definite concentration can be specified at which each electrolyte causes a certain, experimentally determinable, degree of coagulation in a definite time. Now recent investigations have demonstrated the remarkable fact that this coagulation-concentration is nearly the same for different ions having the same electric charge (or valence), but that it diminishes enormously with increase of the electric charge of the ion of unlike sign to that of the colloid, while it is not affected by a change in the electric charge on the ion of like sign.

These principles are well illustrated by the results given in the table, which were obtained by Freundlich, on the one hand with the negative colloid, arsenious sulphide, and on the other with the positive colloid, ferric hydroxide, by determining the concentration of various salts which in two hours caused such coagulation as would prevent any of the colloid from passing through a hardened filter.

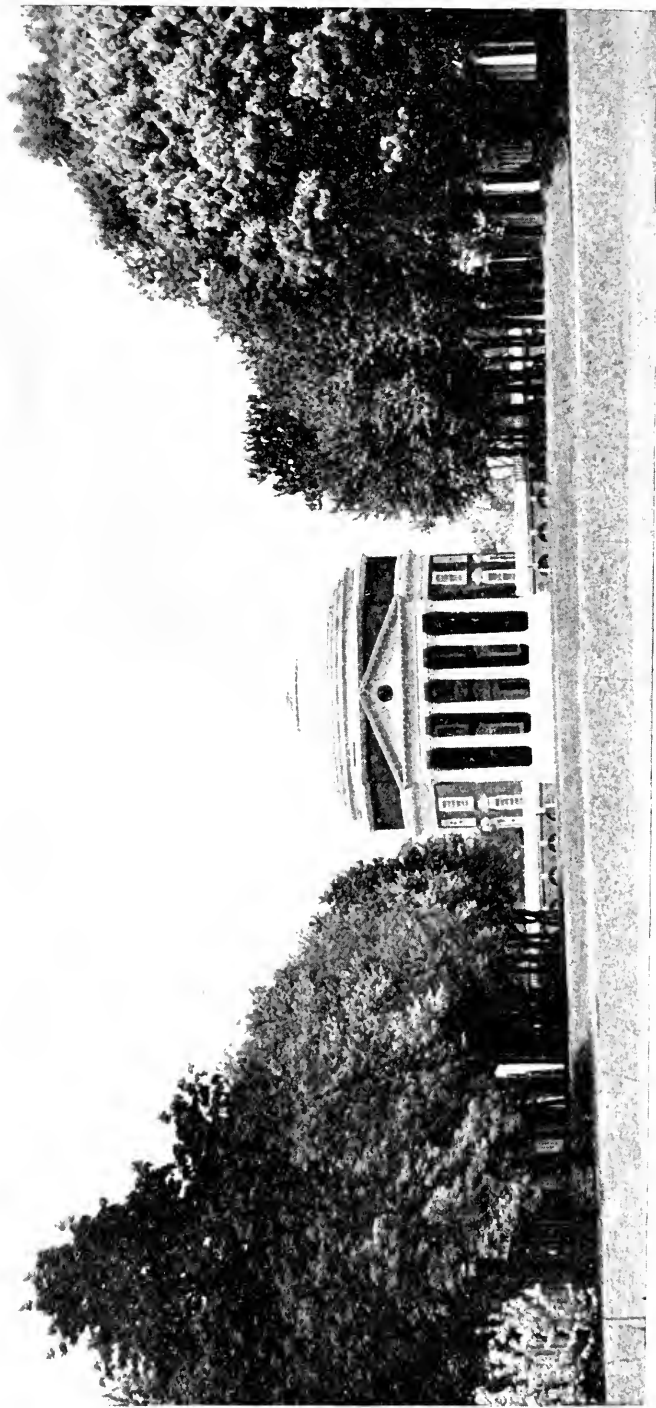
Coagulation-concentration in milli-equivalents per liter									
of As_2S_3 , a negative colloid, by			of $Fe(OH)_3$, a positive colloid, by						
NaCl.....	71	MgCl ₂	2.0	AlCl ₃	0.39	NaCl	9.3	K ₂ SO ₄	0.41
KNO ₃ ...	70	Ba(NO ₃) ₂ ..	1.9	Al(NO ₃) ₃ ...	0.41	KNO ₃	11.9	K ₂ Cr ₂ O ₇	0.39
K ₂ SO ₄	91	MgSO ₄	2.3	Ce ₂ (SO ₄) ₃ ...	0.40	BaCl ₂	9.6	MgSO ₄	0.43

It will be seen by comparing the first two values in each column that so long as the electric charge or valence of the ions of the salt remains the same, their chemical nature has no influence. It will be further seen from the third value in each column that a variation of the electric charge of the negative ion has no great influence upon the

coagulation of the negative colloid, and that this is true of that of the positive ion in the case of the positive colloid. On the other hand, by comparing the numbers in the same row, it will be seen that the coagulation of the negative colloid takes place at a much lower concentration when the salt produces positive ions with a higher electric charge, and that an increase of the electric charge upon the negative ion has a similar effect upon the coagulation of the positive colloid.

It is evident from these facts that it is the ion with a charge opposite to that of the colloid particles that is mainly responsible for their coagulation, but what the mechanism of this coagulation is, is not yet understood, though it has been the subject of much discussion. Interesting though they are, it is not worth while to describe the explanations that have been suggested; for, in the opinion of the writer, mere speculative hypotheses, that is, hypotheses which have not been shown to facilitate to an important extent a knowledge of the actual phenomena, are of little value except to the investigators of them, and to them only because of the possibility of their future development into really useful conceptions. The recent literature of colloids furnishes a striking example of the unfortunate tendency even of our modern investigators and text-book writers to attach greater importance to hypothetical interpretations of imperfectly known phenomena than to a determination and presentation of the laws in regard to them.

Even an elementary consideration of the properties of colloids should include a discussion of the absorption or coprecipitation of other substances with them when they are gelatinized or coagulated—a phenomenon which is of great importance in analytical chemistry, as well as in other directions. But, for lack of space, this side of the subject will have to be entirely omitted. Moreover, only a mere reference can be made to the importance of a knowledge of the properties of colloids, not only in the industrial applications of chemistry, but also in many other sciences and arts. It must suffice to mention that the industries of dyeing, of tanning, of glass-making and coloring, and of the manufacture of photographic materials and of modern explosives have to deal primarily with substances in this peculiar state of aggregation; that the clarification of syrups and other liquors by charcoal, and that of water and sewage by precipitation, are based on the phenomena of absorption by colloidal substances; that it is with these substances as constituents of living bodies that physiology is mainly concerned; that they constitute the culture-media of the bacteriologist, to the employment of which the development of his science is largely due; and that to the geologist the phenomenon of the sedimentation of mud and slimes, which is closely related to that of the coagulation of colloidal suspensions, is one of much interest.



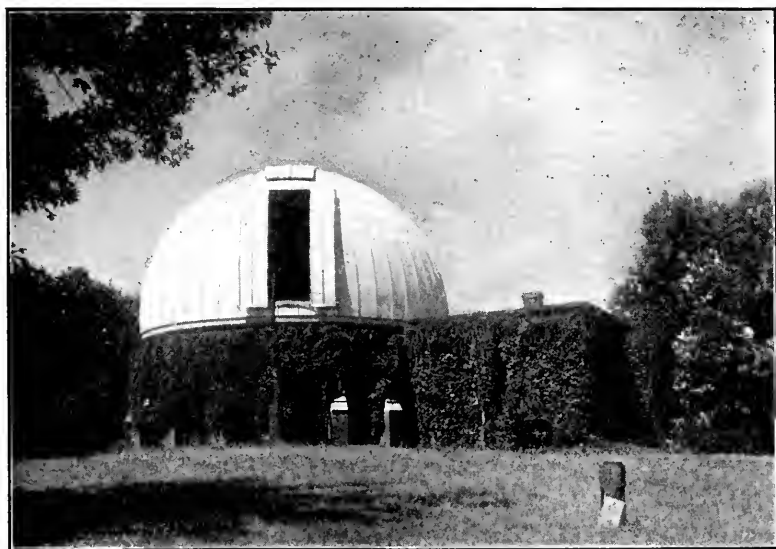
THE LIBRARY, UNIVERSITY OF VIRGINIA.

THE PROGRESS OF SCIENCE.

THE UNIVERSITY OF VIRGINIA.

THE inauguration of Dr. E. A. Alderman as the first president of the University of Virginia closes a historical period of eighty years, during which the institution has occupied a somewhat unique position in our educational system. The inscription prepared by Jefferson and inscribed on his tomb reads: 'Here was buried Thomas

dent, the administration being conducted by the faculty with their elected chairman and a rector and visitors representing the people through the governor's appointment. There were originally eight independent schools or departments—ancient languages, modern languages, mathematics, natural philosophy, moral philosophy, chemistry, medicine and law. A stu-



THE LEANDER MCCORMICK OBSERVATORY.

Jefferson, author of the Declaration of Independence, of the Statute of Virginia for Religious Freedom, and Father of the University of Virginia.' The catalogue of the university devotes a page to the statement: "Founded by Thomas Jefferson.—'An institution is the lengthened shadow of one man.'" And it is true that the university has maintained much of the intellectual aristocracy and democratic simplicity of its founder. There was no presi-

dent could matriculate in any one of these schools, and the elective group system was thus early established. There were no entrance examinations; no distinction was made between cultural and professional studies; no degree other than 'graduate' was given on the completion of a course, but those who carried on research might receive the doctor's degree; no honorary degrees have ever been awarded; there were no required religious exer-

eises. The university was one of the first to be endowed and supported by a state, and Jefferson planned that it should be the head of the public school system. Much of this sounds very modern, or rather perhaps in accord

United States senators and at least ten who are presidents of colleges and universities. The illustrations here given show that even after the disastrous fire of ten years ago, the university possesses suitable and



THOMAS JEFFERSON, FOUNDER OF THE UNIVERSITY OF VIRGINIA.

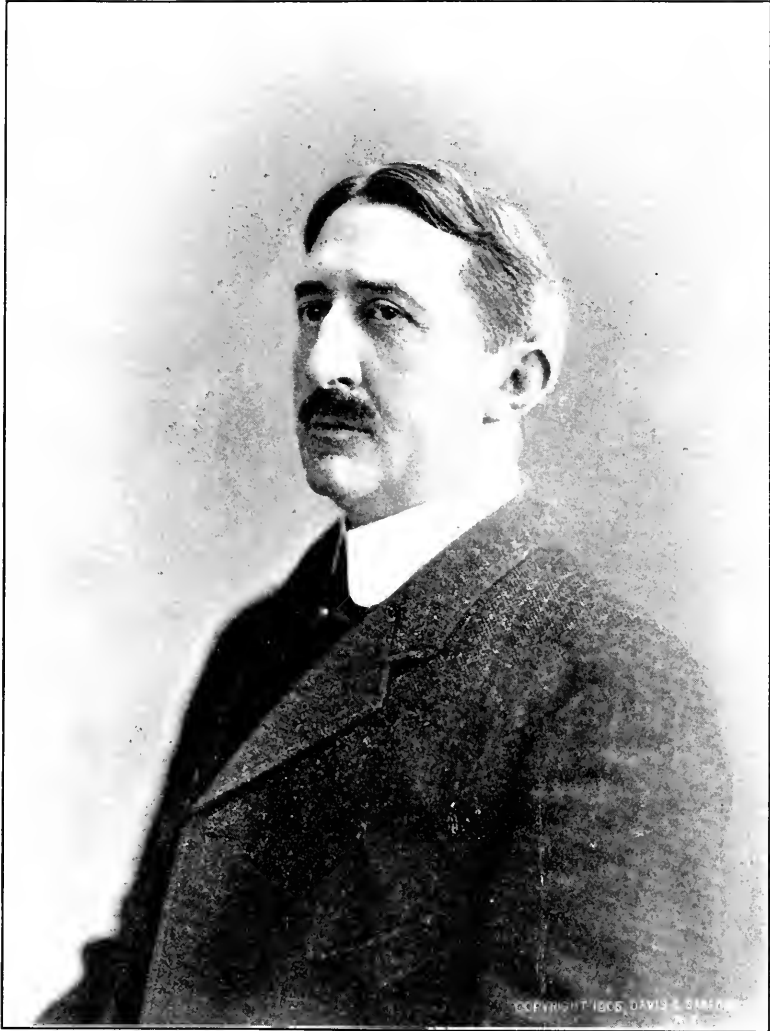
with the views of certain modern educators.

Virginia long maintained its position as the university of the south, being its home of scholarship and school of training for public life. Perhaps no other institution in the country prepared so many men for high official positions; and when the civil war came, it supplied about 1,500 officers to the confederate army. In spite of the ravages of the war, it by no means lost its prestige. Thus there are at present seven alumni who are

beautiful buildings, and that the sciences are well cared for. It will suffice to name Professor Ormond Stone, director of the observatory, and Professor J. W. Mallet, F.R.S., who holds the chair of chemistry, to indicate the position held by the university in the sciences.

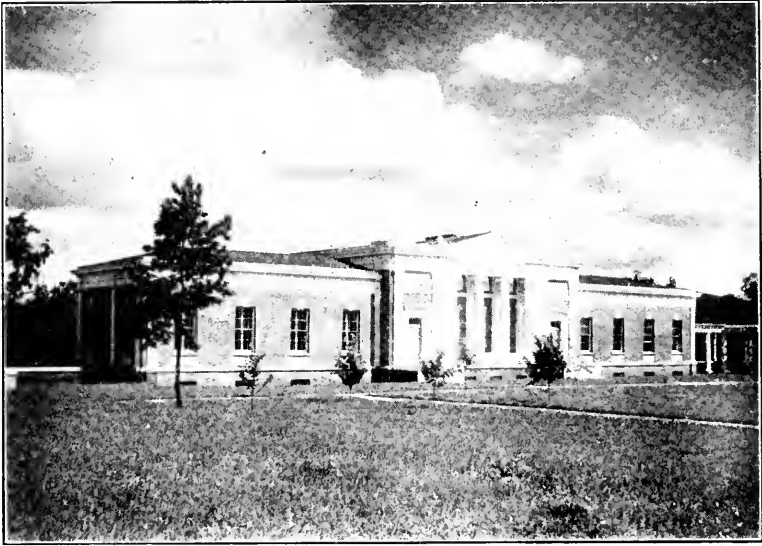
Dr. Alderman, who has been superintendent of schools, professor of pedagogy and for four years president of North Carolina and of Tulane, has the educational experience which will become more and more essential for a

college president, and the gift of oratory which perhaps in the future will be regarded less highly than at present. His administration began with the announcement of gifts from our two promoter, certainly makes for organization and bigness, and for at least temporary efficiency. It was, however, a strange irony that led to the celebration of Jefferson's birthday by the



DR. EDWIN A. ALDERMAN, FIRST PRESIDENT OF THE UNIVERSITY OF VIRGINIA.

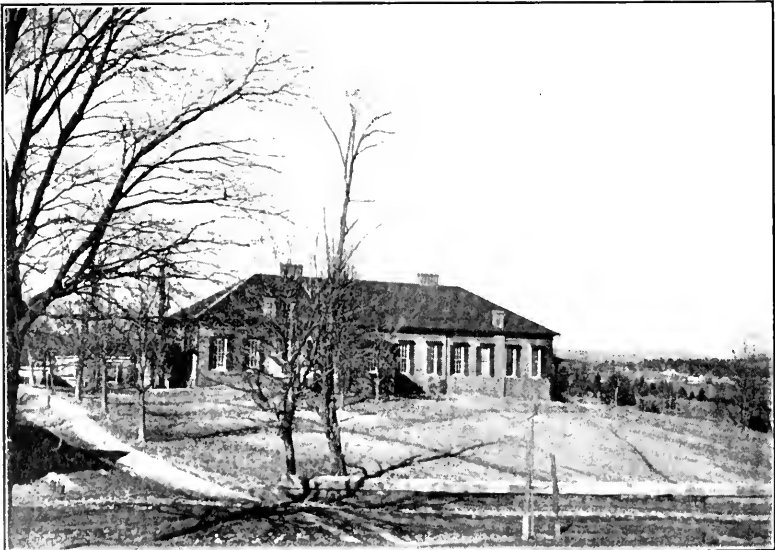
ubiquitous eleemosynaryists, and there is every reason to foresee that the university will increase in wealth and in numbers. The college president, like the political boss and the corporation inauguration of a president of the University of Virginia. A Jeffersonian democrat may hold almost any political opinions, but presumably the line must be drawn at the benevolent despot.



THE ROUSS PHYSICAL LABORATORY. The Mechanical Laboratory is on the opposite side of the lawn and is identical in appearance with the Rouss Laboratory.

While the accumulation of wealth and a certain kind of efficiency are undoubtedly attained by present methods in politics, in business and in education, they are probably passing phases in our democracy. It would be a severe

arraignment of democracy and of higher education to hold that those who make a university can not conduct it. If the people will not directly support a university, they will not continue to do so indirectly through the



THE CHEMICAL LABORATORY.

gifts of millionaires. But the people are ready to maintain their universities. Wisconsin has this year appropriated \$725,000 for its university; Virginia would in the end do more for its university than will ever be done by distant millionaires. It seems a pity that some of the complications inevitable in an imperfect democracy and the temporary backwardness of the south in appreciation of educational matters as compared with the central and western states have led the University of Virginia to diverge in the direction of our private eastern institutions instead of maintaining intact the democratic ideals of its founder.

PROFESSOR CHARLES A. YOUNG.

THE retirement of Professor Charles Augustus Young from the active duties of the chair of astronomy and of the directorship of the Halstead Observatory at Princeton deserves more than a passing comment as a news item in this journal. A service of science for a period of more than fifty years in itself commands respectful attention; and the manner in which this service has been rendered, with lofty regard for truth and genuine interest in its diffusion, is almost unique in this generation.

He was to the manor born, for his grandfather, Ebenezer Adams, was professor of mathematics and natural philosophy at Dartmouth from 1810 to 1833. His father, Ira Young, succeeded Ebenezer in the chair and occupied it with distinction until his death in 1858. Charles Augustus, born at Hanover, on December 15, 1834, was graduated as bachelor of arts from the college of his fathers in 1853. He made his first visit to Europe in that year, accompanying his father, who went to purchase instruments for the Shattuck Observatory then in process of erection at Hanover. The notebooks of the observatory contain many of the son's observations recorded during his undergraduate days. After two years

spent in teaching the classics at Phillips' Andover, with simultaneous studies in the theological seminary, Charles Young went in 1857 to Hudson, to become professor of mathematics and natural philosophy at the Western Reserve College. During several summers he served as astronomical assistant on the government's lake survey. During 1862 he left his books at the call of patriotism, and assumed for some months the captaincy of a regiment of Ohio volunteers, largely composed of students.

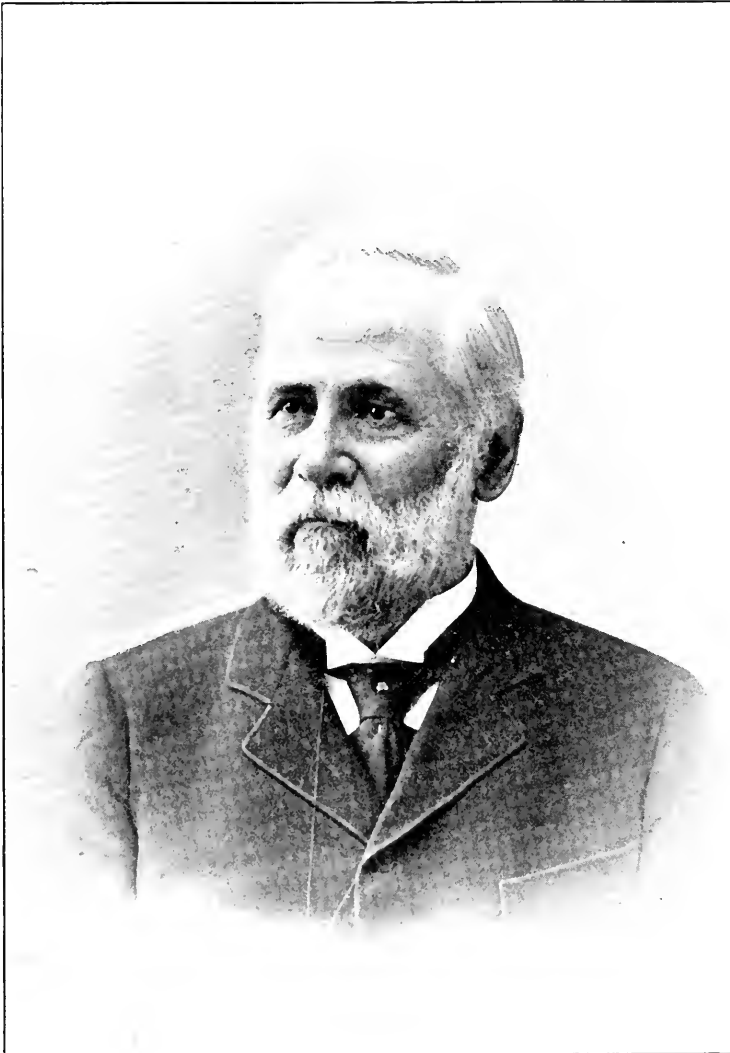
He returned to Dartmouth in 1866, to the professorship of natural philosophy and astronomy formerly held by his father. It is fortunate that laboratory instruction was not then included in the teaching of natural philosophy, for otherwise time could hardly have been secured for the researches in astrophysics to which Professor Young's attention was enthusiastically given in the hours not spent in the class room. The significance of the spectroscope was clearly foreseen by him, and he devoted much time to its development.

At the total solar eclipse of 1869, he observed the spectrum of the corona. He looked for, but did not see, the reversal of the dark Fraunhofer lines at the instant of internal tangency of moon and sun. But in the following year, at a station in Spain, his expectations were realized in his detection of the 'flash spectrum.' This difficult visual observation was not photographically confirmed until the eclipse of 1896, when Mr. W. Shackleton, of Sir Norman Lockyer's party, obtained a fairly good plate; and in 1898 Sir Norman and others obtained very fine photographs of the elusive phenomenon.

In the early seventies, Professor Young assiduously observed the solar prominences and the spectrum of the chromosphere. He obtained in 1870 the first photographic record of a solar prominence, but the lack of sensitiveness of the wet-plates then in use made

it undesirable to follow the matter since that date, and that by Professor further at that time. Young himself at Princeton. In 1876,

Professor Young's expedition to with the first grating spectroscope used Wyoming in the summer of 1872. to in astronomical work, he made the



PROFESSOR CHARLES A. YOUNG.

utilize the advantages of an altitude of over eight thousand feet, added a hundred chromospheric lines to the list of 170 which he had observed at Dartmouth. It may be mentioned that this list has been but slightly enlarged

pioneer measurements of the rotation of the sun from the relative displacements of lines on the approaching and receding limbs. We are indebted to him for important observations on the spectrum of sun-spots, made after his

removal to Princeton in 1879; also for measurements of Uranus and double stars with the 23-inch refractor of the Halstead Observatory. Professor Young observed the transit of Venus of 1874 at Pekin, that of 1882 at Princeton; and he traveled to favorable points of observation of the solar eclipses of 1869, 1870, 1878, 1887 and 1900.

Despite the value of his original researches, so imperfectly sketched above, it is not for them that we most highly honor Professor Young. Nor is it for the excellence of his numerous textbooks on astronomy, which have been used by far more than a hundred thousand students and readers. It is rather for himself, his own personality, and for the lofty ideals which his life has so fully illustrated. A personal acquaintance is not necessary for the recognition of these qualities, for they appear in all his writings, whether popular or technical. Whatever things are taught must be 'correct and accurate *as far as they go.*' Truth must not be debased for the sake of popularization. The assumption premised must always be clearly indicated; and the limitations of our mode of observation kept in mind. Such principles as these have ever been illustrated by this teacher in his writings, on the lecture platform, and in the classroom.

The total absence of dogmatism or assertiveness, even in works on which he is preeminently an authority (as in *The Sun*), is conspicuous; and his tolerance for views different from his own, with his uniform avoidance of anything controversial in his teachings and writings, furnish an example which many younger and older men could follow to great advantage.

The vein of quaint humor which pervades his speech and literary work have been always appreciated by his friends and readers, and is an obvious part of his genial philosophy of life. Worries, cares and disappointments have not been absent, and for some years ill-

health has added its burden. But the gentle influence of an ideal conjugal companionship, extending over more than forty years, always lightened these cares until the crushing bereavement came four years ago.

As Professor Young now retires from active duties upon 'coming of age,' thousands of pupils, readers and friends, salute him. May many coming years be allotted to him, now in the ripe maturity of his mind, for reflection, study and contributions to the world's knowledge of other worlds.

SCIENTIFIC ITEMS.

THE faculty of Princeton University gave a dinner on the evening of May 17 in honor of Professor Charles A. Young, who becomes professor emeritus after a service of twenty-eight years as professor of astronomy. Among the speakers were President Woodrow Wilson, of Princeton; President Francis L. Patton, of Princeton Theological Seminary; Mr. M. Taylor Pyne, of New York; Professor Silas Brackett, Professor W. F. Magie and Dr. Henry Van Dyke, who read a poem. A loving cup was presented to Professor Young.—Professor J. J. Thomson, F.R.S., of Cambridge University, has been elected professor of natural philosophy in the Royal Institution to succeed Lord Rayleigh, who becomes honorary professor.

PROFESSOR GEORGE T. LADD, who has resigned from the chair of philosophy at Yale University, has arranged to pass the latter half of next year as professor of philosophy at Western Reserve University. At the close of the war in the east he expects to go to Japan to lecture on educational methods under the auspices of the Japanese Imperial Education Society.—Sir Patrick Manson has been invited to give the Lane lectures at the Cooper Medical College, California, this year. He will lecture on some aspect of tropical diseases.—The courses that Professor Wilhelm Ostwald, of the University of

Leipzig, will offer at Harvard University during the first half of the approaching academic year are: 'The Philosophy of Natural Science,' three lectures a week, and 'The Fundamental Conceptions of Chemistry' and 'Catalysis,' each one hour a week.

At the annual anniversary meeting of the Royal Geographical Society, on May 22, Sir Clements Markham resigned the presidency of the society which he has held during the past twelve years. Sir George Goldie, founder of Nigeria, was elected to the presidency, Sir Clements Markham and Colonel D. A. Johnston were elected vice-presidents.—Columbia University has conferred its doctorate of science on President R. S. Woodward, of the Carnegie Institution.—Cambridge University has conferred the honorary degree of Sc.D. upon Commander R. F. Scott and Sir Francis E. Younghusband, K.C.I.E., LL.D.

THE proposed affiliation of the Massachusetts Institute of Technology with Harvard University was approved at a meeting of the corporation of the institute, on June 9. Thirty-two of the forty-seven members of the corporation were present, and by a vote of 20 to 12 it was agreed to accept the terms of the agreement recently drawn up by the committee of the two institutions.

It will be remembered that on May 5 the faculty of the institute adopted by a vote of 56 to 7 the report of the committee adverse to the affiliation.—At the annual meeting of the National Academy of Design it was voted to accept the offer of Columbia University to form an affiliation. It is planned to collect \$500,000 for a building, which will be erected on a site furnished by Columbia University.—The cornerstone of the library building of Leland Stanford Junior University was laid on May 15. The building will cost \$800,000. At the ceremonies an address to the students by Mrs. Stanford was read. In it she makes the amount realized from the sale of her jewels, which are estimated to be worth \$500,000, an endowment fund for the library.

It is proposed to affix a marble tablet to the Villa Medici, which is French property, to remind passers by and posterity that Galileo was kept prisoner there from June 24 to July 6, 1633. Italy has already erected a small monument to Galileo at the very door of the villa, with the following inscription: "The neighboring palace, which belonged to the Medici, was the prison of Galileo Galilei, guilty of having seen the earth revolving round the sun."

THE POPULAR SCIENCE MONTHLY.

AUGUST, 1905.

AN ECLIPSE OBSERVER'S EXPERIENCES IN SUMATRA.

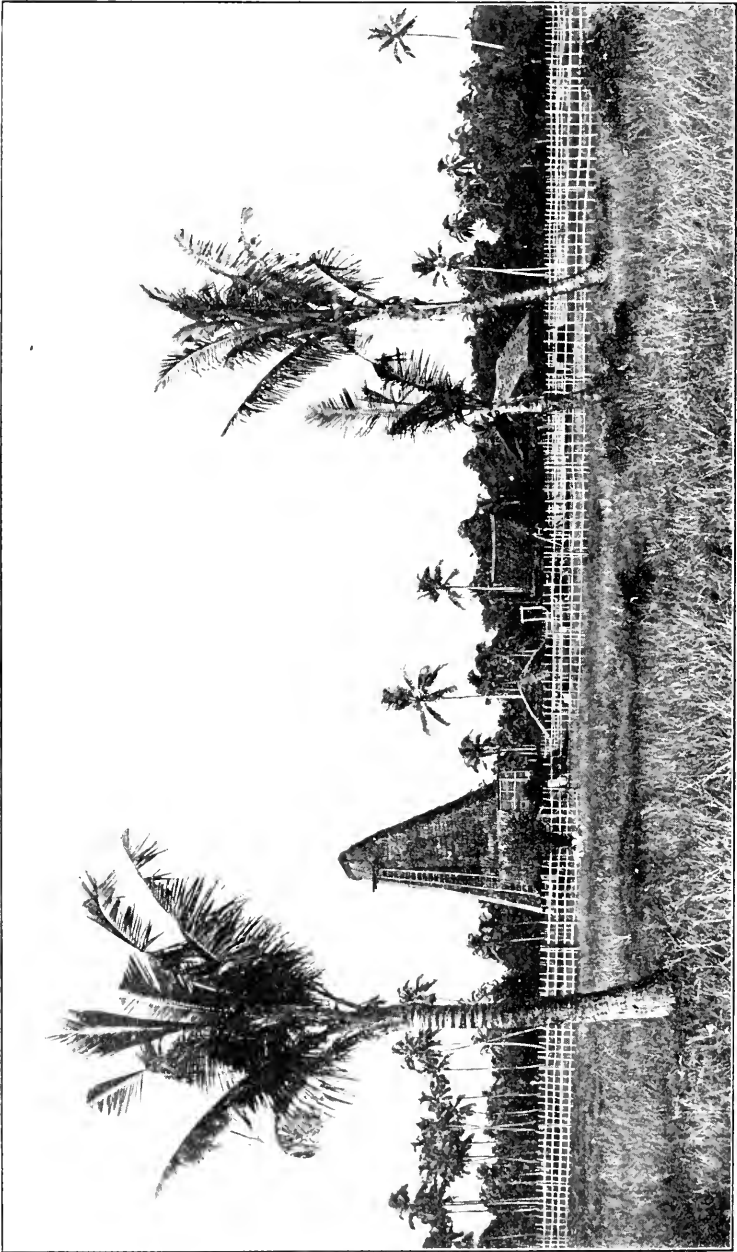
BY PROFESSOR CHARLES DILLON PERRINE,

ASTRONOMER AT THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA.

TOTAL eclipses of the sun are often visible only from out-of-the-way corners of the earth, necessitating long journeys from the fixed observatories to observe them. The path of totality of the Sumatra (1901) eclipse extended from the southern Indian Ocean near the African coast northeast across Mauritius, thence across central Sumatra and the neighboring islands, Borneo, Celebes and New Guinea. The most favorable location, astronomically speaking, was in Sumatra, where the duration of totality was longest and the sun, at the time of the eclipse, was near the zenith. These considerations led nearly all of the expeditions to choose points near Padang as sites for their observing stations.

The two observers* from the Lick Observatory, with four tons of instruments and supplies, sailed from San Francisco on February 19, going by way of Honolulu and Japan to Hong Kong, and thence to Singapore, Batavia and Padang. At Singapore we took a steamer of the Koninklijke Paketvaart Maatschappij for the 500 mile run to Batavia. On the 'Coen' Dutch customs prevailed. The early morning, from daylight to nine o'clock, sees the men promenading the decks or lounging about in pajamas and loose slippers. There is no rising call or call for breakfast. One rises when he pleases (usually early, to take advantage of the coolest part of the day), bathes and breakfasts at will. The ladies appear at breakfast attired in loose

* C. D. Perrine, astronomer in charge of the Wm. H. Crocker Eclipse Expedition, and R. H. Curtiss, chief assistant.



THE LICK OBSERVATORY — CROCKER ECLIPSE STATION.

'mother-hubbards' or in short sarong skirt and loose white sack—the costume of the early part of the day.

The low eastern shore of Sumatra and its fringe of small outlying islands are in view most of the time, presenting an almost unbroken line of green—the dark dense green of tropical vegetation. The coconut palms afford the only clue to the native villages which are hidden away in groves of these graceful trees. An occasional light-house projects its white shaft skyward from a sand-spit or submerged reef, a grateful relief to the eye from the green which one comes to associate with this part of the world, where even the oranges are green.

About 80 miles south of Singapore we crossed 'the line' and lost our compass-needle, for there is no southern Polaris.

Our time at Batavia was consumed in attending to the transfer of the instruments to the Padang steamer. Owing to the nature of the expedition, and to prevent delays, the handling of the eclipse freight was personally supervised at every change. The officials of the steamship companies were always most courteous in making room for the observers and the instruments on steamers already full, and in meeting our requirements at all points. This was nowhere more true than in Java. For example, during the two full days that the steamer which had the eclipse freight on board was waiting at Tandjong Priok to coal and come to the pier—no one knowing just when these events were to happen—the dock officers and coolies were waiting the entire time, under instructions from the agents of the steamship company, in order to make the transfer at the earliest possible moment.

The steamer for Padang went through the Straits of Sunda, where in 1883 occurred the great outburst of Krakatoa. Soon after entering the Straits we had our first glimpse, just a needle-like point above the horizon, of the torn and shattered remains of the volcano. All about us were evidences of that fearful catastrophe. In front of us was 'Dwars-in-den-weg' (Right in the way), a single island prior to the eruption, but now a group of several islands.

Many stories are heard of this outburst. One, told by a fellow passenger on the 'Prinses Sophie,' a Dutchman who had visited the region a few weeks after the occurrence, concerned a miraculous escape. A trading-ship was lying in the harbor of Telok Betong at the southern end of Sumatra. This town is at the head of a long bay or gulf and is seventy miles or more from Krakatoa. On the morning of the disruption, the captain of the ship was visiting a native prince at his home among the hills. The prince, who had been observing the phenomena on Krakatoa, warned the captain that it would be unsafe to return to his ship and persuaded him to stay. A few hours later the tidal wave came up the bay and carried the ship inland more than

two miles from her moorings, over the town and over a hill eighty feet high.

Early on the morning of April 5, forty-five days after leaving San Francisco, we entered Koninginne Bay, a beautiful little indentation in the precipitous coast of Sumatra. Here is a safe harbor (Emmahaven) where ocean ships go alongside of stone docks. The railroad system of the island has its coast terminus at this point. The coal brought down from the mines in the interior is carried to the ships' bunkers in flat baskets by an endless chain of natives, while the ships are loading with coffee, rice, rattan, gutta-percha, hardwoods and spices of all sorts.

The city of Padang, about four miles north of Emmahaven, is reached by the railroad. Carriages from the two principal hotels were at the railway station, and after a circuitous drive through avenues of trees, our journey was temporarily ended at the Oranje Hotel, 'Het Grootste Hotel van Sumatra.'

My first business was to present my letters of introduction, and to call upon the governor. His Excellency, Governor Joekes, received us cordially and gave the necessary instructions to the heads of all departments who could in any way assist the expedition.

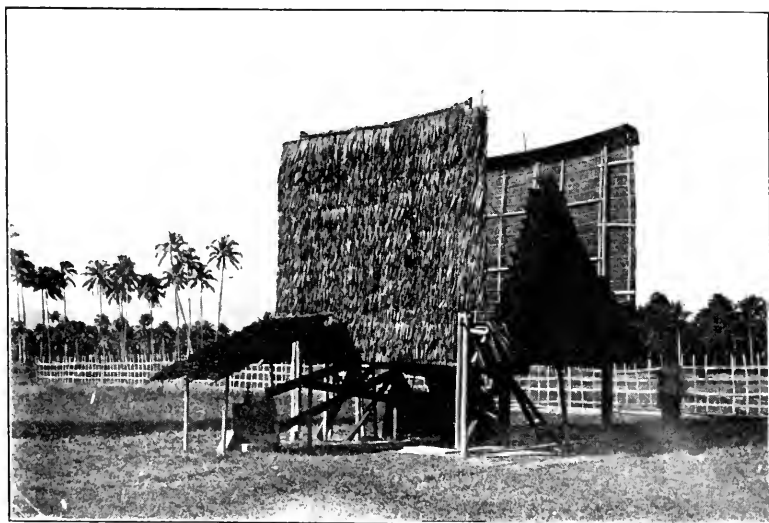
The old race-track (Patuoën Kuda) near the edge of the city was chosen as the site. Shelters for the instruments were built by the native carpenters out of bamboo and atap (palm thatch). A few small cart-loads of these simple materials, which are supplied almost ready for use by a bountiful nature, sufficed to build everything. Shelters, sheds and fence (even to the hinges and fastenings of the gate) were constructed from them.

One orangdjaga (watchman) was employed to guard the small native house at the eclipse camp where the freight was stored and two more to watch the mounted instruments, only a furlong distant. The day after one had been employed to watch the instruments, he came with a frantic appeal for another, because he could not possibly stay alone. Upon questioning him I found that Patuoën Kuda was 'haunted' and that no native would stay there alone at night. A companion was found for him, after which the two were regularly found sound asleep in the midst of things. Their mere presence seemed to be effective, for nothing was missed during our stay.

The advent of so many foreigners, composing the astronomical expeditions, excited great interest among the natives. At first the Malays were disturbed, for they thought the sole object of these foreigners, particularly the British and Americans, was to spy out their country. As the serious preparation for observation began they became less suspicious, but still scouted the idea of an eclipse, saying that 'if these men could foretell such an event, they would be half

god.' The advent of a great comet shortly before the eclipse, and an epidemic in the native kampong, shook the little faith which the natives had acquired in the astronomers. There was a rumor that our camp was to be destroyed. I do not know that there was any real danger, but the police department was on the alert until after the eclipse was over.

The six weeks before the eclipse were busy ones. There were ten telescopes to be mounted and carefully adjusted. Frequent time observations had to be made, experiments were carried out to determine

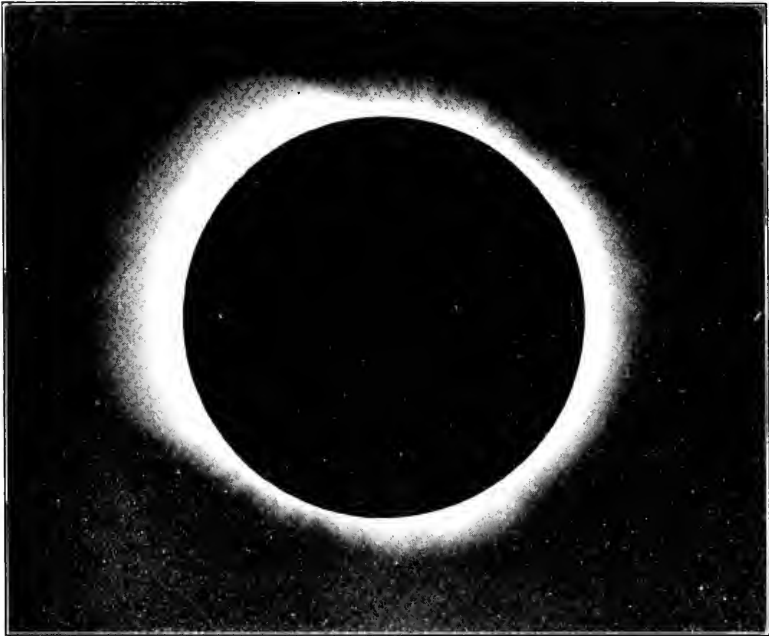


INTRAMERCURIAL CAMERAS (SHUTTER OPEN).

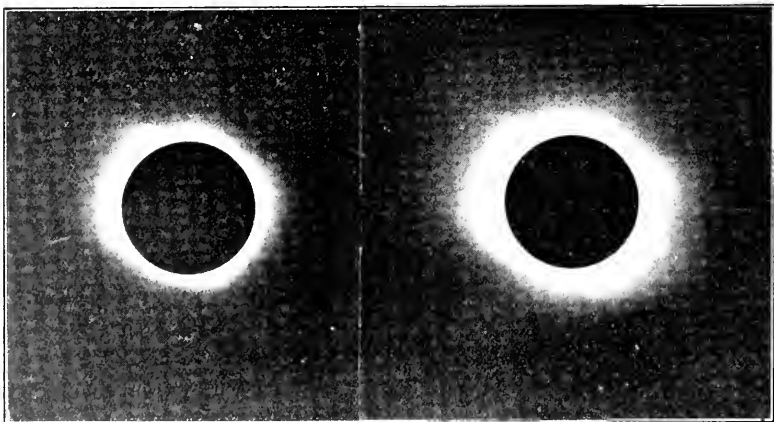
the best methods of developing plates in that climate, for all the observations were to be photographic. A succession of minor difficulties came up for solution.

Our day began at half past five, with a bath. After the Dutch breakfast of cold meat, bread and jam, we were taken to camp by a tram. At 'pocool stenga satoo' (12:30 o'clock) the tram came for us and we were soon drinking an iced 'lemonada' at the Oranje. After a short rest and riztafel (luncheon) we were on our way to work again. In the afternoon the Malay driver turned his pony out to graze at the station, and, finding a comfortable bit of shade, went to sleep until it was time to return to the hotel. This was usually about 6:30, when it became too dark to work. The inevitable 'mandee' (bath) was always the first luxury indulged in upon reaching the hotel in the evening. The 'badkamer' (bath room) was a large room of brick or cement, in a separate pavilion, lighted by a small, high grating in daytime and by a diminutive candle at night. The floor

was of cement. It sloped to a drain at one side, which carried off the bath water. About half of the floor space was occupied by a



THE CORONA OF MAY 18, 1901. PHOTOGRAPHED WITH THE 40-FT. CAMERA, EXPOSURE, 18.



EXPOSURE, 28. EXPOSURE, 88.
THE CORONA OF MAY 18, 1901, PHOTOGRAPHED WITH THE FLOYD CAMERA.

cistern two or three feet deep. The only furniture which the room contained was a chair and a small pail. The water was poured over the head, the bather standing on a small platform.

The principal work of preparation was accomplished nearly a week before the eclipse. The remaining time was devoted to arranging the final details and to training the assistants. As soon as it was known that help would be needed to make the observations, it was tendered in abundance by the Dutch residents. Fifteen, including several of the army officers, and the general manager of the government railways, were invited to assist. The observations with each instrument were very minutely planned. Every motion to be made by each observer was carefully considered and arranged beforehand, and numerous rehearsals enabled the operations of taking the photographs to be performed with certainty and great rapidity.

Although light clouds covered the sun during totality, the resulting observations were very successful and yielded much important information. Photographs were secured with three sets of cameras especially designed to record the inner, middle and outer corona. The large-scale photographs of the inner corona showed a peculiarly disturbed region, which later was found to have been at the time of the eclipse above a group of sun spots. The inference that there was a close connection was irresistible.

This eclipse was particularly favorable on account of the great duration of totality—six and one-half minutes—for the search for any planets between Mercury and the sun. Four cameras of long focus were especially designed for the search. They were capable of recording any such objects as faint as the ninth magnitude. The photographs were taken in duplicate to guard against defects. They covered a region 6° wide and 30° long, in the direction of the sun's equator, as the most probable orbit of such a planet would lie in that region. Although the search was not so complete as desired, owing to the clouds, our knowledge was considerably extended. In two thirds of this area, stars fainter than the eighth magnitude were photographed and in the remaining third, stars of sixth magnitude and brighter. All the objects on the plates were identified as known stars. It is practically certain from the observations, therefore, that there is no such planet as bright as fifth magnitude, and little probability of there being any as bright as eighth magnitude. A planet thirty miles in diameter in the region searched would appear as a star of the eighth magnitude. To account for the observed deviations of Mercury from its computed orbit would require *over half a million bodies 30 miles in diameter and as dense as Mercury.*

Another investigation undertaken concerned the nature of the coronal light. The bright coronal lines observed at previous eclipses showed that a small portion, at least, of the light was due to incandescent gases. But the great portion of the light gave a spectrum which appeared to be perfectly continuous. Some observers had

noted a few dark lines in this continuous spectrum, indicating refracted sunlight, while others had failed to find any traces of such lines. By means of two spectrographs designed especially for the problem, and of a camera for photographing polarized light, observations were secured which satisfactorily explain the nature of this light. These observations showed no dark lines and very little polarization in the inner corona, whereas the dark lines and polarization were strongly marked in the outer corona. This seems to indicate that the light of the corona, out to a distance of nearly three hundred thousand miles from the sun's surface, is due to small particles of solid matter in a state of incandescence. This incandescent matter must also reflect light from the photosphere, but the reflected light is too weak, as compared with the inherent light, to show any of the dark lines seen in the spectrum of the sun's surface, or to give much evidence of polarization. The light from the outer corona, being chiefly reflected, gave the same spectrum as the sun's photosphere, and it was found to be very strongly polarized.

These results strengthen the belief that very finely divided solid or liquid matter exists in the region surrounding the sun (together with a very small proportion of gaseous matter); that close to the sun this matter is highly heated and shines principally by its own light; that further away it becomes cooler, and reflects more light than it emits.

On account of the clouds, the eclipse lost its great spectacular interest. Nothing of the corona was to be seen with the naked eye except a faint ring without any structure whatever. The photographs are, however, as sharp, and show as much detail in all except the extreme outer corona, as if the sky had been entirely clear.

With the passing of the shadow and its terrors for these superstitious orientals, confidence in the 'Zoneclips' people was fully restored, and it was difficult to get away from the island without a retinue of volunteer servants.

The U. S. S. 'General Alava' was at Padang during the eclipse preparations, and a number of entertainments were given in honor of her officers and the astronomers. I attended two of these functions, a reception given by the governor, and a farewell ball given by the American consul. The governor's reception was on a Sunday morning at his mansion, and dancing was indulged in for an hour or more. The ball was an evening function and elaborate entertainment was provided. Nice things were said in several languages, and healths were freely drunk. One of the toasts by a prominent Dutch official was to the 'shirt-sleeve astronomers.' These people who had so much cheap native labor, and who never needed to be in a hurry,

were impressed by the methods of astronomers who rolled up their sleeves and did all kinds of manual labor themselves.

The traveler who sets foot in Netherlands India must, within three days of his landing, procure a permit to remain or travel in the country. No charge is made for issuing these 'toelatingskaarten,' but they are made out on government stamped paper, and a guilder and a half collected for the stamp. Upon arriving at a hotel the guest must give a complete account of himself and his movements in a register which is examined every few days by a government official—the resident or assistant resident. Through this means the movements of every traveler, Dutch or foreign, become known to the government. This elaborate and cumbersome system of espionage can not but discourage all except those having urgent business from visiting this interesting corner of the world.

Padang is the capital and principal city of Sumatra. Padang is the native word for plain. It was applied originally to the level stretch of sandy country in which the city is located. The oldest part of the city, the business section, lies along the north bank of a small river, where the native prahus with their cargoes of coffee, rice, spices, etc., from up and down the coast, lie securely sheltered by a high promontory (the Appenberg) across the river to the south. Only the barest ridge of sand, which has been raised by the surf, separates the city from the Indian Ocean. As the tropical seas are ordinarily calm, a murmur is all that usually finds its way to the ears of the inhabitants. To the east rise the steep, heavily wooded slopes of the Barisan range, a dense, greenish black chain from three to five thousand feet in altitude. A wild inhospitable region of tropical jungle it looks and is. In the early morning the sky is often clear, and the mountains free from clouds. At such times the symmetrical cone of the extinct Talang, further inland, is clearly visible. To the north the Singalang and Tandikat, and the Merapi with its plume of smoke, raise their green slopes against the sky.

In Padang are the home of the governor, the government officers, the headquarters of the army and the Staatsspoorweg or government railway. Here also are located the government warehouses, and a branch of the Java Bank, the government banking institution of the colonies. Padang is the center of the coffee trade of Sumatra. Most of the plantations, both government and private, are near the central portion of the island, the crops coming to this point for sale and shipment.

Although the city contains a population of over thirty thousand people, it is difficult to realize the fact; for, situated in a grove of cocoanut trees, it is almost entirely hidden from view. There are about 2,000 Europeans, practically all Dutch, and 5,000 Chinese; the



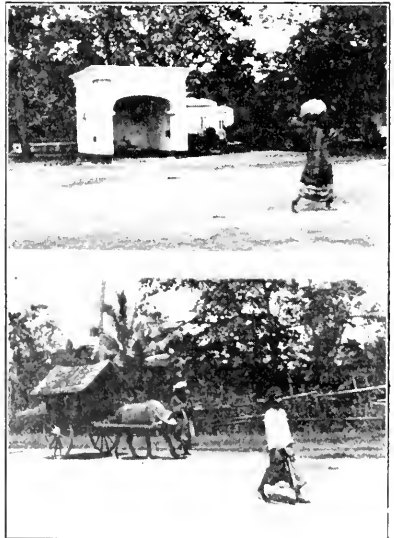
VIEWS IN PADANG.

'HET GROOTSTE HOTEL VAN SUMATRA.'
 'THE MEN . . . FREQUENTLY CARRY NOTHING
 BUT THEIR DIGNITY OR A DOVE-CAGE.'
 THE SHIPS ARE COOLED BY AN ENDLESS
 CHAIN OF MALAYS.

from the adjoining apartments, are features of all the accommodations. The buildings have generally but one story and are raised above the ground three or four feet. They are usually constructed of brick and have cement floors or tiles in the sleeping rooms as well as in the outdoor apartments. With thick tile roofs and overhanging trees they are protected from the direct rays of the sun, but still they are not cool.

remainder are Malays. Here we find the lean-fingered Chinese comprador in the commercial houses, and his cousins in all the trades. Throughout the Dutch possessions the Chinese are heartily disliked and are considered proper subjects of a very searching taxation. Our Chinese interpreter complained that he had to pay a yearly tax on his queue and that another tax prevented his cutting it off. Notwithstanding these measures, they thrive and grow wealthy.

The Oranje, which was our home for two months, like most of the hotels in Netherlands India, is built upon the pavilion plan. The main building contains the dining-room in the center, the out-door reception room in front, and some guest rooms flanking the dining-room. Nearly all the sleeping rooms are in the detached pavilions, and these are the most comfortable. Wide verandas, cut off



VIEWS IN PADANG.

A SHELTER FOR THE POLICEMEN, PADANG.
 A KARROW CART IN PADANG.

The furniture of the apartments is simple, but very comfortable. A huge, square bed with a canopy of mosquito netting forms the chief feature of the sleeping room. There are no bed covers. A good mattress with thin soft pillows for the head and two long, round, hard, cooling pillows complete the sleeping accommodations. There is an open rack on which to hang the clothes, a small table with its 'goode nacht' light and one or two chairs. The open-air apartment invariably contains a Dutch steamer chair—a most comfortable piece of furniture in a warm climate. A clothes line is stretched in front of each suite of rooms, and one must become accustomed to looking out from behind his wardrobe at his neighbors. Every few days all wearing apparel, particularly the woolens, must be hung in the sun to save them from mildew. Even with these precautions it is practically impossible to preserve shoes, gloves and leather goods from damage.

The call 'Spada' summons one of the numerous servants always near.

The meals at these Dutch hotels are much after the table d'hôte system of Europe; one breakfasts when he pleases, but all guests are supposed to have the remaining two meals at the same hours. Before riztafel and dinner, 'spada' brings to the open lobby of the hotel a tray containing the ingredients for the *piht*, the national drink of the Indies, and leaves it for all guests who care to indulge. Holland gin and a little bitters compose this counterirritant to the climate.

Riztafel is a unique meal. As its name implies, it is composed chiefly of rice. An expanded soup-plate is placed before each guest, and from an immense bowl of steaming, boiled rice, he ladles out a liberal supply. After the rice-bearer follows a procession of bare-footed servants with dishes containing chicken, boiled, stewed, fried and roasted; turkey, fried cocoanut, potatoes, gravies, a half dozen kinds of vegetables and lastly an elaborate assortment of condiments and preserves. The guest selects such of these as he wishes, and placing all on his mound of rice, mixes them thoroughly and the *pièce de résistance* is prepared.

The streets of Padang make no more pretensions to being straight than elsewhere in the Orient, but wind about in ways most confusing to the resident of a right-angled republic. The scenes are as unfamiliar as the sounds; the pedestrians and vehicles are jumbled together; there are no familiar lines of buildings anywhere; the canals are filled with native bathers, sousing their heads and rinsing their mouths in the yellow, turbid fluid.

The common beast of burden is the water-buffalo, or *karbow*—great shuffling creatures looking as docile as lambs. It is difficult to believe that many of the animals which we see on the streets have been wild



' PADANG'S STREETS WIND ABOUT IN WAYS THE MOST CONFUSING.'

in the jungles within a few years. Right noble game they make too, ranking with the elephant and tiger in ferocity and danger. In the rivers one frequently sees what looks like the partly submerged branch of a tree, but which, upon closer inspection, proves to be the horns of several karbow enjoying a bath.

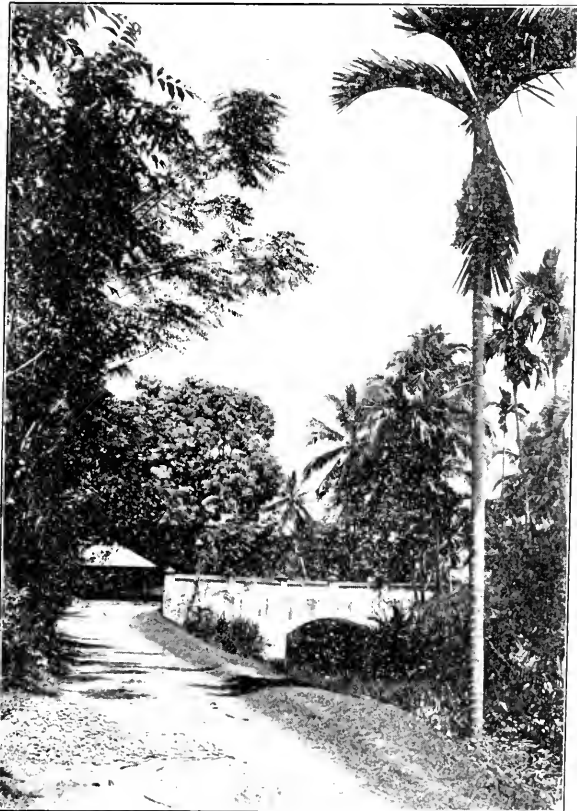
The streets are kept in excellent order for either foot or wheel. There is not a sidewalk in all Padang. The foreigner does not walk much nor far in such a climate, nor does the native if he is fortunate enough to have a fare in his pocket. The ordinary conveyances are two varieties of carts: the dos-a-dos (pronounced dos) with the seats back to back and holding four persons, and the tram with two short seats lengthwise behind the driver's seat. The latter is the more comfortable, if not crowded to its full capacity of five persons. Both varieties are two-wheeled and are drawn by a single diminutive pony of the most contrary disposition. Traveling by this means is cheap, the legal rate being one guilder (40 cents American) per hour. The legal rate is, however, seldom paid if a bargain is made beforehand. As four persons ride as cheaply as one, the Chinese and Malays ride in groups.

At frequent intervals throughout the city are small shelters to protect the policemen and pedestrians from the sudden rains. They are open on one side, and each contains a gong made of a hollow log with a skin stretched across, or sometimes a bell. In cases of fire or crime this gong is beaten to summon help. Many of these shelters contain benches, which are usually occupied in the daytime by some

'Orang Malay,' idly kicking his heels in the air, while his better half passes by with the burden on her head.

We frequently witnessed the operation of repairing worn places in the streets. This work was all done by native prisoners and most elaborately. At first we wondered where the representative of the law was, for no uniform was visible other than the brown one of the convict and the white band of the 'trusty.' Inquiry furnished a more than adequate explanation. The convicts in Sumatra were Javanese, and the hatred between the natives of the two islands is so bitter that there was no danger of prisoners getting away. A similar system was followed in the disposition of native soldiers. To prevent thieves being abroad at night all natives and Chinese were required to carry lights.

Cocoanut trees were plentiful in and around the eclipse camp, and the fruit often furnished a delicious bit of refreshment. No one drinks the milk of the ripened fruit; for this purpose the green nut is selected, before the formation of the meat has begun. One of the native boys



A SIDE STREET IN PADANG. (BETEL TREE IN THE FOREGROUND.)

would tie a cord around his ankles, which enabled him to get a grip of the straight, branchless trunks. A single blow of the heavy knife which he carried in his belt would send the nut to the ground with a thud that was ample evidence of the danger of being hit by one. The large monkey also gathers the nuts with a skill that is marvelous. He is sent up the tree, with a rope attached to his collar. Selecting the ripe nut, he gets it between his hands and rolls it back and forth until the stem is twisted off, whereupon he throws it to the ground. Stories are not wanting of vicious beasts taking this opportunity of killing their keepers with well-aimed nuts. The cocoanut monkey is the enemy of the baby. If he finds one unguarded, he immediately sets about twisting its head as he would a cocoanut.

The dress and habits of the Dutch are well adapted to the climate. Early rising, usually about daylight, is the rule. After a bath and light breakfast, the serious work of the day is taken up and generally finished by midday, when the heat becomes oppressive. After *riztafel* all the tropical world goes to sleep. About 5 o'clock life begins to stir again, the more comfortable hour before sunset and the twilight being utilized for the promenade, for calls and for recreation.

During the early part of the day the costume is almost anything one cares to make it, if one is not engaged in official or other business. The gentlemen are usually seen at home or about the hotels in sarong trousers and loose white jackets, sometimes without slippers and usually without hose. This costume is not uncommon on the streets also during the early morning hours. White duck or drilling is usually worn for business. For the afternoon promenade and for evening functions, dark clothes are customary, and most uncomfortable.

The ladies have much the best of etiquette in this land. Their dress is at all times simple and comfortable. A short sarong skirt, reaching only to the ankles, a loose white jacket of some thin stuff, bare feet encased in slippers or sandals, compose the morning or home costume. Their evening dress much resembles that of their sisters in the temperate zones.

It is not until one has been ashore on the low plains that he fully realizes the character of the heavy tropical heat. The air is saturated practically all the time. With a nearly vertical noon-day sun at all times of the year, and with little wind, there is an oppressiveness during the day in these islands that is unknown in temperate climates. One marvels at the windows and doors, without glass and with large slats, and wonders if it is never cool. He soon finds the wisdom of it and courts all breezes, by night as well as by day. Here it is eternal summer, where clothes are not a necessity, but a nuisance, and where one envies the little brown babies the entire lack of raiment which they enjoy for the first few years of their existence.

One is early impressed with the amount of life: the land is overflowing with the human species and the jungles with the lower forms. Even the atmosphere is charged with it; a piece of paper waved through the air gathers the microscopical forms. A lamp is no sooner lighted than a perfect zoo appears. Great beetles three and four inches long go banging around in their crazy fashion, occasionally taking a header down the back of the unwary. The friendly yellow lizards with their queer little squeaks dart about the walls and ceilings catching flies and small bugs. I have counted a dozen of them in my apartments at one time.

Were the insect and reptile life as active as in the temperate regions, the lot of man would indeed be a hard one. The same conditions, however, which tend to keep the human species inactive, affect the pests also. Perhaps the greatest pest of this part of the world is the white ant, a bloated, bleached-out, repulsive little beast. He does not venture out into the light, but woe unto anything organic if it is left in a dark corner for any length of time. He comes from somewhere and immediately sets to work.

The natives of Sumatra are a wilder, freer race than their Javanese relatives, quicker of action, with keener eyes and bolder looks. At only a few points in the Island have they become subject to the Dutch, and nowhere to the extent that one finds in Java. Many of the Sumatranese are still independent. Friction still exists between them and the Dutch, but I was told that a white man could go almost anywhere unmolested.

Much trouble was experienced by the Dutch in the early part of their rule from the Hajjis. These natives, who had made the pilgrimage to Mecca, exerted almost absolute control over the ignorant masses. There were but few of them, and the necessity for keeping them friendly was consequently great—and very expensive. The Dutch hit upon the idea of making many Hajjis.

The Dutch have been very successful in their management of the natives. They do not interfere with the mild form of Mohammedanism practised by the Malays nor do they allow any outside influence to be exerted. No missionaries are permitted to proselyte or teach among the natives, and the few who have found their way into the country are required to confine their efforts to the Chinese or other foreigners.

Almost the first glance shows the status of the sexes. The women are usually seen with large bundles on their heads and in their arms, stepping along briskly, while the men idle about with slouching gait, frequently carrying nothing but their dignity or a dove cage.

The dress of the men usually consists of a pair of gaudily figured sarong trousers and a jacket, with a large square of sarong cloth twisted into a cap. A sarong is usually worn by the men as a sort of badge

of caste. It is thrown over one shoulder or folded about the waist. They seem to be of no real use, but they can not be left aside. The dress of the women consists of two garments only, a sarong skirt and a long coat of figured calico. Small bundles and babies are carried in a sarong worn as a pouch under the left arm. The sarongs are all of brilliant colors and striking patterns, and few are really pretty.

Labor was very cheap, the watchman at the eclipse station being paid 15 guilders per month, equivalent to \$6.00 of our money. Ordinary labor was to be had in plenty for three guilders per month, and many a family was supported on such an income.

The Malays have their own particular vices. Ordinarily they are not quarrelsome, but when aroused they can be fiends. Knives are the usual weapons, little crescent-shaped things no longer than the finger. This knife is held, as they hold all knives, between the tips of the fingers. The objective point is the abdomen. I tried to get a knife as a souvenir, but found it impossible, their sale having been prohibited, I was told. The most unique method of taking life is that often practised upon faithless husbands, who are given finely chopped tiger whiskers mixed with their food.

During our stay occurred the yearly celebration of the 'soldiers' of Hasan and Hosain. A motley crowd of natives of all ages, in all sorts of grotesque costumes, with faces painted and carrying banners and symbols, paraded the streets day and evening for a week. Their only attempt at music consisted of discordant sounds from tin pans, sticks, gongs and whistles, subdued, fortunately, by the climate. The object of this exhibition is a superstitious one. When the blowing of trumpets fails to bring their gods to life, the believers gather money, throw an image of some kind into the sea, and subside for another year.

The headland which juts out into the Indian Ocean just south of Padang commands an extensive view of the surrounding country. This Appenberg of the Dutch (or Boekit Munyeet of the Malays) is also interesting on account of its sacred monkeys. One Sunday when we had no pressing duties at the eclipse station, we paid a visit to the hill. The natives visit the hill and its monkeys to perform religious rites. On our way we passed one of their cave temples, with its group of worshippers. From the summit it was impossible to see anything of the city except a few of the warehouses along the river; all else was completely hidden in the great grove of cocoanut trees.

I had the privilege of seeing something of the coffee and spice industry through the courtesy of the American consul, who was extensively engaged in the export trade. He showed me through the 'peeling mill' where the hard outer husk of the coffee berry is removed by machinery (of American manufacture), and through his own and the government's warehouses. Much of the government coffee was

very inferior, said to be due largely to the system of labor. The finer grades of coffee come from the private plantations. The coffee business is a monopoly, the government buying the product at a fixed price and then grading it for market. The price received by the government varies all the way from 15 to 60 guilders per picul, the average being about 40. The consul was very proud of the fact that he had sold the highest priced coffee which ever left Padang—90 guilders the picul, equivalent to about 27 cents of our money per pound. This coffee came to America.

The warehouses were redolent with the odors of all kinds of spices. Bales of cinnamon bark, piles of mace and nutmegs, bins of pepper and cloves attested the fitness of the early name for these islands. All of the spices must be sorted very carefully and many of them tested. For example, the bales of cinnamon bark contained a large portion that was absolutely worthless, put in knowingly by the natives who gathered it. This worthless bark can not be told by sight and so each piece must be *tasted*.

After the instruments had all been packed, and while waiting for the steamer, a short trip was made into the Padang Highlands, where the natives were seen at home in their peculiar horned houses.

This little-visited corner of the world offers an attractive field for the traveler who cares to go off the beaten paths. When the official calls had all been paid and the time came to say 'slamat,' I left the island of Sumatra with many regrets.

PUBLIC INTEREST IN RESEARCH.

BY PROFESSOR JOHN M. COULTER,
UNIVERSITY OF CHICAGO.

THE subject I propose to discuss seems to me both timely and important. I recognize that to many scientific men it is a subject to which they are indifferent or which may afford them passing amusement. And yet, there appear in it certain possibilities that may be worth consideration. I do not refer to the general public, to whom information concerning research would be like 'casting pearls before swine,' but to what may be called the intelligent public, the public that thinks and brings things to pass. To develop in proper order what I have in mind, I shall speak of public interest in research under three divisions: (1) its present condition, (2) its possible condition, and (3) its possible results.

1. *Its Present Condition.*

The most available index of the present interest in research is furnished probably by the newspapers and magazines, which try to respond to the desires of their readers. Even a cursory examination of the material they furnish, which may be said to deal with research, shows that it is scant in amount, sensational in form, and usually wide of the mark. The fact that it is scant in amount is a cause for congratulation if it must involve the two other features. The sensational form is a concession to what is conceived to be public taste; and while to a scientific man this form seems to exhibit the worst possible taste, the serious objection is that to secure the form truth is usually sacrificed. That the real significance of an investigation thus reported is usually missed is not to be wondered at, since the reporter is not the investigator and has no scientific perspective whatsoever. Some of the results of this kind of information are as follows:

Men engaged in research are looked upon in general as inoffensive but curious and useless members of the social order. If an investigator now and then touches upon something that the public regards as useful, he is singled out as a glaring exception, and is held up as an example for us all to follow. If an investigation lends itself to announcement in an exceedingly sensational form, as if it were uncovering deep mysteries, the investigator becomes a 'wizard,' and his lightest utterance is treated as an oracle. The result is that if the intelligent reading public were asked to recite the distinguished names in science,

they would name perhaps one or two real investigators unfortunate enough to be in the public eye, several 'wizards' and still more charlatans. The great body of real investigators would be known only to their colleagues, thankful that they were not included in any public hall of fame. And yet the public is not to be blamed, for it is giving its best information; and the fact that it has even such information indicates an interest that would be wiser were it better directed. And this better direction is dammed up behind a wall of professional pride, which makes an investigator look askance at any colleague who has broken through it.

I have been especially interested in noting the rising tide of quasi-scientific papers in the leading magazines, seeking to inform the public of certain striking things and occasionally written by scientific men. These men are bold, if they have their colleagues in mind, but they may have something more important in mind. I judge that from the daily paper to the great magazine is the range of agencies by which research can reach the intelligent but non-scientific public; and the conclusion seems justified that while the daily press is as bad as it can be in this regard, it still voices an interest in such subjects; and that the leading magazines are becoming distinctly stronger in this feature. The intelligent public is certainly interested, but it is just as certainly not intelligently interested.

2. *Its Possible Condition.*

The present condition of public interest in research, as described above, does not seem to invite a large measure of hope that it can be improved, even if this were thought desirable. The desirability of a stimulated and intelligent public interest will be discussed later; for the moment the securing of such interest will be considered. The problem is to substitute information for misinformation, so that interest may become intelligent.

I have taken occasion to discuss this subject with managing editors of newspapers and magazines, and find a general opinion that many subjects of research would be of great interest to the intelligent public, but that such material is the most difficult of all to obtain. This does not mean that such subject matter is difficult to obtain, but that the necessary simplicity and attractiveness of presentation are usually lacking. These editors recognize that when the simplicity and attractiveness must be supplied by a 'middle man,' the result is almost sure to be not only a series of misleading statements, but also a disappearance of the scientific atmosphere. This middle man who stands between science and the magazine public is a curious product of the present situation. He may simply *interpret* for the public, putting the language of science into the language of literature; but when he begins

to *observe* for the public he joins the clan of 'poet-naturalists,' who, as John Burroughs has said, 'hold the eye close to the facts and will not be baffled.' It must be confessed that very seldom are they baffled. The judgment of the editors referred to, therefore, is that the middle-man should be abolished, in so far as he is merely an interpreter. As for the poet-naturalist, he will cease to appear scientific when the middle men are abolished.

This means a distinct invitation to investigators to become their own interpreters, an invitation which will come to most of them with a distinct shock, if not as an absurdity. Taking it seriously, however, and waiving its absurdity for the moment, what is there in the way of accepting the invitation?

The readiest answer to this question is that it would be a waste of time, and under the present conditions the answer seems true. The investigator's chief concern is his investigation; and he does not see how it can be benefited by any information he may give to the public. If such a benefit is not evident, the invitation should be declined; for to accept it under these circumstances is to strain after a little cheap notoriety.

But the invitation involves a change of conditions, a change in the policy of editors, on the one hand, and of investigators on the other. If under the new conditions it can be made to appear worth while to accept the invitation, what is there still in the way? It is not to be expected that investigators in general will undertake to learn the art of popular writing, or will take the time to exercise it if they do not need to learn it. The only thing asked for is a simple statement, in terms that intelligent, but non-scientific, persons can understand, of the nature and bearing of an investigation. This would be authoritative, and would be used, so our friends, the editors, assure us, not only in checking the wild vagaries of the reportorial imagination, but also in bringing to the public a large amount of information which no reporter could discover. Emphasis is to be laid upon the *bearing* of an investigation, for, naturally, this is the point of vital interest to the public, and the point of importance, as I shall show later. For example, I might describe in perfectly simple English the results of some experiments I had performed with evening primroses or with pigeons, and people would simply wonder at the things that amuse some men; but if it were added that these experiments have a bearing upon the origin of species and upon heredity, the investigation at once assumes a dignity and an importance that even the public will be quick to appreciate.

One sees repeatedly in the public press joking, if not sneering, allusions to the immediate subject matter of some investigation, which seems insignificant or even ridiculous to the uninformed, when, in fact,

it has to do with a very important general subject, which would intensely interest the intelligent. I presume that every investigation by an experienced investigator is suggested by its general bearing, the immediate material merely being that which is most available. It is this feature that the reporter always misses, and a strategic movement is represented to the public as a dress parade.

It may be well to intimate here that in all this discussion professional investigators are in mind, and not that host of still-born investigators whose first and last publication is a doctor's thesis.

Just how the clean-cut statements referred to may reach the public, and in what form, are matters of detail which purveyors to the public interest must work out. The general principle is that the investigator's own statement shall be available for such use.

3. *Its Possible Results.*

This is the vital consideration, for all the trouble and the outraged feeling involved must be justified. It means a campaign of education in reference to investigation, an education of the intelligent public. Perhaps it remains to be proved whether this public can become educated in this matter, but the interests at stake seem to make it worth trying. I shall put aside as of secondary importance the more just estimate of investigators that would result, the pulling down of some conspicuous names to a proper level, and the better leveling up of scientific men in general. The present situation in this regard may be irritating and even disgusting, but it is not of sufficient importance to justify what has been proposed. In my judgment, the justification will be found in two results, which, taken together, must seem important to every investigator.

1. *It will show that research is practical.*—I recognize at once, in using this statement, that if the universities have stood for anything, they have stood for what is called 'pure science.' I would be the last one to recommend a departure from this standard, for my thought is to show that pure science is the real foundation for any effective applied science; and that the 'practical science' of popular definition is the rankest empiricism.

A recent and conspicuous illustration in my own field may be cited. When Moore was busying himself with the study of algae, he would have been characterized by the public as highly impractical, for not only were his studies apparently foreign to human interest, but that group of plants is peculiarly within the domain of 'pure science.' However, when he was transferred to the Department of Agriculture, and began to apply his training, the problem of polluted water-supplies, which had cost empiricism, called 'practical science,' many thousands of dollars in attempting to solve, met with almost immediate and bril-

liant solution. The same training has devised inoculation for nitrogen-impooverished soils; and now the public regards Moore as a distinguished example of a scientific man who began to amount to something as soon as he abandoned pure science! The illustration is probably the more striking since the investigator himself applied his pure science; but it illustrates the fact that such practical results are reached most surely and most quickly from the vantage ground of pure science.

What the public needs to know is that an effective and economic applied science must root itself in pure science, just as a tree must root itself in the soil. It was with this in view that I laid emphasis upon the general bearing of an investigation as the important feature of its public report. It need not be a practical bearing, to use 'practical' in its conventional sense; for in many important investigations such a bearing is either lacking or trivial; but simply the real bearing, which, if it does not appeal to the current desire for immediate practical application, does appeal to that better desire for information about important things, to that delight in feeling that the great things are being sought after. The public must be taught that even research that merely means increased knowledge is immensely practical, for it means an attitude of mind, a method, a body of knowledge that must be available for every important problem, whether it happens to be one of economic interest or not.

Such education, as all education, will be slow, but the increasing number of investigators who are being drawn from pure science to applied science will give increasing illustrations of the necessary training for results.

2. *It will secure endowment for research.*—To show to an intelligent public that the investigations in pure science are the only kind that are fundamentally practical would not be worth while if it did not result in a better support of research.

It is clear that the question of adequate support for research is the most serious one that confronts American science to-day. Teaching and administration tax the time and energy of established investigators; the expense of investigation is becoming greater; the opportunities for it in the way of position and equipment are so few that there is no inducement for young men to become investigators. Not equipped for the men we have, the very desirable multiplication of men is impossible. And yet, such equipment as we have is dependent in certain measure upon our output of men. In spite of these conditions, the volume of research is increasing yearly, and young men are still found who will not sell their birthright for a mess of pottage. These conditions will continue to become harder unless some relief is found.

The Carnegie Institution was intended to furnish some relief.

and the great flood of dammed up opportunities that broke loose when this chance offered itself is a matter of record. This endowment, vast as it seemed to any individual, proved to be a mere pittance as compared with the pressing needs of research in America. To choose among these needs was bewildering, and no committee could choose wisely in every instance. But whether the choosing was wise or not has nothing to do with the impressive illustration afforded of the pressing needs of research even in its present stage of development. There is no need at present of a fund to *stimulate* research; what it needs just now is *opportunity*.

What Mr. Carnegie was brought to see, the intelligent American public must be brought to see, for one institution and one board of control can not hope to meet the need. The appeal to American interest is utility, and there is no need to blink the fact. If our relief, therefore, is to come from American interest, we must tell the public what we are doing and of what service it may be; and this is to be done, as I have shown, without any change in our subjects or methods of research. I may say in passing, however, that it has long seemed to me wise to select among profitable subjects of investigation, which are included in our immediate interest, those that may have some bearing upon human interests. Nothing is lost by such a choice, and investigation is strengthened thereby in public estimation. I have not the slightest sympathy with those who select subjects for public effect; but I have also no sympathy for those who avoid them when they come in the natural sequence of work.

Why should not the public expect some tangible service from the large body of men best equipped to render it? This is the question I was asked by a prominent business man whom I was trying to interest in a botanic garden, and after I had explained that such an equipment would make certain important investigations possible that could not be undertaken without it. One may inveigh against this utilitarian point of view, but that it exists is a fact, and it does not alter a fact to despise it. Should it have been expected that this business man would break suddenly with the training of a lifetime, even when a botanic garden with an alluring corollary of experiments was presented suddenly to his vision? It was impossible to educate this particular man in a short time, but had he heard over and over again, for he is interested in horticulture, that the very experiments proposed made possible a better horticulture, he would not have asked such a question. An appreciation of the utility of purely scientific investigations must get into the atmosphere. An atmosphere of appreciation can be created for such non-utilitarian things as music and art, even in a commercially saturated environment, but it is not by keeping still about them or by only revealing them to the cult.

I am afraid that scientific training leads too often to idealism. We know the conditions we should have for our work, and we are impatient with those who do not recognize them. We act as though the suitable conditions should be offered to us freely as our right; and when they are not, we rail at those who could help us but do not. In fact, I have been surprised at the confidence shown in us by those who have no conception of what we are doing, and whom we do not take the trouble to inform. This argues well for the possible results of a persistent general campaign of education.

I have no large faith that there will be any such campaign, for in my experience investigators have cultivated indifference. Each man is anxious for his own investigation, but not troubled to the point of effort about investigation in general. My chief concern is to secure recognition of the fact that we are being treated about as well as we can expect; and that there is an opportunity for us to do better for ourselves, and far better for investigation in general, if we care to avail ourselves of it.

This is not a matter for organization or concerted action on the part of scientific men, but it is the cultivation of a general sentiment among them in favor of giving the public such information as has been suggested; a sentiment that acts when opportunity offers. This general sentiment is absolutely necessary, for, so far as I know, it is all the other way at present; and the man who sees his work reported in the public press shudders a little when he thinks of his colleagues. After all, it is the good opinion of his colleagues that a scientific man prizes most, and rightly; and he must feel them solidly behind him in any new departure.

The attitude of our colleagues across the Atlantic can not be taken as our guide in this matter, for our institutions and our people, whether we approve of them or not, are different. Besides, our European brethren are facing to-day the same problem, and with a much more hopeless outlook. I have been assured by my German colleagues that since their government has become deeply interested in world politics the chances for increased support for research have diminished, and they regard private support as hopeless. We have behind us a public more prosperous and much more generous, accustomed to support liberally what it is interested in. If this can be taken advantage of, there is no reason why research in America can not be developed to an extent that is without precedent.

THE VALUE OF OLD AGE.

BY JOHN F. CARGILL.

DO the creative or initiatory faculties of the mind begin to wane at middle life? And would the ransacking of all historical data show that a majority of the greatest things in the world have been achieved by men under forty? To undertake anything like a positive solution of so great a problem is naturally out of the question; but one plain aspect of the matter may be shown—leaving it to the reader, or to some future writer having a passion for statistics, to determine upon which side are ranged the exceptions that prove the rule. It may be said with confidence that one fact is indisputable: We can mention no field in the broad domain of science—including astronomy, geology, biology, psychology, sociology, electromagnetism, electricity, engineering, invention, mathematics or medicine that does not owe much indeed to men of advanced years. This statement holds good of the fields also of mechanics, philosophy, statesmanship, letters, history, finance, music, art, discovery, exploration, navigation and many others.

A noteworthy beginning may be made with the five great savants who, within the hundred years just past, have given to mankind entirely new concepts, new understandings of the universe and of life; have revolutionized the greater sciences, and made it necessary to build anew from the beginning. We will take them in chronological order. Immanuel Kant died in 1804 at the age of seventy-six. His *Kritik* ('Critique of Pure Reason') was written, or appeared, after he had reached fifty-seven: a work of such vast comprehensiveness, such subtle, active and far-reaching intellectual resourcefulness, that the world has produced but a handful of men since his day who could fully appreciate or appraise him. His 'Contest of the Faculties' appeared when he had passed seventy. His primary formulation of the nebular hypothesis was when he was in the thirties; but much of its elaboration was concluded many years afterward. Pierre de Laplace, his coadjutor in the hypothesis which shook the world, died in 1827 at the age of seventy-eight. Laplace issued the earlier portion of his great 'Exposition du système du monde' at about the age of fifty; and the completion of this monumental work containing the nebular hypothesis was not published until he was past seventy years.

The next great step forward in enlightenment is from the field of astronomy to that of geology, and we come to Sir Charles Lyell, who

died in 1875 at the age of seventy-eight. The most important portions of Lyell's work were done after he had passed forty years; complete and sweeping revisions and enlargements of his earlier work were done late in life, and even down to within three days before his death, at the age of seventy-eight years, he finished a revision of his 'Principles of Geology,' a work which amazed and electrified scientists of all nations, and remains to-day the unchallenged great text-book in that field. Lyell's is the broadest and best-balanced mind which has dealt with deep-lying geological problems. In effect, he may be said to have created the science of geology. His work marked the second epoch in the thought of mankind, supplying the needed second link in the chain of evidence of planetary evolution. He applied in geology the principle of gradual development to the earth's crust, which Laplace and Kant had previously wrought in astronomy concerning sun systems and planets; which Darwin accomplished afterward in biology for living forms and organic life, and Spencer achieved for psychology in human consciousness and thought, and for sociology in human society and government. And, moreover, the fuller amplification of Lyell's work was made after he had passed sixty years.

With Lyell's work planetary evolution came to be a recognized and definite truth; and then came Charles Darwin. Darwin was born in 1809, and lived until the age of seventy-three. His lifelong habits of thought, and his methods of research are too well known to be repeated, but it may be said that up to the age of forty-nine years he devoted himself almost wholly to accumulating stores of experience and observation, and to the planning of the great work which was to come afterward. 'The Origin of Species,' written at the age of fifty, sounded the farthest depth of biological knowledge and created such a whirlwind of controversy as no other book has done. His 'Descent of Man,' written at the age of sixty-two, was not less remarkable, and had an effect almost as widespread and profound. No man then living, either young or old, had the preparation, patience in the working out of details, breadth of mind, modesty or the honest simplicity of character, necessary to the carrying out of his tremendous task. Darwin may not have created the science of biology, but unmistakably he brought it out of a vague, confusing and conflicting state, reduced the mass of evidence and details to concrete form, and made it into an orderly and perfect system.

Herbert Spencer, the latest of this remarkable group of investigators, died in 1904, at the age of eighty-three. Spencer's mind did not begin its best functions until he was well on into the forties. He was storing up until then—his mind was incubating, as it were. At forty he had made merely a rough outline or program of his 'Synthetic Philosophy,' which massive work he was to carry out triumphantly in

his riper and broader years. 'First Principles,' the first work in the series, was finished when he was forty-two years old; 'Principles of Psychology' when he was fifty-two; 'Principles of Sociology' when he was fifty-six and one of the greatest in his ethics series, 'Justice,' came at the age of seventy-one. He was close upon eighty when his monumental 'Synthetic Philosophy' was completed, and the person has not yet appeared who has discovered any diminution of his powers from the earlier work to the last page of the final volume.

The only aspect of the matter that is worth troubling about is the assertion that no creative, original or vitally important work is accomplished by men who have passed forty years. The difficulty is to make selections from the abundance of rich material at hand. We have a casual list, and one of the first names is that of an American. Benjamin Franklin was eighty-four years old when he died in 1790. His early life and achievements do not concern us, and are well known. When he was past sixty he was the chief instrumentality in the repeal of the Stamp Act; and after he had reached seventy years he was the main element of inspiration, energy and brains in the first continental congress. At this period (1776)—when he was at the head of the mission to the court of France in aid of American finance—it is said of Franklin that he was 'one of the most talked-of men in the world.' This mission in its all-around results to America and to the world at large has had no parallel. Its chief elements were the bringing about of an alliance between France and the colonies; and the negotiation of a loan of twenty-six million francs, obtained mainly through his own wonderful personality—it certainly was not upon any established or recognized basis of credit. This, after he was seventy years old. At the age of seventy-seven Franklin was one of three commissioners who negotiated the peace treaty with Great Britain after the revolution. Even at the age of eighty his countrymen considered his services invaluable, and refused to be deprived of them. He devised the most original, valuable, important and far-reaching feature of the constitution of the United States, namely, that which gives the states equal representation in the Senate and representation according to population in the House.

A large book could be filled with equally interesting and pertinent data concerning the achievements of men past middle life; but we may do little else than mention some of them. Christopher Columbus was fifty-six years old when he discovered America; and when he returned from his last voyage to the West Indies and South America he was sixty-eight. Magellan was forty-nine years old when he sailed away upon his globe-girdling voyage—the first man to circumnavigate the world. Baron Humboldt postponed until he reached seventy-six the crowning work of his life, finishing it ('The Kosmos') with high

honor and credit. It is a work which despite certain shortcomings, inevitable on the part of any writer at that date, has been declared a successful attempt to portray the universe. Perhaps more than all else it displays the grand and comprehensive intelligence of a great man even at the age of eighty years and beyond. Goethe was eighty-three when he died. At past sixty he finished his 'Theory of Colors,' and he laid out for himself a completely new field of literary activities after he had reached sixty-five. He finished 'Faust' at eighty, and careful criticism has long ago declared that the second part of 'Faust' is the most important part of the poet's life work. Richard Wagner died at seventy. Wagner did not reach the zenith of his powers until he was fifty. The entire 'Nibelungen Ring' was produced after he was sixty years old; 'Parsifal' was written at sixty-four. Haydn died at seventy-seven; his oratorio, 'The Creation,' was written at sixty-seven years, and 'The Seasons' some years later. Handel died at seventy-four. He composed 'Saul' at fifty-three; his greatest work, 'The Messiah' at fifty-six; 'Belshazzar' at fifty-nine, and other works until he had passed seventy years. Gerome the artist died at eighty. He did not reach his greatest power until after he was forty, and much of his splendid work was done after sixty years. Verestchagin was sixty-three when he was cut off in what might be called the vigor and prime of his work by the blowing up of Admiral Makaroff's flagship a year ago. W. W. Story, the sculptor, died at seventy-six; he was a lawyer and writer of law books in early life, and did not take up sculpture until forty. In this he was eminently successful, as well as in the literary field which he continued almost to the end of his years. Lord Kelvin (Sir William Thomson) is now eighty-one. He was at the head of the department of natural philosophy at the Glasgow University until seventy-two years of age, and his work in the departments of physics and mathematics has continued to the present. After he had passed forty years he originated the mirror galvanometer, and the siphon recorder which solved one of the greatest problems in submarine telegraphy. His works upon navigation, matter, physics and geology, executed after he had passed sixty years, are among his strongest and best. Faraday died at the age of seventy-six. His discoveries of the effect of magnetism upon the polarization of light, and diamagnetism were between the years of fifty and sixty, and many important discoveries in chemistry and electro-magnetism continued until late in life. Dr. O. W. Holmes entertained and delighted the world with his writings until he was eighty, and died at the age of eighty-three. John Fiske did all of his historical work after he reached forty, and the most important of his productions, both historical and philosophical, were after he passed fifty. Commodore Vanderbilt made eighty

millions after he was seventy-five years old. These are but a few of the names at hand.

Coming down to the present day, and to men who are in advanced life, and living and working amongst us, we might mention our beloved Mark Twain, now seventy, who failed in business for a heavy amount at sixty years, has paid his debts to the last dollar and has retrieved his own fortunes, whose writings at three-score and ten are scarcely less amusing than those of his youth, besides being vastly more instructive. Dr. Wier Mitchell is now seventy-six, and after a life of distinguished services to the world in his profession he is still active, and in the present year is completing a work of fiction which is thought to be his best. Dr. Mitchell did not begin writing until he was past forty; since when he has published various scientific works as well as books of fiction. Andrew D. White is now seventy-three, has performed important diplomatic missions up to the age of seventy, and has contributed much to philosophy and letters since he reached sixty. Professor Simon Newcomb, now seventy, did not begin to write until he had passed forty, was called to the chair of mathematics at Johns Hopkins University at the age of forty-nine, and his mind is still undimmed and vigorous. Professor Goldwin Smith is now eighty-two; most of his work has been done since he passed fifty years, he is yet writing, and it is still a pleasure and profit to read anything that comes from his pen. John Hay* is to-day, at the age of sixty-seven, with the exception perhaps of Benjamin Franklin, the greatest diplomat America has ever produced. He was appointed minister to England at the age of fifty-nine and secretary of state at sixty. J. Pierpont Morgan is now sixty-eight; his greatest achievement—the greatest industrial organization the world has ever known—the formation of the United States Steel Corporation, was long after he reached the age of sixty years, and nobody has thus far perceived any weakening of his mental powers. Andrew Carnegie is in his seventieth year; has achieved his uncounted millions since he reached fifty years, and his intellect to-day is sufficiently strong so that when he speaks the whole world pauses to listen.

The world's need of men of advanced years has perhaps never been so well presented as in Nathaniel S. Shaler's book, 'The Individual,' the main purpose of which was to present an account of what man's individual life means in the great order. In considering that valuable work it is well to bear in mind that five years ago, when it was written, Professor Shaler was in his sixtieth year, and that he is still professor of geology in Harvard University and dean of the Lawrence Scientific School.

In the chapter wherein Professor Shaler considers the question of

* This article was in type before the lamented death of John Hay.

the uses of the period of old age, he shows how the presence of three or four generations in a single social edifice gives to it far more value than is afforded by one or two. While the elders may contribute little to the direct profit of the association, they serve to unite the life of the community and bridge the gap between the successive generations. Professor Shaler shows that the average man up to the age of perhaps fifty has little or no time for calm reflection; that the necessities of existence demand that he pursue the gainful life, which is always more or less strenuous. Whatever possible period there may be for the individual to pursue the intellectual life must come afterward. And it does come. Is it necessary to argue that the world needs the assistance of the calm reflective mind? Remove this possibility, and mankind may never be able to learn whether life has either meaning or value—in the larger sense.

Recurring wars, he says, repetitions of political follies and the successions of commercial disasters, all show the need of adding in every possible way to the strength of the bond between generations, so that the life of society may gain a larger unit of action than is afforded by the experience of most of its active members. If the deeds of any single period could be the result of the experience of three or four generations of experienced men, rather than that of one, civilization would be an immense gainer. There would be fewer recitals of failure, fewer reversions toward savagery. This necessity is made evident, he says, because, notwithstanding the resources of our printed records, they convey only imperfectly the quality of one time to that which succeeds it. The real presence of the generations is necessary to the greatest extent that can be had.

He says that the idea of the apparent uselessness of man in advanced years is a survival from the time when a man's value in warfare was the paramount consideration; and he adds, "The generation which has seen an aged Gladstone guide an empire; a von Moltke at the three score limit beat down France; and a Bismarck at more than three score readjust the Powers of Europe, has naturally enough given up the notion that a seat by the chimneyside is the only place for the elders."

A SUGGESTIVE CASE OF NERVE-ANASTOMOSIS.

BY PROFESSOR GEORGE T. LADD,

YALE UNIVERSITY.

SUCCESSFUL cases of the anastomosis of motor nerves presiding over different groups of muscles have been several times reported since 1897. Some of these cases have resulted in the transference of function between the flexor and the extensor nerves of the same extremity; in other cases, nerves serving so different purposes as the sympathetic and the pneumo-gastric have been successfully crossed. The anastomosis of mixed nerves offers, of course, a more complicated problem.

In 1898 Dr. Faure attempted to cure a case of facial paralysis due to destruction of the *Nervus facialis* by uniting its peripheral end with that portion of the *Nervus accessorius* which supplies the trapezius muscle. But in this case a satisfactory restoration of the function of the facial nerve was not secured. Still later experiments upon animals in Munk's laboratory, with a view to effect a functionally satisfactory anastomosis of the same two nerves, resulted in a partial success. And one instance of this particular operation in the case of a man, which was attended by a somewhat marked recovery of function, was communicated to the Royal Society by Dr. Kennedy, of Glasgow, in November, 1900. The same authority reported several instances of the same class of cases in the London *Lancet* for March 1, 1902. In one of these cases, Dr. Kennedy, operating "for facial spasm, divided the facial nerve and united it to the spinal accessory with the result that the face recovered its power of movement to a great extent, but that whenever the patient lifted the right arm a spasm of the face was produced."

The case of anastomosis, to which I wish now to call your attention, was performed by Dr. Harvey Cushing of Baltimore, in the spring of 1902; and it consisted in transferring the proximal stem of the divided accessory nerve *in toto* into the distal end of the injured and paralyzed facial. The injury to the facial nerve was in this case caused by a bullet wound which completely severed the nerve on the right side of the face; and it involved a loss of the sensations of sweet, sour and bitter substances over the anterior two thirds of the tongue on that side, and a total motor paralysis of the same side. The patient could not close his right eye; lachrymation and other discomforts of facial paralysis were present; and none of the muscles

responded either to the emotions or to the volitions which control them in their normal state.

The character of the anastomosis, surgically considered, will easily be seen from the charts (Fig. 1 and Fig. 2); and the unfortunate condition of the patient on making the effort to close his eyes is represented by the accompanying photograph (Fig. 3).

Dr. Cushing's surgery, so far as the completeness of the union effected between the two nerves was concerned, seems to have been unusually successful. This fact gives additional interest to the discussion of the results from the physiological and psychological points of view. At the time of the operation, owing to the healing of the injury done to the chorda tympani, the sense of taste had largely returned; but 'the patient's face had become, even during repose, much drawn to the left, and an effort to close the eyes would result in the peculiar grimace characteristic of facial paralysis, with tilting up of the eyeball,' as shown in the photograph (Fig. 3).

Almost immediately after the operation the patient insisted that his condition was improved; that he was no longer troubled with lachrymation, less troubled with saliva, and better able to dislodge food from his flaccid cheek. He also thought that some power of motion had returned to the eyelid. The doctor urges that this last symptom of improvement could only be due to the inhibitory action of the muscle concerned in raising the upper eyelid; the other 'subjective assurances of improvement' he confesses that he is at a loss to explain. About them it would seem we must say, either that the patient was altogether mistaken, or that at least some slight nervous impulse was already passing over the recently united nerve-tract?

On the tenth day after the operation the patient was sent home, provided with a small galvanic battery which he used for daily electrical treatment, and was later required to exercise the facial muscles persistently before a mirror. From this time on a fairly steady improvement was noticeable, beginning with the decrease in the asymmetrical appearance of the face while at rest, the lessening of the cleft between the eyelids; and ending with the more and more highly differentiated voluntary control of the facial muscles and even with the partial recovery of their response to the varied forms of emotional excitement. On the ninety-fifth day the patient reported that, while galvanizing the muscles and at the same time watching his face in a mirror, he noticed to his surprise, on moving his shoulder, that he could produce considerable contraction in the paralyzed muscles. As he expressed it: 'When I wish to laugh straight, I can help it out with my shoulder.'

A more particular description of this patient's condition at only two points of time subsequently will be quite sufficient for my purpose.

At the end of 168 days the asymmetry of his face when at rest was barely appreciable. He could to a slight extent dissociate movements of eye, nose and mouth. He could almost close his eye by voluntary effort. He could pronounce labials perfectly. He could pucker his lips, although not enough to whistle. He had considerable freedom of facial movement without lifting the arm or shrugging the shoulder. But "Elevation of arm and shrugging of shoulder still called forth general contraction of facial muscles which could not be controlled and which was sustained." The condition of the patient's facial muscles at rest is seen by the photograph taken at this time (Fig. 4). Another photograph (Fig. 5) shows the result of a volitional effort to contract

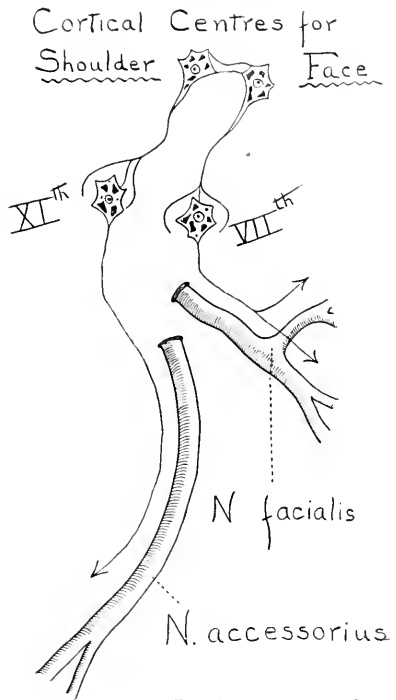


FIG. 1.

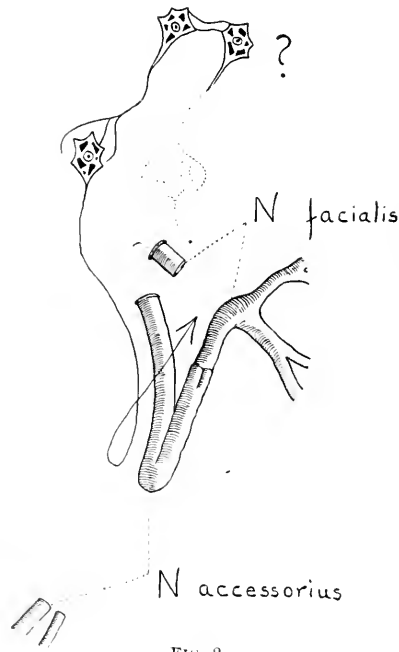


FIG. 2.

the facial muscles, when aided by the arm elevated but completely at rest. At the end of 287 days the volitional control of individual groups of muscles had quite completely returned and could be effected without associated shoulder movements of contraction in the other facial muscles. And although emotional expression had not improved to the same extent, it had returned in considerable measure. How involuntary contraction of the face was still produced by a sudden and vigorous elevation of the arm and shoulder is apparent from a photograph taken at this time (Fig. 6). But how, at the same date, symmetrical closure of the eyes was possible, without associated shoulder movements or the contraction of

other facial muscles is seen illustrated in another photograph (Fig. 7).

A recent letter from Dr. Cushing summarizes the results obtained at this date, November 1904, by several similar operations in the



FIG. 3.



FIG. 4.

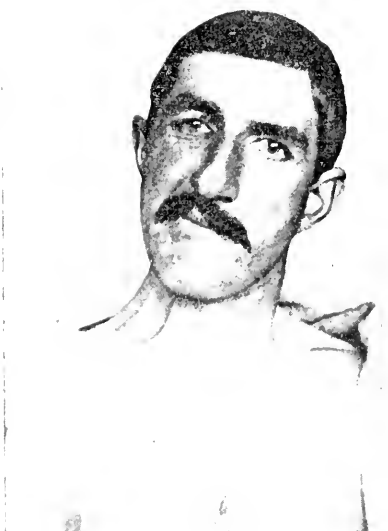


FIG. 5.



FIG. 6.

following words: "The first thing to return after the anastomosis is an involuntary movement of the face, associated partly with a volitional movement (shrugging the shoulder, for example) of the muscles

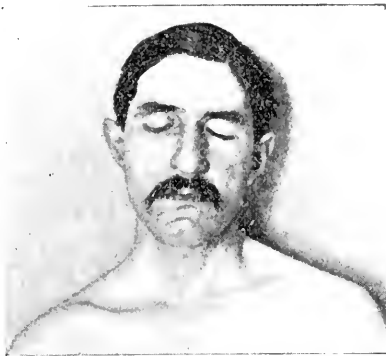


FIG. 7.

supplied properly by the spinal accessory. Following this in a few weeks there is some power of volitional movement in the paralyzed muscles of the face, without association of shoulder movements. Last of all comes—if it comes at all—the emotional movements over which the patient has no conscious volitional control.”

This case which I have now presented in barest outline (and all similar cases of recovery of voluntary and emotional control of paralyzed muscles after anastomosis) raises a number of questions of interest to students both of cerebral physiology and of psychology from the physiological and experimental points of view. Among these the chief is, perhaps, the problem as to what takes place in the cortical centers that is brought about by the changes in the peripheral tracts through which the centers control the different groups of muscles. No completely satisfactory answer to this problem seems at present to be anywhere in sight. But there are three or four tenable hypotheses which may—probably with at least some factors taken from each—contribute toward the better understanding of the problem.

Of such hypotheses the first which I will mention suggests that a more or less nearly complete substitution of function took place between the center of the N. facialis and that of the N. accessorius. Their proximity would be favorable to this—the two centers being not more than about one inch apart. That the cortical center of the accessory nerve did exercise some control over the facial muscles through the united accessory and facial nerves is apparent from the effect produced upon those muscles by raising the arm or shrugging the shoulder. With the general fact of a certain power of substitution of new cerebral areas for disused or injured ones, cerebral physiology is familiar. But how centers so unlike in the character and variety of the muscular functions which they control as are the center for the facial muscles and the center for the trapezius muscle could substitute for each other, is difficult to imagine. Inasmuch, however, as the cortical

area, which was formerly 'accessory' in the control of the arm movements, evidently was accessory still in the control of the facial movements, as soon as the juncture of the new nerve-tract was complete; it is possible that the continued *exercise* of its functions by electrical and volitional stimulus developed the required variety and differentiation of function necessary for facial control. How the cortical center for the *N. accessorius* knew (*sic*) that it was called upon to come to the rescue and improve its discerning qualities, as a part of a more complex and intelligent motor system, may remain for us an unanswerable question.

In connection with this hypothesis we may perhaps help ourselves out with another. The fitting of hitherto unused nerve elements with the medullary sheaths necessary for their employment in voluntary motor functions would seem not to be an improbable assumption in the present case. The researches of Ballana, Stewart and others have shown that the regeneration of fibers in cut nerves is not, as was formerly supposed, effected by the growth of the proximal extremities of the axis-cylinders, but by axis-cylinders shot out from longitudinal cells which appear in the distal segment itself. Thus chains of cells are formed which fuse together and become invested with medullary sheaths. Flechsig has also shown that in the human infant at birth, while all the fibers of the spinal cord except those of the pyramidal tracts, which are used especially as conductors of voluntarily initiated impulses, have become myelinated, the vast multitude of fibers in the brain have not become so. According to Professor Sherrington, all this suggests a conclusion which has other evidence in its favor, namely, that a nerve-fiber is not a single nerve-cell process, but a series or chain of nerve-cells forming a functional continuum. The reason, then, why regenerated nerve-fibers do not attain maturity, and so perform their appropriate functions, unless they become united with the central end of some nerve, is that only by this union can they get an opportunity of actually performing these functions. That seems to amount to saying that the call upon them to perform unaccustomed work causes them to fit themselves for this work.

It is not, therefore, too violent an assumption to suppose that, in such a case of recovery of voluntary and emotional control of paralyzed muscles by anastomosis as I have narrated, a new cerebral apparatus of control may be called into use by the process of myelinating the necessary nerve-elements. Such a process might be relied upon either to equip the cortical center of the accessory nerve for its new and more varied functions of control, or to prepare new paths of connection between this center and that which had formerly exercised exclusive control of the muscles of the face through the facial nerve. In a word, the building process in the brain, finding much of the

old mechanism thrown out of its accustomed use, may have made ready another center and new tracts for the same use.

This hypothesis leads pretty directly to another which seems to be demanded by some of the facts of the case under examination. A more and more highly differentiated volitional control was obtained over the facial muscles; the stimulus of the various emotions, without the accompaniment of volition, met with a better response; and the sight of the condition of the facial muscles as afforded by a mirror was of help in gaining this increased control. All this experience would seem to prove beyond doubt that the higher cortical centers concerned in conscious volition, in emotion and in the perceptions of sight had somehow established the necessary new connections with the center, lower down, in control of the N. accessorius. In a word, whereas formerly, when the accessory nerve was only concerned in helping to lift the arm and shrug the shoulder, these volitional emotional, and visual centers, had paid little or no attention to their influence over the cortical center of this nerve, now that this center and this nerve were being called upon for unaccustomed and more elaborate functions, they found out a way to get into connection, and to bring the new apparatus under their control. But these volitional, emotional and visual centers are widely spread over the cortical area. About their special connections with one another, and especially with the center of the accessory nerve, under normal conditions, we are much in the dark. And how they could go to work to solve, in any length of time and even partially, the problem of readjusting their functional relations to the new and abnormal conditions, offers a problem as yet quite unanswerable by cerebral physiology.

There is one other assumption which would seem to be at once more simple, more sure, and more effective in explanation, than either of those hitherto made. What was the old cortical center for the control of the muscles of the face through the N. facialis doing all this time? We can scarcely suppose it to have been entirely idle or resting in indifference to the functions of which it had been so suddenly and rudely dispossessed. Indeed, it is as certain as anything about such matters can be that the cortical center of the facial nerve would not be allowed to rest. The fifth pair of nerves, whose function is to transmit the sensory impulses from the facial areas, was unimpaired; and since the discomfort from increased lachrymation, saliva and gathering food in the flaccid cheek was very great, this cortical center must have been perpetually sharply reminded of its neglect of duty. Moreover, every time the faradaic current was applied to the cheek, and the patient tried to get control over the facial muscles, helping himself meanwhile by looking in the mirror, there was undoubtedly a very excessive demand for activity made upon this now

powerless area from the other cortical areas, which were under excitement.

Now we know with certainty that increased intensity of the stimulation is followed by increased area of neural excitement. A spreading of the nervous processes on which the initiation of motor impulses depends—whatever the chemico-physical character of those processes may be—would, then, necessarily take place in the center of the *N. facialis*, in answer to the increased demands made upon it by the more intense stimulation from various higher areas. This spreading would, it is likely, have the double effect of enabling the center to use hitherto unused paths between itself and the center of the accessory nerve; and it might also compel the immature nerve-elements to myelinate themselves in preparation for the discharge of their new functions. When this enlarging area occupied, during its excitement, by the center of the facial nerve, had broken over, so to say, into the center of the accessory nerve, and had made good and useful the newly established connection between the two, then it could virtually resume its old functions of control, although now by a new and more roundabout path.

The assumptions previous to the last would all seem to be helpful, if not needful, to explain some of the features of this case of nerve-anastomosis and sequent recovery from facial paralysis. The last assumption is absolutely essential in order to make any satisfactory progress toward explaining it at all. The other assumptions very speedily bring us to the hitherto impenetrable veil of mystery which is met when any attempt is made to explain the facts of experience by our theories of cerebral physiology or of experimental and physiological psychology. But the last assumption seems somewhat to lengthen the distance to the veil. The picture of the unity in variety of the histological elements, and collections of elements, and of the physiological functions, which belong to the nervous system, offered by such experiences as that of this patient, assists in confirming the views arrived at experimentally by Professor Sherrington and other explorers in this field. But the unity and the variety of this infinitely complex system are not so much matters of wholly predetermined and, so to say, 'made-up' sort, dependent upon unchangeable histological peculiarities externally combined into a whole; they are, the rather, a growth, changeful, adaptable to varying conditions, dependent upon need and use, and conditioned chiefly, if not wholly, upon the possibility of establishing the necessary connections amongst the differently located elements.

Many of the more important and interesting problems of psychology are suggested by this case of anastomosis. No other group of muscles is so expressive, so responsive to ideas and emotions, as those which

are controlled normally by the facial nerve. To read the face is to read the soul, so far as the latter can express itself, or repress its expression, in any physical way. The whole history of this case reverses the normal history of the original development. Instead of the power of control being more and more acquired by experience of muscular and tactual sensations, and of the results produced by the external or emotional stimulation of these sensations, we have the increasing effect of the deliberate and persistent voluntary attempt to regain control, with its advancing degrees of success and increased differentiation; and last of all, and most imperfectly, the resumption of non-volitional motor functions under the stimulation of sensation and emotion. All this certainly looks like the picture of a mind learning how to use a tool, the construction of which has been suddenly so changed as to render it, for the time being, substantially a different tool. This, so far as the cerebral functions are concerned. The transmission of the motor impulses, when once started from the cortical centers, by new and unaccustomed tracts, is an affair of comparatively little significance either to physiology or to psychology.

In this psycho-physical progress, which I will call *the evolution of a more highly differentiated self-control*, all the various familiar forms of functioning, and laws of functioning, when seen from the psychological point of view, are apparent. The ease and ability increase with practise; the motor results are in a measure cumulative; the different forms of sensation-experiences inhibit or supplement and assist each other; and the effects of fatigue make themselves manifest. Such an evolution does not, however, seem explicable as *nothing more* than an increasing complexity, ease and precision of sensory-motor reflexes; although it has all the marks of dependence upon such a mechanical basis. To speak figuratively, what takes place in such cases of nerve anastomosis can not be completely and satisfactorily explained in terms that are applicable to a nervous mechanism, however complex, or complexly and mysteriously subject to improvements of a mechanical sort. An *agency*, that must be described in terms of ideation, apperception of an end to be attained, and purposeful volition consciously directed toward that end, seems also necessary to account for the whole result. If involuntary emotion and externally originated sensory-stimuli were the means of evoking and educating the motor organism, in the first instance; it is, on the other hand, conscious and purposeful voluntary effort which is the most important factor in the recovery of function and new education of the motor organism. And how astonishingly complex and even antecedently improbable, we might almost say, are the resulting histological and functional changes in the organism brought about by repeated volitions, our conjectural analysis of this case has suggested, if it has not made clear.

I am well aware that I shall be charged by some, both physiologists and psychologists, of harping again upon the same old string. But I confess that I am more and more indifferent to this charge. For I am more and more convinced that neither the idealistic nor the psycho-parallelistic theories of the relations of the nervous mechanism to the life of consciousness explain such a case of recovery from paralysis as this to which your attention has just been called. Indeed, both forms of theory seem to me to introduce a confusion, which increases rather than clears up, the fundamental mystery of the facts. To my thinking, nothing which can possibly be said as to why the mind has a body goes any way at all toward explaining how this patient got control of his paralyzed facial muscles, for purposes expressive of his emotions and his volitions, through the N. accessorius and its cortical center, after the direct connection by the N. facialis with its center had been totally destroyed. Nor does any explanation which could conceivably express itself in terms of psycho-physical parallelism seem much more satisfactory.

In a word, this suggestive case of anastomosis, and all similar cases, together with hundreds of other species of phenomena—some of them belonging to our ordinary experience and some of them due to extraordinary situations and developments—all seem to me to point unmistakably to the existence of *dynamical relations* between the nervous mechanism and the conscious mental life. And is not our science, whether we start from the physiological or from the psychological point of view, nothing but a description of this net-work of dynamical interrelations? But in being this, how is it any less scientific or any more essentially mysterious than is any other science? To all science, indeed, of every species, it is just these dynamical interrelations which are the ultimate facts. Behind them it is impossible for science to go. Every science consists in the discovery, classification and formulating under so-called 'laws' of these interrelations. To say *a priori* that that can not be, or is not, which most obviously is—this is to be essentially unscientific.

A VISIT TO LUTHER BURBANK.*

BY PROFESSOR HUGO DE VRIES,
UNIVERSITY OF AMSTERDAM, HOLLAND.

FOR many years I had wished to make a study of fruit culture in California and especially of the production of new varieties. One reason which, more than others, made me decide to accept an invitation to visit California was the prospect of making the personal acquaintance of Luther Burbank.

Burbank is *the* man who creates all the novelties in horticulture, a work which every one can not do. It requires a great genius and an almost incredible capacity for work, together with a complete devotion to the purpose in view, to accomplish such results. Burbank possesses all these qualifications, and his previous achievements have excelled all expectations to such an extent that it is rightly presumed that no possible improvements are beyond his reach. In fact, the most impossible things are attributed to him, and the credulous American people expect from him novelties which any person who knows would immediately declare to be nonsense. I once had a conversation, in a Pullman car, with a lady and a gentleman who told me all kinds of interesting stories about plants and fruits, about climate and places and many other things. They knew, of course, Burbank. Every American does, who pretends to know anything about fruits. They told me all about the large and juicy plums, the new pears, the beautiful flowers, and a number of other creations of his. But by far the best and most delicious fruit, entirely new in form, color and flavor, was, they said, a hybrid between a raspberry and a mulberry! Over this mystic novelty her enthusiasm was inexhaustible!

As soon as I had decided about my plans I wrote to Burbank and told him my desire. I had previously been in correspondence with

* Authorized translation from the Dutch, by Dr. Pehr Olsson-Seffer, Stanford University. This article was written by Dr. H. de Vries, the eminent botanist and originator of the mutation-theory, while in California last summer. It was originally published in the magazine 'de Gids' in Holland, and forms a part of the third chapter of a book 'Naar Californië' by de Vries, which recently appeared in Amsterdam. It is of considerable interest to note the impressions de Vries, the scientific botanical experimenter, received during his first visit to Luther Burbank, the foremost practical plant-breeder in the world, whose remarkable achievements have created world-wide admiration, and to whom the Carnegie Institution recently granted an annual appropriation to insure the undisturbed continuation of his work for the next ten years.

him, and a few years ago I had hoped to meet him at the Congress of Hybridologists in London, but his arduous labors prevented him from being present. I feared even now that there would not be many chances of speaking to him, because July is his busiest time, when all the numberless crossings are made and the selection of prunes takes



LUTHER BURBANK.

place. These fruits at the present time are represented by a larger number of varieties than any other plant in his orchards. It is no small matter to select the best plum out of 300,000 different varieties. This requires not only talent and experience, but also a great deal of time, and it all has to be done within a few weeks while the prunes are ripe on the trees.

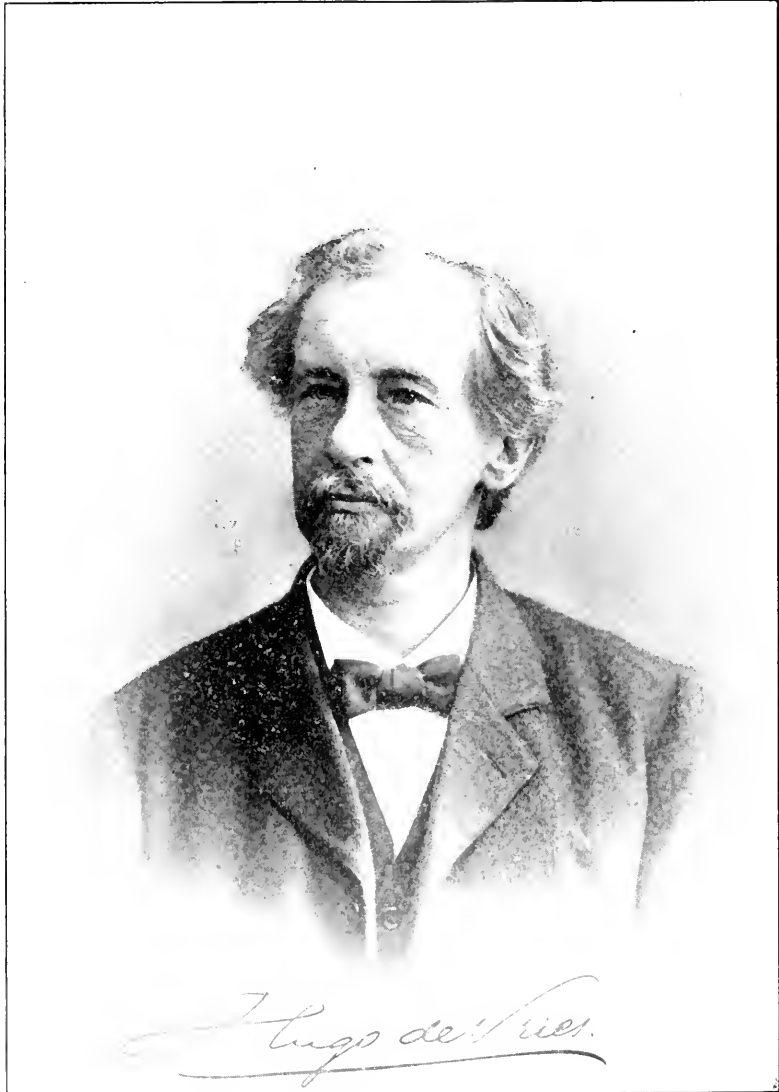
My wish to see him was, however, met with the greatest cordiality. Others had naturally the same desire, and we were consequently all invited to come together to Santa Rosa, where Burbank lives, and to inspect, under his personal guidance, his experimental plots. He set apart an evening and a whole day for our visit. How many crossings and selections he had to sacrifice for this I do not know. Our party was a rather large one. There was first Professor Svante Arrhenius—the man who with van't Hoff laid the foundation of modern physical chemistry. Among all the savants I ever had the fortune to meet, he certainly is the man with the widest knowledge and the broadest interests, and his opinion about Burbank's methods was of the greatest value to all of us. In our party was also the physiologist, Jacques Loeb, the discoverer of many important phenomena in regard to fertilization in lower animals. His studies have led him to the question of the causes of life and of those life-functions which give animals and plants their characteristics, expressed in the differences of kinds and varieties. These characteristics can not be studied to advantage except by means of hybridizing. So far no one in the whole world has made crossings on a larger scale than Burbank, and it was only natural that there should be many points in common between the studies of both these men. Our party was under the guidance of Professors Wickson and Osterhout, of the University of California. Both are personal friends of Burbank and, notwithstanding the distance, often visit him to keep posted on the progress of his work.

Americans, and especially Californians, feel a great deal of pride in their Burbank. He is a very modest man; he does not work for fame, or for honor, or for the acquisition of wealth. He has none of the aspirations of a merchant. He loves his plants, and is enthusiastic over his work and plans. To accomplish something great for his country is his ideal. For his personal self he is satisfied if his work furnishes him a living and enough to carry on his experiments.

In outward appearance Burbank is a very plain man, more a gardener than a savant, with clear blue sparkling eyes, full of life and fun, appreciating humor in others, telling us stories that kept us constantly laughing. He lives in a small house with his mother and sister, and has but one servant on the place, as he does most of the work personally. The walls of his room are covered with small photographs of his victories, and during our visit these pictures were taken down and demonstrated to us.

As a matter of course prunes interest him more than anything else. Of the hundreds of thousands, which he got by crossing, a few are already in the market. To give an idea of the interest connected with such a new kind I may only name the Waynard plum. This is a delicious, big and round, dark blue fruit with a taste that makes one think

of a peach. One seedling of this tree, the selection from hundreds of thousands, he sold to a company, formed especially for the purpose of multiplying and introducing it into the market. This company was not to raise crops from it and to sell the fruit, but to produce grafts



and as many plants as were required to introduce it into those states of North America where it will thrive, to make it one of the most commonly cultivated trees in the United States and thereby to add millions upon millions of dollars to the annual production of the country. How

much Burbank realized for this one seedling he did not mention to us, but it was certainly enough to compensate for his entire plum-culture of many years.

Such are Burbank's ideals. For himself it is sufficient to receive the cost of producing his creations. He has no children, and does not feel the necessity of accumulating money. The sole aim of all his labors is to make plants that will add to the general welfare of his fellow beings. Therefore he looks in his selecting for other qualities than those upon which we, in Europe, generally lay stress. 'Shipping qualities,' that is the ability to withstand handling in packing and shipping by railroads or vessels, are most important to him. Next comes the property that makes it possible to cultivate them in regions which previously have been unsuitable for this purpose. To produce varieties which combine with great productivity a sufficient degree of frost resistance is one of the chief aims of Burbank.

As an example of this, he spoke of his crossings with the Beach plum (*Prunus maritima*). Here and there along the coast, especially in the eastern states of North America, this shrub grows wild. It is satisfied with almost any conditions. The most infertile sandy soil is just as good as the richest loam; the driest place as agreeable as the temporarily inundated ground. On the eastern coast it thrives equally well in the north and in the south, being nowhere affected by the climate. It never suffers from frost, and always forms a dense shrub, often to the exclusion of all other tree-growth. In addition to all these qualities it is immensely prolific. It does not, of course, produce any edible plums; the fruit is of the size of a small cherry, with a large seed and a very thin layer of fruit-flesh. Late in the season the branches are bent down under the weight of the fruits, which cover the branches in great profusion. This plum has, further, a great number of varieties, with all kinds of forms and colors, some ripening in July and August, others as late as September or October. Even in taste there are differences. Although the fruit is uneatable, it is possible to judge about its flavor.

In many parts of California water is very scarce, but still the soil is fertile. In such regions the population is scanty and remains so, limited by the available water supply, in spite of the perfect climate and the fertility of the soil. Some kind of fruit tree that by means of long roots is able to get water from the deeper strata would be a blessing to such regions. Wealth and prosperity would increase and a large population could exist where lack of water now prevents cultivation. Burbank thinks he will be able to produce such a fruit tree by combining the deep-rooting tendency of the beach plum with the delicious flavor and richness of our common plums. He brought to his place all kinds of beach plum in order to cross them with other species.

His aim will not be accomplished by one crossing. Connecting links are required, and therefore the North American beach plum has to be crossed with other American and Japanese plums (*Prunus triflora* and *P. Americana*), and each of these hybrids with four or five kinds of the common plum. Finally a series of hybrids is developed from which almost anything can be expected.

It is natural that by such crossing we must expect the appearance of undesirable characters as well as desirable ones. Some plants produce only good, others only bad, characters, but the greater part exhibit some good points in connection with a larger or smaller number of undesirable qualities. From hundreds of thousands only those must be selected which possess all the desired characters. To make this possible it is necessary not only to cross six or eight kinds with one another, but to use as many sub-species and varieties as possible for the experiments. This work necessitates hundreds and even thousands of experiments. The result of each crossing can only be judged by the fruit, and this indicates new combinations. It can easily be seen what an immense amount of work, patience and capacity of judgment and choice is required to reach the ultimate aim. Yet Burbank told us on that remarkable evening of many such instances. He was enthusiastic in his hope to be able to realize all this during his life.

The making of hybrids from the different species of plums naturally brought us to a subject which, for me, was of the greatest importance from a scientific standpoint. As Arrhenius and Loeb also felt more interest in the theoretical side of these problems, I took the first opportunity to bring the conversation to that point.

I had in mind the 'pitless prune.' Just imagine this, reader! Next day Burbank took us to a plum tree heavily loaded with clear blue, very attractive, yet small plums. He picked a few and asked us to bite right through the middle of the fruit. We did as requested, and although we knew there was no stone in the plum, we experienced a feeling of wonder and astonishment. Inside the plum was a seed, like an almond in its shell, and with the taste of an almond, but without the stony covering. When cutting through the fruit, we found the seed surrounded by the green fruit-flesh, the innermost part of which was a jelly-like mass, in which could yet be seen some remnants of hard little stones, that scarcely offered any resistance to the knife. Burbank declared, however, that he was not at all satisfied with the result, and said that he had already young trees with fruits, in which nothing could be detected of the stone.

Osterhout told us about the impression this plum made on Professor Bailey, professor of agriculture at Cornell University. He came unprepared before this tree, and Burbank, always full of humor, thought it a good opportunity to play a little trick. Bailey had declared that

a stoneless plum was entirely an impossibility, something that was outside of one human lifetime; he refused to believe the statement and could not be induced to risk his teeth on the experiment. To the great amusement of Burbank and Osterhout, he took a knife from his pocket, commenced to peel the plum and to cut away the fleshy part, in order to expose the stone, which he was sure would be there. How great was his astonishment when he finally did not find anything but the naked eatable kernel!

A couple of years ago when I read in one of Burbank's price lists about a stoneless plum, I shared a similar astonishment. How was it possible to bring about such a great change? Hybrids do not present, as a rule, any new simple qualities, only new combinations of already existing properties. The evident properties are often developed from more than one factor, and such composite characters may thus appear, without any new essential factors having been present. This is a fundamental principle in crossing, whether it is done for scientific or for practical purposes. But although the elimination of the stone is only a loss and not a gain of a character, such a loss is just as much outside the sphere of hybrid making.

My astonishment was, therefore, as great as that of Bailey, and I had long ago made up my mind to ask Burbank, if I ever had the opportunity, what secret method or what happy coincidence had enabled him to effect such a fundamental change in a plant. I put my question to him that evening, convinced that on the answer depended largely the scientific value of our visit. And for the second time I was surprised over the unexpected and simple reply: "About two centuries ago they knew in France a 'prune sans noyau' and I bought the fruit and raised a plant in order to cross it with others of my prunes." Thus there is no exception to the rule, there has been no real production of a new character, but we have only had a case of the general American principle: 'try everything.' Over the whole world Burbank looks for different kinds and varieties of prunes, no matter how insignificant they may be, however wild and uneatable, as long as they possess only one or another characteristic, which, in combination with the common kinds, may bring out a new variety of greater value.

To Professor Loeb and myself this was, to a certain degree, a disappointment. We had expected to learn a great deal about this point, the fundamental idea, if not the ultimate aim, of the studies of both of us—that is, the question of the nature and origin of new characters. We now surmised that Burbank's experience did not throw any light on this question.

I had before experienced a similar disappointment. About twenty years ago I was occupied with experiments on hybridization for horticultural purposes. I had already found at that time the general

principle that only combinations, but no primary characteristics, were produced. Only in one instance I encountered what seemed to be an absolute exception to this rule. It was an announcement of Lemoine of Nancy, the most celebrated breeder of garden novelties in France. He claimed that he had been able to produce by crossing double lilacs. Double flowers remain longer on the branches than the single, which usually drop off after a few days. To find out how it was possible to develop by crossing from single lilacs new varieties with entirely new characteristics I visited Lemoine in Nancy. Walking through his gardens, I put the question to him and received the following answer: "That is very simple. As a boy I had seen in the garden of an old relative a specimen of *Syringa azurea*, a very rare lilac of an ancient type with double flowers. Remembering this, I bought that tree from the person who owned my relative's home. With this tree I crossed all varieties of single lilacs I had and got the double variety." Here we find again the same procedure: first buying, then crossing, later grafting or budding on other forms, but no creation of an absolutely new character. The number of combinations may be unlimited, yet the creation of new prime characters is entirely excluded.

This principle came into full evidence while we were in Burbank's grounds. He demonstrated to us 'white blackberries' with large fruit of a delicious flavor, which now are an article of commerce. I asked him about the origin of this crossing. Burbank explained that here and there in California occurred a wild blackberry with white fruit. He had crossed this plant with other forms. A white variety of the common raspberry has similarly been known in Europe since olden times.

Another striking example is furnished by the spineless cactus, one of the novelties of which Burbank expects much. It is one of the *Opuntias*, a desert plant, the fruit of which is eaten and known as Indian figs. Its stem consists of big, flat slabs, joined together in the most fantastic manner. It reaches a height of six feet, spreading widely and growing luxuriantly. The fruit is much relished by cattle, as it is juicy, rich in foodstuff and has but few thorns. The whole plant is eaten by animals only when they are driven to do so by hunger, as it is covered with hard prickly thorns. If the plant is cooked for some time the thorns soften and the cactus becomes a nutritious food. This process of cooking is, however, too expensive for practical purposes, and hence a cactus without thorns would transform a barren desert into rich pastures. To reach this Burbank brought together wild *Opuntias* from Mexico, South Africa and various other countries as well as the commonly cultivated species. Among the specimens Burbank received, one was accidentally found without prickles on the leaves and another with no thorns on the young shoots. It was, there-

fore, necessary to combine in one plant both these negative characteristics, something that experience has shown can be done. However easily this is explained, still it elicits astonishment and wonder to see a cactus without spines. All that is now left to be done is the crossing with forms known as the most nutritious, and at the same time to watch the development of other characteristics, especially the root system. It will not take many years for Burbank's cactus to transform large stretches of desert into fertile fields even without irrigation.

Along the road in front of Burbank's house is a long row of high trees with wide spreading crowns and dark foliage. These are Burbank's first hybrids, walnuts, that are a combination of the edible nut and an ornamental tree of the same genus (*Juglans regia nigra*). From seeds of this hybrid Burbank raised a few rows of seedlings which show a surprising variety in growth and leaves. These latter are all lanceolate, sometimes with broad leaflets, sometimes with narrow, some are petiolate, others sessile on the branchlets, now coarse and then fine, frequently reminding one of the common English walnut, and again approaching the ancestor, the black walnut. We saw some of the variety of forms resulting from crossing, and from these the best have to be selected for certain purposes.

Burbank's entire garden contains only two and a half acres, while the experiment farm near Sebastopol, about one hour's drive from Santa Rosa, comprises twenty acres. Two days each week Burbank spends on the farm, riding there on his bicycle; the rest of the week he is at home. Here are all the more delicate crossings, and it is here every new experiment is started. It is only when certain definite results are in view and when the cultivation of thousands of specimens is required that they are raised on the farm near Sebastopol.

He showed us a bed of wild flowers in his garden. He collects these in the vicinity, transplants them, selects and crosses the various forms as soon as they promise anything of advantage. Others he crosses with cultivated species of sufficient relationship. His idea in doing this is to make a large number of garden plants, which will be so fertile, and consequently so cheap as to come within the reach of any one. Briefly, he wants to spread over every garden spot in California a still richer treasure of flowers than it already possesses. Thus, for instance, he has crossed the large and deliciously night-scented *Nicotiana affinis* with the wild, tree-like *Nicotiana glauca*, which can not be called an ornamental plant on account of its greenish flowers, but by flowering profusely and by having such large bunches of flowers, it offers an excellent object for hybridization. We noticed several kinds of Cape gooseberries (*Physalis*), of the blood-red *Heucheras* and others already hybridized. The common garden poppy (*Papaver somniferum*) he had

crossed with the large flowered, brilliant orange-red, perennial poppy, and a great number of hybrids were now growing. These were almost all sterile. Some of them terminated in a dried-up stub without flowers, others had a minute rudiment of fruit, others only remnants of calyx and corolla. There were all stages up to normal flowers, and seed capsules in which the not yet fully developed seeds could be seen through a lens.

After crossing all kinds of color varieties of the common poppy he got one with a light blue color. Although the color is not very pretty, yet this plant is very interesting, as blue poppies have been hitherto unknown. Probably the change in color is caused by the combination of pigments in some flowers and the chemical constituents of cells of others. This is, however, only a supposition.*

Many other wild plants, as *Brodiaea*, *Erysimums* and *Cephalyptrum Drummondii*, he had hybridized, getting flowers which first came out carmine red, but then slowly changed to white, a very unusual mode of variation. In order to reduce the price of *Amaryllis* and *Gladiolus* to a few cents, and thus make these beautiful red and white-striped flowers common in every garden, he devoted attention to the increase of side-bulbs. He had already plants with twenty to twenty-four bulbs instead of the old forms with hardly any or but a few side-bulbs. Burbank has his own peculiar ideas about the power of nature and natural phenomena, which play such an important part in his work. His principal theory is that 'heredity is the sum of all past environments.' This he repeated time and again in his explanations. Crossing brings together in one individual the sum total of the environmental influences to which the two lines of parents have been subjected, and hence increases its variability.

Among the remarkable results of Burbank's work which we saw at the Sebastopol farm were a couple of trees of Loquat (*Eryobotrya japonica*) about six feet high, but with spreading fruit-laden branches. One of these trees was the original Japanese kind with small yellow fruit, the size of a cherry, of acid taste and almost filled with the large seed. It has a peculiar flavor, found in no other fruit. This aroma was also found in the fruits of the other tree, but these were larger than walnuts and had an orange-red color. The seed was not larger than that of the wild tree, but the juicy fruit-flesh was greatly developed in thickness and very delicious. This improvement of the loquat, which fruit makes one of the finest delicacies for the table, was accomplished by Burbank without crossing, by selection only. This is the same process by which, since the time of the celebrated Belgian horti-

* The original reads: De kleur berust waarschijnlijk op een verbinding van de kleurstof van sommige soorten met de scheikundige inhoudstoffen van de cellen van andere. Maar voorloopig is dit nog slechts een vermoeden.

culturist, Van Mons, our large and juicy apples and pears have been produced, that is, by sowing the seed on a large scale and then continuing the selection for one or more generations. About one half of Burbank's grounds was taken up by prunes. He has at present about three hundred thousand different kinds. The number of trees is not so great, however, as he grafts his seedlings on other trees, when they are two or three years old and show some promise for the future. For this purpose he uses the whole seedling, throwing away the roots. We saw small trees with from thirty to forty grafts, and large ones upon which two hundred to four hundred branches were grafted. When the foliage is of different color and form and the branches bear plums, red, yellow or blue, flat or round, small or large, some ripe and others only half developed, the result is strikingly bizarre. When the fruit is ripe he walks along the rows, marking those which are undoubtedly the best, as far as can be judged by a cursory examination. Then a workingman removes all those which for one reason or another are considered valueless. By this method only about half of his original stock is left, and this then receives his careful investigation. Possessed of an in-born talent, he is able to select in a few summers four or five of the best kinds among the hundreds of thousands on his grounds. These are then multiplied, while all the others are destroyed and replaced on the mother trees by the next series of seedlings. These are often somewhat assorted even before transplanting from the shallow boxes where they have been grown. Sometimes the color of the leaves indicates the value of a tree, as in crossings between the common cherries and prunes with *Prunus Pissardi*, which, on account of its brown foliage, often is cultivated as an ornamental tree. In other cases the size of the leaf is an indication of certain properties of the fruit, Burbank's long experience enabling him to see some correlation between leaf and fruit. Thus he can with some certainty discard a number of trees before transplanting, which naturally saves time and room.

One of Burbank's favorites is a large 'Marguerite,' which he calls the 'Shasta Daisy,' after the great California mountain of that name. It is one of his improvements of a perennial daisy which grows wild in Shasta county, and is very variable. By crossing and selecting, it has been developed into a plant that excels by its rapid growth and its profusion of extremely large beautiful flowers, which for months cover the ground. These and other characteristics will make the Shasta daisy one of the commonest and cheapest, still one of the most beautiful, of garden plants.

What makes Burbank's work entirely different from that of other plant breeders is the immense scale on which his selecting is made. He is, therefore, able to make greater improvements than others and in much shorter time. In his work Burbank is guided by a special gift

of judgment, in which he excels all his contemporaries. The best proof of this is to be found in the great success his creations have made, not only in North America, but also in Europe.

His methods of work are the same as those followed by plant breeders in Europe. Secrets he has none, and if he is not willing to demonstrate his cultures to everybody, this must be attributed to the fact that his time is too valuable. There is no fear that any one could 'steal his trade' by merely looking at it. Every one is left free to follow in his path, but without the special disposition for it nobody will succeed, and for simple imitation the entire process is too complicated.

To give an idea of the immensity of his cultures, it is sufficient to cite one instance. When selecting a new kind of blackberry he picked out the best from 60,000 specimens, all in full bearing, dug up the rest and burned them. This is his way of working, not only with one kind of fruit or flower, but with all. The most remarkable trait, however, of his work is that he experiments with as many forms as possible. This method is carried to the highest degree of perfection, and thereby his results are so stupendous that they receive the admiration of the whole world.

However large may be the number of forms subjected to crossing and selecting, this method is in itself limited. Burbank's products are all, with a few exceptions, reproduced not from seed, but by vegetative propagation. Grafts or cuttings, bulbs, shoots or division of roots are the means of multiplication. It is well known that vegetative propagation results in much greater stability than raising from seeds, which often produces degenerate types. Because of this fact, Burbank hardly ever experiments on annual or biennial plants, but confines himself to perennials.

In Burbank's methods selection plays the most important part. To accomplish a good selection, however, the greatest possible degree of variation is a prerequisite. This variation is attained mainly through selection of the starting points and through artificial hybridization. The results are next cultivated on a large scale under environmental conditions which will develop as many differences as possible.

Varieties coming from separate localities differ not only in regard to external characteristics, but their capacity of modification varies considerably, and can often be ascertained only in the special environments of an experimental garden. The greater this power of adaptation the more chances for the experimenter.

As a general rule, it holds true that the results of crossing depend primarily on the selection of varieties used for that purpose. These indicate, so to say, the program, the list of possibilities from which the choice and the combinations have later to be made. Outside of this

list very little good is obtained, and then only by accident. This occurs very seldom in Burbank's cultures.

When he wishes to experiment with wild flowers Burbank goes out himself in search of specimens. He carefully compares the different places of growth and investigates the variation in individuals. Many days are thus employed in gathering together one kind in order to find out existing dissimilarities or to see whether they promise anything for future cultivation. Such specimens are then transferred to his experimental grounds, and when established are subjected to crossing.

With crossing or hybridization we usually understand the sexual union of two individuals belonging to different species or varieties. In practical plant breeding, however, it is not sufficient to combine two types, but three, four, and even five or six kinds are thus united, so as to bring out as many desirable qualities as possible in one single variety. It is, of course, impossible to predict what result will be obtained, and it must be left to chance and the future to decide what combinations are the most desirable. Often crossings are made only with the object in view that among all the combinations something good may turn up. In this case the breeder wants to destroy the equilibrium of existing characters, to make the constant forms unstable, and then to select the best out of the many balancing properties. When the parents themselves are variable their offspring will naturally be more so, and the number of differences increases with the number of hybrids experimented upon.

There is also a chance that latent or sleeping characters may be brought to light. From a scientific point of view we know, as yet, nothing about this, but Burbank holds the opinion that in many cases one character prevents another from becoming visible. For instance, in crossing, the first one meets an opponent which has kept it back—as is often the case in the crossing of varieties—and this latent character gets an opportunity of becoming active. We can naturally not detect what dormant qualities are hidden in a plant, and may, therefore, expect all kinds of surprises. The combinations may be desirable, and the hybrids can be propagated immediately, or they may be the reverse and need further crossing before the unfavorable traits are eliminated. Unknown atavistic properties may in this way become evident and may play an important part in the development of future generations.

In other cases the crossings are made with a certain purpose in view. These are the instances from which we learn the most, and which at the same time give the best chances for quick and favorable results. A certain number is selected of species or varieties, which together contain those characters we want combined in one type; the undesirable properties we try to eliminate. As the crossings result in all kinds of combinations, it is necessary to produce them in

as large numbers as possible, so that among the numberless undesirable and imperfect plants we may choose the best. The chances are that from the five or six desired good characters only three or four are found together. Thousands of seedlings have to be developed in order to create a possibility of finding one form in which the expected qualities are present. It is a game of solitaire on a large scale. I may mention as an example of this the production of the Alhambra plum, which was obtained by combining European, American and Japanese kinds. It took thirteen years to combine all these. First came the crossing of the Kelsey with the *Prunus Pissardi*. Their hybrid was crossed with French prunes. In the meantime various other crossings were created, and it was made possible to work the pollen of these 'into the strain,' as the term is called. First came *Simoni* \times *triflora*, and then *Americana* \times *nigra*. This sevenfold combination gave us the variety now known in the market as the Alhambra.

We can go still further and cross species that are yet more widely separated. It is then naturally even more difficult to predict the results. Burbank endeavored to combine the plum and the apricot and succeeded in getting a new fruit, which he calls plumcot, of very delicious taste and looking very much like an apricot, but combining the soft skin of this fruit with the dark color of the plum. Burbank had a number of varieties of this new fruit, some with a yellow fruit-flesh, others of dark red color, light rose or white. In taste these plumcots differ considerably.

Burbank is equally successful in hybridizing flowers. In the instance of the *Callas*—well known through the many varieties of *Richardia aethiopica*—all the new cultivated forms have been hybrids of a few species. Burbank, however, crossed *Calla hastata*, the yellow 'Pride of Congo,' *C. Elliottiana* with dark yellow flowers and spotted leaves, *C. Pentlandi*, also yellow with dark purple spots, the rose-colored *C. Rehmanni*, and the small light yellow *C. Nelsoni*. From all these he received a great number of different hybrids, among which were found the most varying shades of color, very large-sized as well as dwarfish forms. The colors were not limited to spadix and spathe, but spread over peduncles and petioles, and even the leaves were variegated with spots and stripes. In addition to these peculiar colors and forms the hybrid *Callas*, of which Burbank had long rows in bloom at the time of our visit, possess a hardiness and adaptability to extreme temperatures, which fit them for outdoor cultivation, where formerly *Callas* could be forced to full development only in hothouses. Every year these hybrids are again subjected to the process of crossing, and each year new and often unexpected forms appear. How far this will go it is at present impossible to predict.

Because of the favorable climatic conditions under which Burbank

conducts his experiments, he is able to work on a much greater scale than is possible in Europe. While we can only select from a few hundred of seedlings, Burbank can get tens of thousands into blossom. In this way the number of years necessary to bring about improvements can be considerably reduced. It required in Europe more than half a century to produce the beautiful *Amaryllis* forms, which we admire so much. Burbank has got wonderful results in much shorter time. In the process of selecting he preferred those forms which required the shortest time to come into blossoms, and by following up this method he succeeded in greatly shortening the duration of life from seed to seed, as it is called. It is evident what this means. Instead of having to wait four or five years after a crossing, before the result could be judged by the flowers, Burbank can make his selection in half the time. This, of course, not only includes saving of time, but also reduces the size of the cultures, and consequently the expenses. Burbank's aim is to make *Amaryllis* one of the most common ornamental garden plants, which will find its place in parks and private residences, in city gardens as well as near the farmer's humble dwelling. In order to introduce new forms into the stock of *Amaryllis*, Burbank endeavored to cross them with the related *Crinums*, and, from what we saw, his first trial was crowned with success. From the Florida swamps he obtained a wild *Crinum Americanum*, which has proved its fitness for crossing, and at the same time he had in his hothouse varieties from tropical regions, which he was going to cross with more hardy forms, so that they would feel at home in the California climate.

Among all the above mentioned points upon which I desired to draw special attention is the shortening of life from seed to seed. As the experiments, with a few exceptions, are conducted on perennials, and as vegetative propagation only is resorted to for multiplication, it would in many cases necessarily take several years before the plants flowered. Where repeated crossings have to be made this would cause considerable difficulty.

The means which make it possible to shorten the vegetative period are three: first, the splendid climate of California; second, the selection of the earliest flowering seedlings, and, finally, the method of grafting. Experience has taught us that the best way of forcing the stem or branches of seedlings to an early development is by grafting them on older trees. On a good-sized plum tree may be grafted, as said before, hundreds of seedlings. They will bloom in a couple of years, and as soon as they bear fruit selections can be made. The inferior grafts are then removed, so as to allow room for the good ones to develop more rapidly.

In the process of artificial crossing the greatest possible precautions have to be taken in the application of pollen. Yet the method is as

simple as possible, because the hybridization is carried on on such a large scale. First the stamens of the flowers to be crossed have to be removed. This is usually done while the flower is in bud and the stamens close together. One circular cut only is sufficient. Care must, of course, be exercised so as not to hurt the pistil. Next protection against insects has to be provided for, as otherwise pollen might be transferred from other flowers and the expected results spoiled. In scientific experiments a great deal of attention is paid to this, and the flowers are carefully enclosed in cases of metal gauze or in especially prepared paper bags, so that no insects can reach them. In practical plant breeding this would, however, be too cumbersome. By the circular cut mentioned not only are the stamens cut through, but the corolla is also removed, and the flowers are consequently not so conspicuous and do not attract the insects, except where there is fragrance. The majority of Burbank's improved fruit trees belong to the first category. In practical work the visit of a single insect is not so much feared, because all the mischief it may do in bringing the pollen is to produce a valueless hybrid. This can later be destroyed. Besides, the insect may come too late to bring about any result. But there is also a possibility that a new and good hybrid may be produced. The application of any cover is, therefore, entirely out of the question. This is the reason why unexpected results of such practical work are never entirely free from the suspicion that they are due to accidental introduction of pollen. Such results, therefore, do not enable one to draw reliable scientific conclusions.

Burbank's method is to collect the pollen required for these crossings on watch-glasses, as it keeps fresh for about a week. With these glasses he goes to the plants he wants to pollinate and applies with his finger tip a little of the pollen on the stigma. This is, as a rule, not yet ripe, but the pollen adheres to it until it matures. Fecundation thus begins at the time the stigma becomes glutinous, which lessens the possibility of other pollen being introduced.

I wish now to consider one of the most remarkable features of Burbank's work, the immense scale upon which it is conducted. This is the best plan for obtaining the most variations in a short time. He starts thousands of seedlings for each hybrid, and when the culture admits and the interest requires it, this number is increased to 50,000 or 60,000. In order to give an idea of the significance of these figures and of the work they imply, Burbank shows in one of his catalogues an autodafé of hybrid raspberries and blackberries. For the purpose of getting a hybrid with larger berries and bigger bunches he cultivated 65,000 seedlings until they blossomed and were in full bearing. A few dozens were selected, and the balance, heavily loaded with fruit, were dug up and gathered in a pile, which was then reduced to ashes. And

this goes on every year; fourteen or fifteen such bonfires a year are not uncommon. One consisting of 10,000 to 15,000 roses, luxuriantly flowering seedlings, annihilated the work of a number of years after the selection of only three good varieties. Half a million lily bulbs were entirely destroyed after fifty of the best had been separated for further cultivation. And so I could cite a number of instances.

It is evident that the chance of finding something good is much greater if the selection can be made from hundreds of thousands instead of from a few hundred only. Those who wish to compete with Burbank will have to accept this principle, and if this can not be done, they had better follow a different method and select species that admit the use of different methods.

It is theoretically of great interest to compare Burbank's principle with the methods of selecting generally in vogue in Europe. There the work is not performed on such a large scale. Preference is given to repeated selections, and the idea is prevalent that the desired results can be reached only by following the regular road. The question is whether by such repeated selection we proceed faster than by a single sowing on a larger scale. We can easily calculate the proportion, and it can be said that with five years' work a hundred times smaller number of plants have to be cultivated. This would, of course, lessen the expenses in proportion, but there is always the disadvantage of the result being available so much later.

When novelties are wanted in varieties of *Begonias*, *Geraniums*, *Dahlias* or *Fuchsias*, for instance, which annually produce many new forms, the hastening process would be of no value, but in new genera unexpected results are often attained, and in that case the hastening method will amply repay the expense. Yet these questions are the secrets of breeders. Of scientific importance is the question whether repeated selections are alone sufficient to bring about the same end, and further if by this means more variations are produced.

We have no facts which would decide this, and I would not have brought up the question, had it not been for its great influence on the study of evolution. It is closely connected with the question whether species slowly merge into one another or whether they originate by mutations. In the former case small deviations would increase in the course of generations, and thus a long series of intermediate forms would connect the new and the old species. In the latter case a jump is made without any intermediate stages. So long as there were not sufficient instances of this mode of change, and so long as we had to rely upon cultivated varieties only as proof, the first proposition was naturally the most probable. It rested on experience in agriculture and horticulture in regard to improvements of races, and it was believed that species in nature originated in the same manner. The re-

sult of breeding on such a large scale as that mentioned above was at the time unknown, and it was believed that the results could be obtained only by repeated selections. If by experiments on a large scale the varieties could be produced at once, the former view would evidently lose much of its value.

The magnitude of Burbank's work excels anything that was ever done before, even by large firms in the course of generations. The number of fruits and flowers which he has improved is unequalled. Others confine themselves to one or two genera; he takes hold of everything. The majority of breeders who became famous by their improvements of certain groups took up this work merely as an adjunct, as a means of widening their commercial relations, thus creating a greater demand for their nursery products. Burbank commenced in the same way, but as soon as he had obtained what he thought he required, the nursery business was abandoned, and he devoted himself exclusively to the improvement of flowers and fruit. It is to this resolution he owes his present fame.

Another point of importance which is also evident from Burbank's work is that in many genera the development of hybrids seems to have reached its limit. In some cases neither Burbank nor any other breeder could produce something new. Apples, pears, peaches, strawberries and a few other types are quite exhausted. The circumference of their form-circle, if I may be allowed to express myself this way, or, as Americans say, their possibilities, are already taken up in cultivation. Inside that circle, of course, improvements are possible, and every one who eats canned apples, or pears, or peaches from California knows that progress in regard to these fruits is evident enough. But Burbank himself considers those species exhausted, and he asks for his improvements no higher rank than what already exists. He has added to them only greater productivity and the qualities required for packing and shipping. It is, however, by just these qualities that a great deal of California's prosperity has been created and the fruit export to Europe increased, qualities which the consumer applauds as much as the European orchardists fear them.

From a scientific point of view Burbank's varieties are but individual, by which I mean that the variety has been produced by one single individual, hence from one seed. That specimen has then been multiplied by vegetative propagation into the thousands, or probably millions, of plants which are in the market. As an individual the variety preserves the characters obtained through hybridizing.

Exceptions to this rule are rare. Burbank has, however, obtained a few hybrids which are stable when raised from seeds. These are naturally crossings of stable species or at least stable hybrids. As an example I may mention the hybrid between the California dewberry

and the Siberian raspberry. Both have small and insignificant fruits, while the hybrid on this point greatly surpasses either parent. In Europe we have long known similar instances through the studies of wild hybrids by Kerner, and by Wichura, Janzewsky and many other writers regarding cultivated bastards.

If the relationship between species is not close enough, all attempts to hybridize are frustrated. Either the crossing is a failure, and no seeds are produced, or hybrids are obtained which are infertile. In the case of flowers this is not of so much importance, but in regard to fruit trees such a result is a complete failure. It is evident that nature has here drawn a limit which man can not cross. This boundary line is, however, not marked, and consequently once in a while surprising results are obtained. Hybrids which are infertile in thousands of cases may for once prove a success among hundreds of thousands. Burbank has an example of this in his crossing of *Petunia* with tobacco. From numberless hybrids he got one germinating from seed. He named this curiosity *Nicotunia* (from *Nicotiana* and *Petunia*). It was not very attractive and succumbed after one year, having flowered profusely, but failed to produce any seed.

It is unfortunate that we can not see this limit of nature in advance, but have to learn it by experience. And this experience includes an almost incomprehensible amount of labor of which no one hears anything.

SOME PHASES OF THE EDUCATIONAL PROBLEMS IN CHINA.

BY WALTER NGON FONG,

PRESIDENT OF LI SHING COLLEGE IN HONG KONG; FIRST CHINESE GRADUATE OF STANFORD UNIVERSITY.

IN dealing with any part of the educational problem, it is necessary for us first to define our field. In this paper we shall consider the subject from the standpoint of one endeavoring to introduce 'western' learning among the Chinese. The fact that the Chinese do want to adopt western ideas and learning does not facilitate the task of regenerating the Chinese mind to as great a degree as the casual observer might suppose. While the present conditions are, of course, much more favorable for the introduction of new things into the Chinese life than they were a few years ago, still innumerable obstacles and difficulties remain in the path of one who wishes to be of some real assistance to the 'Coming New China.'

The ignorance of the students' parents and relatives or guardians is one of the most formidable enemies of modern education in southern China. As soon as the student reaches the age of sixteen or seventeen his parents get him a wife. We might think that a student who can get a wife without bothering his head over the affair has the advantage of saving the time which would be spent by a European or an American in courting. Still, to assume the responsibilities of married life at the age when he is just able to begin higher studies will prove an almost insurmountable barrier to the advance of the average student. Perhaps he is furnished with enough money to go to school, yet his wife must have some 'pin money,' and as she does not like to ask her father-in-law for every cent she needs, she soon begins to make demands upon her husband's slender purse.

As the Chinese 'gentleman youth' is not trained to do anything, he can not earn any money by doing 'odd jobs' while in school. Therefore, he embraces the first opportunity to obtain a position of some sort and leaves school. His school career is now ended forever and his desire for higher learning gradually becomes extinguished.

Very few Chinese realize that a useful education must be thorough and that to obtain a thorough education requires time. While they are willing to permit their boys to be crammed with obsolete classics for fifteen or twenty years with the hope of becoming Mandarins, yet they are not willing to let them study six or eight years in a modern

institution of learning. All that they want their sons to obtain is a knowledge 'sufficient for the need.' By this expression they mean that as soon as their sons are able to take positions as clerks, their education is 'finished.' Their highest ambition is to have their sons become chief clerks or compradores in commercial houses, thus insuring comfortable livelihoods.

Even the students who aim higher than 'business English' are anxious to find a short cut to learning and to obtain a general knowledge of science, philosophy or law in a very brief period. They are not willing to spend weeks, if need be, on a single point. They have no desire for original investigation; no craving for research work; no yearning to become wise above 'that which is written.' They are not willing to sacrifice time, pleasure and money and make everything subservient to the one aim of getting a thorough education.

Filial piety, inculcated into them by generations of usage and enforced upon them by their parents, is another great drawback. For instance, if a paternal relative is indisposed, the student must leave school and travel to his village to pay his respects to the sick one, thereby losing from a week to ten days' schooling. In the event of the marriage of a relative or of any other important festivity, the parents desire that the student be excused for another ten days or so, thus breaking into the continuity of his studies.

The poor physical condition of most of the students is another hindrance to their progress, and necessitates many days of absence from classes. Having been accustomed under the old Chinese system of education to commit to memory what was written, many of the students, who enter an institution of foreign learning where they are required not to memorize but to reason out the cause and effect and to give explanation for all that they do, find the work very hard upon them physically. Their ability to think and reason has been dwarfed by their previous training, and the transitional period of their mental readjustment is a great strain upon their weakened constitutions. One might ask, 'How have their constitutions become weakened?' By the use of tobacco and by the conditions under which they have studied. In the Chinese schools they have sat at their books from dawn until dark and read far into the night, seven days a week almost the whole year round, without physical exercise or proper ventilation. Consequently, the physical condition of many of the most diligent students is most deplorable.

Western education in China, like many pioneer undertakings elsewhere, has not had a proper start. Until recent years, very few real educators have come to China to establish schools. Formerly, most of the schools in which western learning was taught were conducted by zealous missionaries; unfortunately, most of the missionaries were not

trained educators. Educational institutions are expensive and even the missionaries who were skilled in the art of teaching had no money for the necessary equipment.

The main reason why no teachers of high standing, who could hold professorships in any of the reputable colleges at home, have been working in China is the lack of money and facilities to induce them to come. When a scholar leaves civilization to go to regions far from home he must see some advantage in going. If he can go with a financial gain or library and laboratory advantages, he is willing to sacrifice the comforts and conveniences of the homeland. But China did not have the money to pay for high-salaried teachers or to provide any library or laboratory inducements for the scholar.

Nowadays we hear much of the colleges of western learning which the Chinese government proposes to establish in all parts of the empire. This calls to mind another difficulty, viz., the inability of the Chinese to manage a school properly. Most of the Chinese who try to start institutions of learning have no idea what a foreign college looks like. They have no means of knowing how to select men; neither are they capable of knowing whether the teachers whom they employ know how to give instruction. Formerly they thought that any foreigner could teach any or all of the subjects constituting 'western' learning. There were always plenty of unscrupulous foreigners willing to take advantage of the ignorance of the Chinese regarding educational affairs and to pose as 'professors' of anything or everything for the sake of the salaries. There were also numerous equally unscrupulous Chinese, who, having obtained a smattering of English in some foreign land, returned to China and undertook to give instruction in many branches.

Experience with such impostors has taught the Chinese to be suspicious of everybody and everything concerning western learning. We can not blame them for this. Confused by such experiences and reinforced by their profound ignorance of modern education, the Chinese school managers are exceedingly difficult to 'handle.' Notwithstanding their good intentions, they really do not know what they intend to do. As a result, the instructors whom they employ have to spend a large portion of their energy in managing the 'school-managers,' instead of being free to devote all of their attention to their school work proper.

Most of the schools in China, present as well as past, have big names only, regulations by the volume and curricula which exist only on paper. With their characteristic power in imitation and their time-honored conservatism, the Chinese school trustees want to follow this or that school instead of leaving the instructors free to administer the affairs of each school in accordance with its own peculiar needs.

What China needs to-day is not so much the higher theoretical

education as some real, practical training. Her people are not ready for the former, but are badly in need of the latter. The first utility of education should be to enable those educated to earn a competency, without which we can hardly expect a man to go about discussing the nice points in law or in science, while a starving family awaits him at home and an empty stomach gnaws within. With her countless millions of population, China has no workmen skilled in the production of any part of the furnishings for the comforts and conveniences of modern life. To-day China is using modern conveniences and appliances that she can not produce. This being the condition, practical manual training in the useful arts is her first necessity. If China wishes to become a member of the great family of civilized nations, she must be educated out of the idea that an educated gentleman should not perform any manual labor, and that learning and labor are divorced from each other.

Though our path is thus strewn with difficulties and obstacles, yet we as educators do not labor without a bright ray of hope. The Chinese mind has all the elements of a good soil for the implantation of the seeds of learning; it only needs proper cultivation. For example, there are in the Li Shing Scientific and Industrial College at Hong Kong, young men and boys who, five months ago, had no idea of what science was, who can now perform chemical experiments understandingly and discuss many scientific topics intelligently. Once having tasted the flavor of the new learning, some of the students try to devour the subjects with the eagerness of a starving dog that sees a piece of meat. When they are interested in their studies, they apply themselves to their books with all the force of mind and body. This better class of students is very orderly, docile, impressionable and respectful.

Although at first many of the students are slow to comprehend the methods and aims of a system of education so new to them, my experience has been that after a few months some of those who were apparently indifferent suddenly take hold as if by inspiration. Having become interested, nothing can woo them from their books, and, instead of having to hold them to strict account for their daily work, we have to keep them back. I have in mind, in particular, one fourteen-year-old boy who, when he entered our school, was a very idle and playful scholar. He was so idle and unruly that he had to be kept standing by the teacher's desk the greater part of the time. Indeed, we had our doubts whether it was best to allow him to remain with us. After a few weeks his reasoning powers became unearthed and he took an absorbing interest in chemistry. From that time forth there was no further occasion for reprimand; there was a marked change in all his work and his progress in English was very rapid. His ability to apply what he learns, his power to grasp new ideas and his faculty for

asking pointed questions are marvelous; it takes a well informed, wide-awake teacher to cope with him. He is but one of the many for whom the modern institutions of learning recently established in China are throwing open the doors of true knowledge.

When the Chinese youths have caught the student-spirit which dominates our western colleges, they become real 'digs,' and not even their physical weakness can deter them. Therefore, we have reason to hope that when their constitutions shall have been strengthened by the abstemious life, the hygienic surroundings and the physical exercises which are features of the new institutions, China will have students able to sit at the banquet of learning with those of foreign nations.

The field being so great, the educators should not try to rival each other, but should rather endeavor to cooperate, in order to facilitate the enlightenment of this vast empire of the east. We can not at present expect to have real universities, where each institution shall have all the departments; therefore, the existing colleges should aim to supplement each other, each trying to establish some thoroughly equipped, special departments that the others do not have.

Colleges established in China need strong men, who are not afraid of hard work or of difficulties, and who will not worry if they attract but few students; men who will endeavor to carry on their respective institutions on a modern educational basis, and who will form plans and policies suited to the demands of the time and place. Thus manned, colleges in China will be able to send forth graduates educated in the true sense of the word and fitted to be useful in society. These college-trained men will act as a leaven which in time will change the whole social fabric of Chinese life, thus removing many of the obstacles which now confront the educator. In this way, existing colleges will advertise themselves by the quality of their graduates much more effectively than by any amount of pomp and show; will serve as models worthy of imitation; and will solve many of the present problems.

THE SOCIAL PHASE OF AGRICULTURAL EDUCATION.*

BY PRESIDENT KENYON L. BUTTERFIELD,
RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

I HAVE been asked to speak in behalf of the study of 'Rural Economics.' This term is, I presume, supposed to cover broadly those subjects which treat of the economic and social questions that concern farming and farmers. The whole range of social science as applied to rural conditions is thus apparently made legitimate territory for discussion. In view of the importance and character of this field of study, it seems wise to approach it if possible through the avenue of its underlying philosophy. Only in this way can the validity of the subject be established and its place in agricultural education be justified. I have, therefore, chosen as a specific title, 'The Social Phase of Agricultural Education.' In the treatment of the topic an endeavor has been made to hold consistently in mind the point of view of the agricultural college.

It is a principle in social science that the method and scope of any social institution depend upon its function. Therefore the organization, the methods and the courses of the agricultural college should be made with reference to the function of the college. What is this function? What is the college designed to accomplish? What is its social purpose? Why does society need the agricultural college? Answers to these questions are of two kinds, those that explain the contemporary and passing functions of the college, and those that illustrate its permanent and abiding service to society and particularly to the rural portion of society. The college of yesterday was obliged to train its own teachers and experimenters; to-day it may add the task of training farm superintendents; to-morrow it may organize an adequate extension department. Courses and methods will change as new contemporary needs arise. But there remains always the abiding, final service of the agricultural college, its permanent function. This function will be defined in different ways by different men, but I venture to define it as follows: *The permanent function of the agricultural college is to serve as a social organ or agency of first importance in helping to solve all phases of the rural problem.* We shall not attempt at once to argue this proposition. We must, however, try to answer the question, What

* Read November 2, at the eighteenth annual convention of the Association of American Agricultural Colleges and Experiment Stations, Des Moines, Iowa.

is the rural problem? And in the answer may be revealed, without need of extended discussion, the mission of the college.

1. The days are going by when agriculture may be classed with the mining industries. Soil culture is supplanting pioneer farming. Skill is taking the place of empiricism. The despotism of the grandfather is passing. Applied science and business practise have been hitched to the plow. Yet the most obvious need of American agriculture is better farming. Improved farm land in the United States gives but nine dollars of gross return per acre; the average yield per acre of corn is 23.5 bushels, whereas a very modest ideal would be double this amount; the wheat yield is 13.5 bushels per acre, in Germany nearly twice as much. These are crude but legitimate illustrations of our inferior farming. We must have greater yields of better products, secured at less cost per unit. The farm problem is, therefore, first of all a problem of increasing the technical skill of our farmers. Science unlocks the cabinet of nature's treasures, but only the artist-farmer can appreciate and use the storehouse thus opened to him.

2. But produce-growing is not the only aspect of the farm problem. Each effective pair of shears needs two blades; in this case produce-selling is the other blade. Mere productiveness does not solve the farm question. The farmer cares less for the second spear of grass than he does for a proper return from the first spear. Business skill must be added to better farming methods. The farm problem is also a business question.

3. The moment, however, we begin to discuss price we enter a realm where economic factors dominate. We commonly say demand and supply determine price; but effective demand and effective supply are the resultants of many forces. The supply of a given product is influenced by the cost of growing in various locations, by cost of transportation, by competition of other countries. The demand is influenced by the state of wages, by standards of living, by effectiveness of distribution. The farmer may not always control these conditions, but he must reckon with them. He must know the laws of economics as well as the laws of soil-fertility. The farm problem becomes then an industrial question; for the farmer's prosperity is influenced most profoundly by the economic life of the nation and of the world. And in a still wider sense is the rural question one of economics. The industry as a whole must prosper. It is of no great moment that here and there a farmer succeeds. The farming *class* must prosper. Of course individual success in the case of a sufficient number of farmers implies the success of the industry. But it is quite possible to have a stagnant industry alongside numerous individual successes. The farmers as a whole must be continually and speedily advancing to better economic conditions.

4. Nor may we ignore the political factor in the rural problem. Doubtless the American farmer, like most Americans, places undue reliance upon legislation. But we can not disregard the profound industrial and social effects of either wise or foolish laws. The political efficiency of the farmer will have much to do in determining class progress. Furthermore, the political duties of farmers must be enforced, their influence must continue to be exerted in behalf of the general policies of government. It is of vital consequence to our democratic government that the American farmer shall in no wise lose his political instinct and effectiveness.

5. The consideration of the political phase of the question leads us to the heart of the farm problem. For it is conceivable that the farmers of this country may as a class be skilled growers of produce, successful sellers of what they grow, and indeed that the industry as a whole may be prosperous, and yet the farming class in its general social and intellectual power fail to keep pace with other classes. It is not impossible that a landlord-and-tenant system, or even a peasant system, should yield fairly satisfactory industrial conditions. But who for a moment would expect either system to develop the political and general social efficiency that American democratic ideals demand? Even if there is no immediate danger of either of these systems becoming established in America, we still desire that our farmers as a class shall secure for themselves the highest possible position not only in industry but in the political and social organization of American society. Indeed this is the ultimate American rural problem, *to maintain the best possible status of the farming class*. No other statement of the problem is satisfactory in theory. None other is explanatory of the struggles and ambitions of farmers themselves. The American farmer will be satisfied with nothing less than securing for his class the highest possible class efficiency and largest class influence, industrially, politically, socially. It is true that industrial success is necessary to political and social power. But it is also true that social agencies are needed in order to develop in our American farmers the requisite technical skill, business method and industrial efficiency. The influence of such social forces as education, developed means of communication, the organization of farmers, and even the church, must be invoked before we can expect the best agricultural advancement. And the end is after all a social one. The maintenance of class status is that end.

This analysis of the rural problem is necessarily brief, almost crude, but I hope that it reveals in some degree the scope and nature of the problem; that it indicates that the farm question is not one merely of technique, fundamental as technical skill must be; that it demonstrates that the problem is also one of profound economic, political and social significance. If this be so, do we need to argue the proposition that

the function of the agricultural college is to help solve all phases of the problem? We all recognize the place of the college in assisting our farmers to greater technical skill. By what pleas shall we gainsay the mission of the college in ministering to rural betterment at all points, whether the conditions demand technical skill, business acumen, industrial prosperity, political power or general social elevation? Why shall not the agricultural college be all things to all farmers?

Assuming that this statement of the permanent mission of the agricultural college is an acceptable one, the practical inquiry arises, does the college as now organized adequately fulfil its function, and, if not, by what means can the defect be remedied? The colleges are doubtless serving the industrial and social need to some degree. But I believe that it is not unjust to assert that the existing courses of study in agriculture, the organization of the college and the methods of work are not adequate if the college is to secure and maintain this supreme leadership all along the line of rural endeavor. This is not criticism of existing methods. The colleges are doing good work. But the present effort is partial, because the emphasis is placed upon the technical and especially upon the individual phases of the problem. The industrial, the political and the social factors are not given due consideration. Our present-day agricultural course, on the vocational side, is chiefly concerned with teaching the future individual farmer how to apply the principles of science to the art of farming, and in training specialists who shall make further discoveries either in the realm of science or in the application of the scientific principle to the art. The technical element absolutely dominates the vocational portion of the agricultural course. Very slight attention is given to the discussion of other phases of the farm problem. To meet the needs of the future the whole spirit and method of the agricultural college must be 'socialized'—to use an overworked phrase for want of a better one. We must get away from the idea that the individual and the technical aspects of agricultural research and teaching are the sufficient solution of the farm problem.

When we ask, what are the means for 'socializing' the agricultural college, the expected answer may be, the study of rural social science or 'rural economy.' But I am pleading not merely for the addition of a few subjects to the course of study, but for an educational policy. The answer, therefore, will not be quite so simple. What then are the methods by which the college may more fully assume its function of helping to solve all phases of the farm problem?

1. The indispensable requirement is that the college shall consciously purpose to stand as sponsor for the whole rural problem. It is to assume a place of leadership in the campaign for rural betterment. Whether or not it is to be the commander-in-chief of the armies of

rural progress, it should be the inspiration, the guide, the stimulator of all possible endeavors to improve farm and farmer. This attitude of mind is purely a matter of ideals, deliberately formed in the light of the abiding needs of the farming class. It is the intangible but pervasive influence of an object which is perfectly definite even if avowedly spiritual. It is a question of atmosphere. It is a matter of insight. The college must have a vision of the rural problem in its entirety and in its relations. At the college we should find, if anywhere, the capacity to understand the ultimate question in agriculture. We know that this ultimate question in agriculture can not be expressed alone by the terms nitrogen, or balanced ration, or cost per bushel, but must be written also in terms of the human problem, the problem of the men and women of the farm. So we shall see the college consciously endeavoring to make of itself a center where these men and women of the farm shall find light and inspiration and guidance in all the aspects of their struggle for a better livelihood and a broader life. The college must avow its intention of becoming all things to all farmers. Whether this means the study of fertility, of animal nutrition, of soil bacteriology, or whether it means the consideration of markets, of land laws, of transportation, of the country church, of pure government, the college will lead the way to the truth.

2. As the first requisite is that of the conscious ideal or purpose, the second is one of organization. It seems to me that the socialization of the college can not proceed very far until the principle of university extension is pretty fully recognized. The college must be in constant and vital touch with the farmers and their associations. Therefore each agricultural college should as rapidly as possible develop a definite tri-partite organization which reveals the college in its three-fold function as an organ of research, as an educator of students, and as a distributor of information to those who can not come to the college. These are really coordinate functions and should be so recognized. The college should unify them into one comprehensive scheme. The principle of such unity is perfectly clear; for we have in research the quest for truth, in the education of students the incarnation of truth, and in extension work the democratization of truth. Until these three lines of effort are somewhat definitely recognized and organized, the college can not work as leader in solving the rural problem.

3. Thirdly, the social sciences, in their relation to the rural problem particularly, must receive a consideration commensurate with the importance of the industrial, the political and the social phases of the farm question. In research, for instance, the colleges should make a study of the history and status of these aspects of agriculture. As a matter of fact, we know very little of these things. There have been but few scientific investigations of the economic features of the industry,

and practically nothing has been done in the more purely social questions. Here is a great untilled field. How the various farm industries have developed, a comprehensive study of the agricultural market, the relation of transportation to the industry, the tendencies as to centralization of farms and tenant-farming, the sociological questions of rural illiteracy, pauperism, insanity, health, education, the effects of rural life upon character, religious life in the country—a hundred subjects of importance in the solution of the farm problem are almost virgin soil for the scientific investigator. It is the business of the agricultural colleges to assist, if not to lead, in such work of research. It is work that must be done before the social phases of agricultural education can be fully developed.

When we come to the course of study, we face a question difficult for some colleges because the agricultural curriculum is already overcrowded. I have not time to discuss this practical administrative question. I believe, however, that it can be worked out. What I wish to emphasize is the idea that in every agricultural course the social problems of the farmers shall have due attention. We should not permit a person to graduate in such a course unless he has made a fairly adequate study of the history and status of agriculture, of the governmental problems that have special bearing upon agricultural progress, of such questions in agricultural economics as markets, transportation, business cooperation, and of such phases of rural sociology as farmers' organizations, the country church, rural and agricultural education, and the conditions and movements of the rural population. For the college can not carry out the purpose we have ascribed to it, unless these subjects are given an important place in the course of study. We talk about the work of the college in training leaders, usually meaning by leaders men who are expert specialists or possibly farmers of extraordinary skill. Do we realize that the greatest need of American agriculture to-day is its need of *social leadership*? Nothing can be more imperative than that the agricultural college shall send out to the farms both men and women who have not only the capacity to win business success, but who also have the social vision, who are moved to be of service to the farm community, and who have the training which will enable them to take intelligent leadership in institute, school, church, grange, and in all movements for rural progress. Upon the college is thrust the responsibility of training men and women to understand the whole rural problem and from the vantage ground of successful farming to be able to lead the way toward a higher status for all farmers.

Possibly the argument for introducing rural social science into the agricultural course is chiefly a sociological one. But there is also involved a pedagogical question of most profound significance. For sev-

eral decades the educational camp has been sharply divided over the ancient but recurring controversy between the Greek cultural ideal and the Roman utilitarian ideal. I venture the opinion that these two forces of educational idealism will soon reach a compromise which for all practical purposes will take this question out of the pale of serious debate. The classicist will concede that the scope of the term culture may be greatly enlarged, and he may even allow a quite new definition of the cultivated man. It will be generally admitted, to use Professor Bailey's phrase, that 'every subject in which men are interested can be put into pedagogic form and be a means of training the mind.' On the other hand, the technical educator will concede that a college graduate, in whatever course, should be a cultivated man and that there are certain studies with which all cultivated men should have some familiarity. The technical college will, moreover, be compelled to employ instructors who can so teach the technical subject that it shall not only give the knowledge and training desired, but shall also yield sound culture, become truly liberalizing and vision-giving. But a greater question remains. As society becomes more fully self-directive, the demand for social leadership increases. Almost instinctively we look to the college-trained man for such leadership. We expect him to understand and to help answer the questions that society has to meet. It is not enough that he do his particular work well; he has a public duty. Only thus can he pay all his debt to society for the training he has had. Yet to-day our technical courses are largely engaged in training individuals who, barring some general culture, are highly specialized experts. What preparation, for instance, does the future engineer get in college for facing such a matter as the labor question? He is likely to be brought into close touch with this question. But as a rule he is not especially qualified to handle it. The point of view of the course he has pursued is technique, ever technique. He secures in college little incentive and less training for intelligent performance of his duty as citizen and as member of society. The problems of mathematics are not the problems of industry, and profound study of chemistry gives neither the premises nor the data for sound judgment upon social questions. These public questions can not be left to social experts. A democratic society must insist that all its educated men shall be leaders in solving society's problems. But even the educated men can not lead unless they have first been taught. I believe society has more to fear from technical experts who either neglect their social duty or are ignorant of the social problem than it has from highly trained specialists who have never studied Greek nor mastered Browning. Moreover, under modern conditions, have we a right to call that man cultivated who ignores the great social problems of the age? We face here one of the coming educational questions, how can the industrial course be

made to train men for the social leadership the new régime demands? I see no answer except that the course must be made truly and broadly vocational, and consequently that large place must be given to social studies, and particularly to the concrete problems of government, industry and social life.

If we examine our agricultural course from this standpoint, we shall have to admit that it has the flaw common to most industrial courses. It is too technical. It is not truly vocational. It does not present the social view-point. It does not stimulate the student to social activity. It does not give him a foundation for intelligent social service when he shall go to the farm. He should study agricultural economics and rural sociology, both because rural society needs leaders and because, in the arming of the man, the knowledge of society's problems is just as vital as either expert information or personal culture.

4. To carry out the function of the agricultural college we need, finally, a vast enlargement of extension work among farmers. This work will not only be dignified by a standing in the college coordinate with research and the teaching of students, but it will rank as a distinct department, with a faculty of men whose chief business is to teach the people who can not come to the college. This department should manage farmers' institutes, carry on cooperative experiments, give demonstrations in new methods, conduct courses of reading, offer series of extension lectures, assist the schools in developing agricultural instruction, direct the work of rural young people's clubs, edit and distribute such compilations of practical information as now appear under the guise of experiment station bulletins, and eventually relieve the station of the bulk of its correspondence. Such a department will be prepared to incorporate into its work the economic, governmental and social problems of agriculture. It will give the farmers light upon taxation as well as upon tree-pruning. The rural school will have as much attention as corn-breeding. The subject of the market—the 'distributive half of farming,' as John M. Stahl calls it—will be given as much discussion as the subjects bearing upon production. We shall find here a most fertile field for work. The farmers are ready for this step. They have, as a rule, appreciated the real nature of the farm problem more fully than have our agricultural educators. Perhaps at times they have placed undue reliance upon legislation. Perhaps in periods of depression they have overweighed the economic pressure as against the lack of skilled farming. But the great body of farmers has rightly estimated the importance of the economic, political and social questions as related to their ultimate prosperity. In grange meetings, for example, the subjects which arouse greatest interest are such themes as taxation, the rural telephone, the country school, business cooperation. The explanation of all the farmers' movements is that the farmers be-

lieve the farm problem to be much more than a question of technique. They want light on the whole problem.

The college, chiefly through its socialized extension department, has a mission also to those professional people whose sphere of work is in the rural community. The rural educator, the country clergyman, the editor of the country paper, and even the lawyer and physician who deal with country people, should have a large share in helping to solve the farm problem. They, too, need to know what the rural problem is. They, too, need the eye that sees the necessary conditions of rural betterment and the heart that desires to help in rural progress. By some of the same methods that reach the farmers themselves can the college instruct and inspire these others.

And, finally, the college will take its place as the 'social organ or agency of first importance in helping to solve the farm problem in all its phases.' The church, the school, the farmers' organization—all these social organs have their work to do. None can do the work of the others. But they should work together. Each should appreciate its own mission and its own limitations; each should recognize the function of the others, and all should intelligently unite their forces in a grand campaign for rural betterment. More properly than perhaps any other agency the socialized extension department of the agricultural college can act as mediator and unifier, serve as the clearing-house and directing spirit in a genuine federation of rural social forces. Inspired by the conscious purpose of the college to help at all points in the solution of the farm question, informed by the knowledge acquired through research into the economic and social problems of agriculture, aided by a multitude of educated farmers trained in the colleges to know the rural problem and to lend a hand in its settlement, dignified by its status as a coordinate branch of the college activities, the extension department may well act as the chief agency of stimulation and unification in the social movements for rural advancement.

In this discussion the practical details of carrying out the program advocated have not been touched upon. When once it becomes a distinct policy of the college to assume leadership in the movement for rural betterment, such questions as subject-matter for study, text-books, qualified instructors and time in the curriculum will settle themselves. Neither has any attempt been made to give illustrations; and, therefore, this paper may seem dogmatic if not academic, a prophecy rather than an outline of progress, the statement of an idea rather than a practicable program. But I think there is abundant evidence that a current is setting in toward the enlargement of the work of the agricultural college, along the social lines indicated. The rapid development of farmers' institutes, the growth of other phases of extension teaching, the sentiment of those in authority that the experiment station must

soon slough off its work of education and confine itself to research, the holding of occasional conferences for rural progress, in which country teachers and pastors join with the farmers, the initiative of the college in federating various state farmers' organizations into one grand committee, the inauguration of several brief courses in agricultural economics and rural sociology, the cooperation of some of the colleges with the Carnegie Institution in an investigation into the history and conditions of agriculture in its economic and social phases, the pride with which a few of our colleges point to the increasing number of young men they are sending to the farms—all these facts seem clearly to indicate that the agricultural college will soon assert its function of leader in the endeavor to solve all phases of the rural problem.

If the analysis thus offered is a correct one, the question of 'rural economics' is far from being merely a matter of adding three or four subjects of study to the agricultural course. It involves the very function and policy of the college itself. It alone gives proportion to the problem of agricultural education, because, while distinctly admitting the need of better farming and the consequently fundamental necessity of the technical training of farmers, it emphasizes the importance of the economic and political and social aspects of rural development. And it thereby indicates that only by a due recognition of these factors, in purpose, in organization, and in course of study, can the American agricultural college fulfil its mission to the American farmer.

EDUCATION FOR EFFICIENCY.*

BY DR. W. H. MAXWELL,

SUPERINTENDENT OF SCHOOLS OF THE CITY OF NEW YORK.

THE National Educational Association meets in its forty-fourth annual convention at the moment when Japan has given the world another great object lesson in the value of education. Ever since Napoleon's retreat from Moscow, the world has stood in awe of that massive and mysterious power which we call Russia. In that fateful campaign it was not the skill of the Russian commanders or the bravery of the Russian soldiers that wrought the catastrophe; it was the snowflakes—the arrows from the quiver of God—that overwhelmed the might of the invader. Ever since, Russia has gloried in a victory that was not of her own achieving. The world accepted her at her own valuation, and stood in awe. Wrapt in the glamor of an unearned renown, Russia pursued her aggressions practically unopposed, until her empire stretched from the Baltic Sea to the Pacific Ocean. There her career of conquest has ended. There, once again, has broken out the irrepressible conflict between ignorance and enlightenment. On the one side stand a people, almost countless in number and rich beyond knowledge in all natural wealth, but ignorant, devoid of initiative, and alienated from their rulers by despotism and cruelty. On the other side stand the Japanese, a people limited in numbers and confined in territory, but born again through the diffusion of knowledge and through the universal training for efficiency which has made their inherited patriotism invincible.

Japan has but repeated at Port Arthur and at Mukden and on the Yellow Sea the lesson of history—the lesson of Marathon, of Zama, of the Invincible Armada, of the Heights of Abraham, of Waterloo, and of Sedan—the lesson that the race which gives its children the most effective training for life, sooner or later becomes a dominant race. Borrowing eagerly from western civilizations, Japan has adopted for her own whatever school exercise or method of teaching gives promise of training for efficiency. Nobly has she repaid her debt to Europe and America. She has demonstrated to the world that the training of the young to skill of hand, to accuracy of vision, to high physical development, to scientific knowledge, to accurate reasoning and to practical patriotism—for these are the staples of Japanese education—is the best and cheapest defense of nations.

* Address of the President of the National Educational Association, Asbury Park and Ocean Grove, July 3, 1905.

Such are the lessons of war. The history of peaceful industrial effort tells the same story. No nation is truly prosperous until every man has become not merely a consumer but a producer. As Emerson most truly said: A man fails to make his place good in the world, unless he not only pays his debt, but also adds something to the common wealth. Efficient universal education that makes men producers as well as consumers is the surest guarantee of progress in the arts of peace—is the mother of national prosperity.

‘But,’ exclaims an objector, ‘this is gross materialism.’ Not so. The history of the world shows that a nation improves morally and intellectually only as its physical condition is strengthened. The futility of religious missionary effort, when unaccompanied by physical betterment, is of itself sufficient to prove the thesis. Better shelter, better food, better clothing, are the necessary antecedents and accompaniments of higher thinking, greater self-respect and more resolute independence.

True, material prosperity too often brings with it a train of evils all its own; sensual indulgence or slothful ease, it may be; or the grasping at monopoly and ‘man’s inhumanity to man’; or a feverish pursuit of material things to the neglect of the spiritual. True, enormous wealth is often accompanied, particularly in crowded centers of population, by extreme poverty. These, however, are but temporary reversions to barbarism—the price we must pay for progress. The best correctives of the evils generated by the accumulation of wealth are not anti-trust laws or other repressive legislation, but a system of schools which provides a training for all that is equal to the best which money can buy; which discovers and reveals genius born in low estate and enables it to fructify for the common good; and which guarantees to every child the full development of all his powers. The trained man will demand and will, in the long run, receive his due share. Education is a chief cause of wealth and the most certain corrective of its abuse. In a community in which every man was trained to his highest efficiency, monopoly and poverty would be alike impossible.

In the light of these historic truths you will permit me, as a prelude to the addresses that are to be delivered before the meetings, general and departmental, of this convention, to state very briefly—I do not venture to say, discuss—a few of the burning educational questions of the day.

The first of these questions is: What does education for efficiency mean? It does not mean that every man should be trained to be a soldier. True, the man who is well trained for the duties of peace is, in these days of scientific instruments of destruction, well prepared for war; but military prowess can never become the ideal of education among a great industrial people. It does not mean merely that each citizen should be able to read the newspapers and magazines so that

he may be familiar with political discussions and able to make an intelligent choice between candidates and policies. The imparting of such knowledge to each individual is essential in a democratic nation, but it falls far short of the education needed to secure the highest efficiency of each unit of society. Still less does it mean that wretched travesty of education which would confine the work of the public schools to those exercises in reading, writing and ciphering which will enable a boy or a girl at the age of fourteen or earlier, to earn starvation wages in a store or factory. Education for efficiency means all of these things, but it means much more. It means the development of each citizen first as an individual and second as a member of society. It means bodies kept fit for service by appropriate exercise. It means that each student shall be taught to use his hands deftly, to observe accurately, to reason justly, to express himself clearly. It means that he shall learn 'to live cleanly, happily and helpfully, with those around him'; that he shall learn to cooperate with his fellows for far-reaching and far-distant ends; that he shall learn the everlasting truth of the words uttered nearly two thousand years ago: 'No man liveth to himself' and 'Bear ye one another's burdens.' Such, I take it, is the goal of American education.

If this ideal of developing the highest individual and social efficiency of each citizen is the goal of American education, obviously the curriculum of our schools becomes an object of extreme solicitude. Particularly is this the case with the elementary schools, for these contain over ninety per cent. of the children under instruction. During the last quarter of a century a great movement for the reform of the elementary curriculum has been gathering strength. The most prominent characteristics of this movement would seem to be the development of the imagination and the higher emotions through literature, and art, and music; the training of the body and the executive powers of the mind through physical training, play and manual training; and the introduction of the child to the sources of material wealth, through the direct study of nature and of processes of manufacture. At first the movement seems to have been founded on a psychological basis. To-day the tendency is to seek a sociological foundation—to adjust the child to his environment of man and of nature.

At various times during the past ten or fifteen years, and particularly during the past year, reactionary voices have been loudly raised against the new education, and in favor of the old. Such was to be expected. Reactions follow inevitably in the wake of every reform, political and social. Analysis will show that the reactionary tendencies in education arise from three chief sources:

1. The demagogic contentions of selfish politicians who see that it costs more money to teach the new subjects of the curriculum than the old, and that thus a large proportion of the public revenue is diverted

from the field of political spoils. These are the men who have invented the term 'fads and frills' to designate art, manual training, music and nature study. It must be theirs to learn that it will require something more than a stupid alliteration to stem the tide of those irresistible forces that are making the modern school the faithful counterpart of the modern world and an adequate preparation for its activities. The saving common-sense of the common people, when deliberately appealed to, will always come to the rescue of the schools.

2. The reactionary tendency is due in part to an extremely conservative element that still exists among the teaching force. For the most part, teachers who are extremely conservative were themselves brought up chiefly on the dry husks of a formal curriculum. They find it difficult to learn and to teach the new subjects. They dislike to be bothered by the assistance of special teachers. Accustomed to mass work both in learning and in teaching, they regret the introduction into the school-room of arts which demand attention to individual pupils.

3. The reactionary tendency has its roots even among the more progressive teachers in a vague feeling of disappointment and regret that manual training, correlation and nature study have probably not accomplished all that their enthusiastic advocates promised ten to twenty years ago.

The feeling of disappointment, we might say even of discontent, among the more thoughtful and progressive teachers, is what might have been anticipated. In the first place, public education has become a much more difficult thing than it was half a century ago. It has become more difficult for two reasons:

1. Because of the constantly increasing migration of population from the country to the cities. Children removed from rustic to urban life lose that most valuable education which comes from the work and the associations of the farm-yard and the fields.

2. Because of the enormous increase in immigration from abroad, and particularly because the character of the immigration has changed. Up to the middle of the last century the majority of our immigrants were of kindred blood with the American people and a large proportion spoke our language. Gradually, however, the tide of immigration, while swelling until it has now reached the enormous total of one million a year, has shifted its chief sources from the shores of the North and the Baltic Seas to the shores of the Mediterranean. The peoples of southern Europe, illiterate, accustomed to tyranny, without individual initiative, and habituated to a low standard of living, huddle themselves together in our large cities and factory towns under conditions inimical alike to morals, to physical well-being and to intellectual advancement. Teachers have a good right to complain that municipal authorities in permitting the over-crowding of immi-

grants in unsanitary quarters have aided the establishment of the most serious obstacle yet discovered to the upward progress of public education.

In the second place, the feeling of disappointment with the results of the newer studies arises from the fact that these studies were introduced before the teachers were prepared to teach them; that for too long they were concerned chiefly with uninteresting formal processes rather than with interesting results; that they were not related to real needs of school and home; and were not properly coordinated with other phases of the curriculum. Much yet remains to be done to assimilate the environment of the school to the environment of the world.

And yet, while we may feel discontented with the situation, and regret the increased difficulties of our work, there is no reason for discouragement. I have no hesitation in saying that in general intelligence, in all-round efficiency, in power of initiative, the pupils whom I see are superior to those of a quarter of a century ago. If the obstacles before us are more formidable, if the problems are more complicated than those presented to our predecessors, the teachers of America are better organized and better equipped to overcome the obstacles and to solve the problems. He who has sailed in a modern steamship through an ocean storm has seen the mighty vessel cleave the billows and scarcely slacken her speed in the teeth of the hurricane. Down in the depths of the ship men are piling coal on the furnaces and releasing a force—the imprisoned sun-power of uncounted ages—that baffles the waves and defies the whirlwind. And so it is with our ship of state. Come what storms of ignorance or wickedness there may, teachers are supplying the fuel of knowledge and releasing the force of intelligence that will hold our nation in the straight course of progress.

And yet, the teachers of America are still far from satisfied with their achievements. They are dissatisfied with the elementary curriculum, because it seems crowded by the new studies that have been added without diminishing the number of the old. They are dissatisfied with the high school curriculum because the old-style language, mathematics and science course, however suitable it may be for admission to college, does not precisely meet the needs of boys and girls who are going directly into life. They are dissatisfied with the specialized high school, because it seems lacking in some of those attributes of culture in which the old time school was strong. And they are dissatisfied with the college course, because the elective system which has taken the place of the old, prescribed course does not seem to give a strong, intellectual fiber to the weaker students who, too often, follow the path of least resistance. And they are dissatisfied because there is less intelligence, less efficiency and less helpfulness in

the world than the world needs. So far from feeling concerned at this widespread discontent, we should rejoice that it exists. There is nothing so blighting to educational enthusiasm as smug satisfaction with what is or what has been; there is nothing so stimulating to educational effort as a realizing sense of present imperfections and of higher possibilities.

As to the curriculum of the higher schools and colleges, the problem is really not what studies shall be inserted and what omitted, but how shall we make it possible for the student to get that culture, efficiency and power out of his studies which his development requires. This is really a question for psychology to answer. Well may we ask of our universities with their psychological laboratories and their sensitive apparatus for measuring mental reactions: Will psychology ever accomplish what phrenology once promised but has never performed—the determination of a young student's capabilities and of the line of work he ought to pursue?

As to the elementary curriculum, surely we shall not go far wrong if we apply to each study and even to each detail of each study these four questions:

1. Is this study or this exercise well within the comprehension of the child?

2. Does it help to adjust him to the material and the spiritual environment of the age and the community in which he lives?

3. Does it combine with the other studies of the curriculum to render him more efficient in conquering nature and in getting along with his fellows, and thus to realize ideals that transcend environment?

4. Does it accomplish these objects better than any other study that might be selected for these purposes?

If these questions are answered in the affirmative, we may reasonably conclude that the study or the exercise in question is an important element in education for efficiency. Examined from the view point established by these questions, every study will assume an aspect very different from that which it bears when taught without a well defined object. Take drawing, for example. Drawing may be so taught as not only to lay bare to seeing eyes new worlds of beauty, but to lead to that reverent appreciation of nature and the reapplication of her lessons to daily industrial art which is the way, as Ruskin has said, in which the soul can most truly and wholesomely develop essential religion.

Again, take the teaching of agriculture. While our soil seemed inexhaustible in fertility as in extent, the need of such teaching was not felt. Now, however, we are obliged to have recourse to lands that produce only under irrigation. The rural schools have added to our difficulties by teaching their pupils only what seemed most necessary for success when they should move to the city. The farms of New

England are, in large measure, deserted or are passing into alien hands. To retain the country boy on the land and to keep our soil from exhaustion, it is high time that all our rural schools turned their attention, as some of them have done, to scientific agriculture. There is no study of greater importance. There is none more entertaining. If every country boy could become, according to his ability, a Burbank, increasing the yield of the fruit tree, the grain field and the cotton plantation, producing food and clothing where before there was only waste, what riches would be added to our country, what happiness would be infused into life! To obtain one plant that will metamorphose the field or the garden, ten thousand plants must be grown and destroyed. To find one Burbank, ten thousand boys must be trained, but unlike the plants, all the boys will have been benefited. The gain to the nation would be incalculable. Scientific agriculture, practically taught, is as necessary for the rural school, as is manual training for the city school.

Nor are our people going to rest satisfied with mere manual training. The Mosely commissioners pointed out that the great defect in American education is the absence of trade schools. Trade schools will inevitably come. The sooner the better. They are demanded for individual and social efficiency.

It is not in secondary schools alone, however, that efficiency demands highly differentiated types of schools. It is absurd to place the boy or girl, ten or twelve years of age, just landed from Italy, who can not read a word in his own language or speak a word of English, in the same class with American boys and girls five or six years old. For a time at least the foreigners should be segregated and should receive special treatment. Again, the studies that appeal to the normal boy only disgust the confirmed truant or the embryo criminal. Yet again, the mentally defective, the crippled and the physically weak children require special treatment. Unless all indications fail, the demand for education for efficiency will lead in all our large cities to the organization of many widely differentiated types of elementary school.

The problem of the curriculum, important as it is, is less important than the problem of the teacher. The born teacher, that is, the man or woman who has a genius for teaching, will teach well, in spite of any curriculum, however bad. Unfortunately, genius is as rare in the profession of teaching as it is in law, or medicine, or any other profession. The great majority of us, as it needs must be, are very common-place persons, who are seeking for light and doing the best we can. Hence the supreme importance of training. And yet there is no part of our work to which so little thought and investigation have been given. Normal schools in this country are still very young—only a little over half a century old. The first normal schools were

high schools with a little pedagogy thrown in. The majority of them remain the same to this day. There is a strong movement, however, toward purely professional schools to which no student who has not had a reasonably liberal education is admitted, and in which he shall devote his entire time to learning how to teach—how to observe, understand and exercise children both mentally and physically. Welcome and necessary as this movement is, if all teachers are to train for efficiency, we are still far from precise scientific notions as to the best methods of training teachers. I commend this subject to the National Council as one of the next investigations it should undertake.

To secure training for efficiency, the conditions of teaching must be such that each teacher shall be able to do his best work. By common consent one of these conditions is that teachers shall not be subjected to the ignominy of seeking political or other influence, or cringing for the favor of any man, in order to secure appointment or promotion. During the past year, two events have occurred which seem to be full of promise for the establishment of this condition. The public school teachers of Philadelphia have been freed from the bondage to ward politicians in which they were held for well nigh a century; and the one-man power, beneficent as such a system proved under a Draper and a Jones in Cleveland, has been supplanted by a seemingly more rational system. Independence of thought and freedom of initiative are necessary to the teachers of a nation whose stability and welfare as a republic depend upon the independence, the intelligence and the free initiative of its citizens. Independence of thought and freedom of initiative may be throttled by bad laws, but under the best of laws they will be maintained only by the teachers themselves. By making it unprofessional to seek appointment or promotion through social, religious or political influence, the teachers of this country have it in their power to establish one of the most essential conditions of education for efficiency.

Under the conditions that confront us, particularly in the large cities, with the rapid increase and constant migration of our home population, with the influx of vast hordes of people from abroad, alien in language, alien in modes of thought, and alien in tradition, the character of our elementary work is undergoing a profound transformation. We are beginning to see that every school should be a model of good housekeeping and a model of good government through cooperative management. What more may the schools do? They can provide knowledge and intellectual entertainment for adults as well as for children. They can keep their doors open summer as well as winter, evening as well as morning. They can make all welcome for reading, for instruction, for social intercourse, and for recreation. But I for one believe they may do still more. When I look upon the anemic faces and undeveloped bodies that mark so many of the children

of the tenements, when I read of the terrible ravages of tuberculosis in the same quarters, I can not but think that the city should provide wholesome food at the lowest possible cost in public school kitchens. To lay the legal burden of learning upon children whose blood is impoverished and whose digestion is impaired by insufficient or unwholesome feeding is not in accord with the boasted altruism of an advanced civilization or with the Divine command: Feed the hungry. Is this not also a subject for investigation by our National Council?

And should it some day come to pass that men will look upon corruption in public and corporate life, such as of late we have seen exposed in New York, Philadelphia and St. Louis, with the same loathing with which they regard crime in private life, it will be when the schools are in earnest about teaching our young people the fundamental laws of ethics, that

The ten commandments will not budge,
And stealing still continues stealing.

But economic perils and racial differences are the teacher's opportunity. Here in this country are gathered the sons and daughters of all nations. Ours is the task not merely of teaching them our language and respect for our laws, but of imbuing them with the spirit of self-direction, our precious inheritance from the Puritans; the spirit of initiative which comes to us from the pioneers who subdued a continent to the uses of mankind;* and the spirit of cooperation which is symbolized by and embodied in the everlasting union of sovereign states to promote the common weal. And as, in my own city, I see the eagerness of foreigners to learn, and the skill and devotion of our teachers, I can not but think that we are overcoming our almost insurmountable difficulties.

There is perhaps no more striking moment in all history than that at which the Apostle Paul, standing on Mars Hill and pointing to the blue Aegean, the center of the then known world, proclaimed the new but eternal doctrine: God hath made of *one* every nation of men for to dwell on all the face of the earth. Standing here as we do, on the border of the Atlantic Ocean, and beholding on the one side the dove of peace alighting from the hand of our President on the fields of carnage in the far east and on the other side the homes of peoples of all nationalities stretching from the Atlantic to the isles of the Pacific, under the protection of the American flag, may we not realize that we, as teachers, have a great part to perform in bringing a vast company to an understanding of the sublime truth that God has made all men *one* to dwell on the face of the earth—that their mission is not to defraud and to slay, but each to do his best for himself and to help his fellows.

* Münsterberg, *The Americans*, Chapter I. and XI.

ADDRESS OF PRESIDENT ROOSEVELT BEFORE THE
NATIONAL EDUCATIONAL ASSOCIATION.

I AM peculiarly pleased to have the chance of addressing this association, for in all this democratic land there is no more genuinely democratic association than this. It is truly democratic, because here each member meets every other member as his peer without regard to whether he is the president of one of the great universities or the newest recruit to that high and honorable profession which has in its charge the upbringing and training of those boys and girls who in a few short years will themselves be settling the destinies of this nation.

It is not too much to say that the most characteristic work of the republic is that done by the educators, by the teachers, for whatever our shortcomings as a nation may be—and we have certain shortcomings—we have at least firmly grasped the fact that we can not do our part in the difficult and all-important work of self-government, that we can not rule and govern ourselves unless we approach the task with developed minds, and with what counts for more even—with trained characters. You teachers make the whole world your debtors.

Of your profession this can be said with more truth than of any other profession, barring only that of the minister of the Gospel himself. If you—you teachers—did not do your work well this republic would not endure beyond the span of the generation.

Moreover, as an incident to your avowed work, you render some well-nigh unbelievable services to the country. For instance, you render to the republic the prime, the vital service of amalgamating into one homogeneous body the children alike of those who are born here and of those who come here from so many different lands lands abroad. You furnish a common training and common ideals for the children of all the mixed peoples who are being fused into one nationality. It is in no small degree due to you and to your efforts that we of this great American republic form one people instead of a group of jarring peoples. The pupils, no matter where they or their parents were born, who are being educated in our public schools will be sure to become imbued with that mutual sympathy, that mutual respect and understanding, which is absolutely indispensable for the working out of the problems we as people have before us.

And one service you render which I regard as wholly indispensable. In our country, where altogether too much prominence is given to the mere possession of wealth, we are under heavy obligations to such a body

as this, which substitutes for the ideal of accumulating money the infinitely loftier, non-materialistic ideal of devotion to work worth doing simply for that work's sake.

I do not in the least underestimate the need of having material prosperity as the basis of our civilization, but I most earnestly insist that if our civilization does not build a lofty superstructure on this basis, we can never rank among the really great peoples.

A certain amount of money is of course a necessary thing, as much for the nation as for the individual; and there are few movements in which I more thoroughly believe than in the movement to secure better remuneration for our teachers.

But, after all, the service you render is incalculable, because of the very fact that by your lives you show that you believe ideals to be worth sacrifice and that you are splendidly eager to do non-remunerative work if this work is of good to your fellow-men.

To furnish in your lives such a realized high ideal is to do a great service to the country. The chief harm done by the men of swollen fortune to the community is not the harm that the demagogue is apt to depict as springing from their actions, but the fact that their success sets up a false standard, and so serves as a bad example for the rest of us. If we did not ourselves attach an exaggerated importance to the rich man who is distinguished only by his riches, this rich man would have a most insignificant influence over us.

I want to interject something here that will make you keep your mind on the real meaning of my words. I am speaking of the rich man who thinks only of his riches, not of the rich man who uses his wealth rightly and regards it as means to an end. It is well, in this connection, to remember the explanation of the parable in the Bible about the difficulty encountered by the rich man who wants to get into heaven. It says that such entrance shall be difficult for 'the rich man who trusteth in his riches.' I am here talking just of rich men who trust in their riches, not of those who are good citizens and first-class men, for those of the latter class are entitled to the same respect as any other men.

It is generally our own fault if he does damage to us, for he damages us chiefly by arousing our envy or by rendering us sour and discontented. In his actual business relations he is much more apt to benefit than harm the rest of us, and, though it is eminently right to take whatever steps are necessary in order to prevent the exceptional members of his class from doing harm, it is wicked folly to let ourselves be drawn into any attack upon the wealthy man merely as such. Remember that, you teachers. It is just as wicked to attack men of wealth as such as it is to attack the man of poverty as such. And, furthermore, the man rendered arrogant by the possession of wealth is precisely the man who,

if he did not have it, would hate with envious jealousy the man who had it. And remember, also, that both sides of this shield are true.

The man roused into furious discontent and envy because he sees other men better off than himself would most decidedly misbehave himself if he got wealth. Moreover, such an attack is in itself an exceptionally crooked and ugly tribute to wealth, and therefore the proof of an exceptionally ugly and crooked state of mind in the man making the attack. Venomous envy of wealth is simply another form of the spirit which in one of its manifestations takes the form of cringing servility toward wealth, and in another the shape of brutal arrogance on the part of certain men of wealth. Each one of these states of mind, whether it be hatred, servility or arrogance, is in reality closely akin to the other two, for each of them springs from a fantastically twisted and exaggerated idea of the importance of wealth as compared to other things.

The clamor of the demagogue against wealth, the snobbery of the social columns of the newspapers which deal with the doings of the wealthy, and the misconduct of those men of wealth who act with brutal disregard of the rights of others seem superficially to have no fundamental relation; yet in reality they spring from shortcomings which are fundamentally the same, and one of these shortcomings is the failure to have proper ideals. The community that cherishes such ideals and that admires most the men who approximate most closely to those ideals—in that community we shall not find any of these unhealthy ideas of wealth.

This failure must be remedied in large part by the actions of you and your fellow-teachers, your fellow-educators throughout this land. By your lives, no less than by your teachings, you show that, while you regard wealth as a good thing, you regard other things as still better. It is absolutely necessary to earn a certain amount of money; it is a man's first duty to those dependent upon him to earn enough for their support, but after a certain point has been reached money-making can never stand on the same plane with other and nobler forms of effort.

The roll of American worthies numbers men like Washington and Lincoln, Grant and Farragut, Hawthorne and Poe, Fulton and Morse, St. Gaudens and MacMonnies; it numbers statesmen and soldiers, men of letters, artists, sculptors, men of science, inventors, explorers, road-makers, bridge builders, philanthropists, moral leaders in great reforms; it numbers all these and scores of others; it numbers men who have deserved well in any one of countless fields of activity; but of the rich men it numbers only those who have used their riches aright, who have treated wealth not as an end but as a means, who have shown good conduct in acquiring it and not merely lavish generosity in disposing of it.

And thrice fortunate are you to whom it is given to lead lives of resolute endeavor for the achievement of lofty ideals, and, furthermore,

to instill, both by your lives and by your teachings, these ideals into the minds of those who in the next generation will, as the men and women of that generation, determine the position which this nation is to hold in the history of mankind.

And now, in closing, I want to speak to you of certain things that have occurred during the last week and of how those things emphasize what I have just said to you as to the importance of this country having within its limits men who put the realization of high ideals above any form of money making. During this week our country has lost a great statesman who was also a great man of letters, a man who occupied a peculiar and unique position in our community, a man of whose existence we could each of us be proud because his life reflected upon each of us; for the United States as a whole was better because John Hay lived. John Hay entered the public service as a young man just come of age, as the secretary of President Lincoln. He served in the war, he was a member of the Loyal Legion. He was trusted by and was intimate with Lincoln as hardly any other man was. He then went on rendering service after service, and of his merits this was one of them: He had the great advantage and great merit of always being able at any moment to go back to private life unless he could continue in public life on his own terms. He went on rendering service after service to the country until as the climax of his career he served for some six years as secretary of state in two successive administrations, and by what he did and by what he was contributed in no small degree to achieve for this republic the respect of the nations of mankind. Such service as that could not have been rendered save by a man who had before him ideals as far above as the poles from those ideals which have in them any taint of what is base or sordid.

I wished to get for John Hay's successor the man whom I regarded as of all the men in the country that one best fitted to be such successor. In asking him to accept the position of secretary of state I was asking him to submit to a very great pecuniary sacrifice, and I never even thought of that aspect of the question, for I knew he wouldn't, either. I knew that whatever other consideration he had to waive for and against taking the position, the consideration of how it would affect his personal fortune would not be taken into account by Elihu Root. And he has accepted.

And now I am not speaking of Hay and Root as solitary exceptions. On the contrary, I am speaking of them as typical of a large class of men in public life, and when we hear so much criticism of certain aspects of our public life and of certain of our public servants, criticism which I regret to state is in many cases deserved, it is well for us to remember also the other side of the picture, to remember that here in America we now have and always have had at the command of the

nation in any crisis, in any emergency, the very best ability to be found within the nation, and that ability given with the utmost freedom, given lavishly and generously, although to the great pecuniary loss of the man giving it. There is not in my cabinet a man to whose financial disadvantage it is not to sit in the cabinet. There is not in my cabinet one man who does not have to give up something substantial, very largely substantial sometimes, that it is a very real hardship for him to give up, in order that he may continue in the service of the nation, and have the only reward for which he looks or for which he cares, the consciousness of having done service that is worth rendering.

And I hope more and more throughout this nation to see the spirit grow which makes such service possible. I hope more and more to see the sentiment of the community as a whole become such that each man shall feel it borne in on him, whether he is in public life or in private life—mind you, some of the very greatest public services can be best rendered by those who are not in public life—that the chance to do good work is the greatest chance that can come to any man or any woman in our generation, or in any other generation. That if such work can be well done it is in itself the amplest reward and the amplest prize.

THE PROGRESS OF SCIENCE.

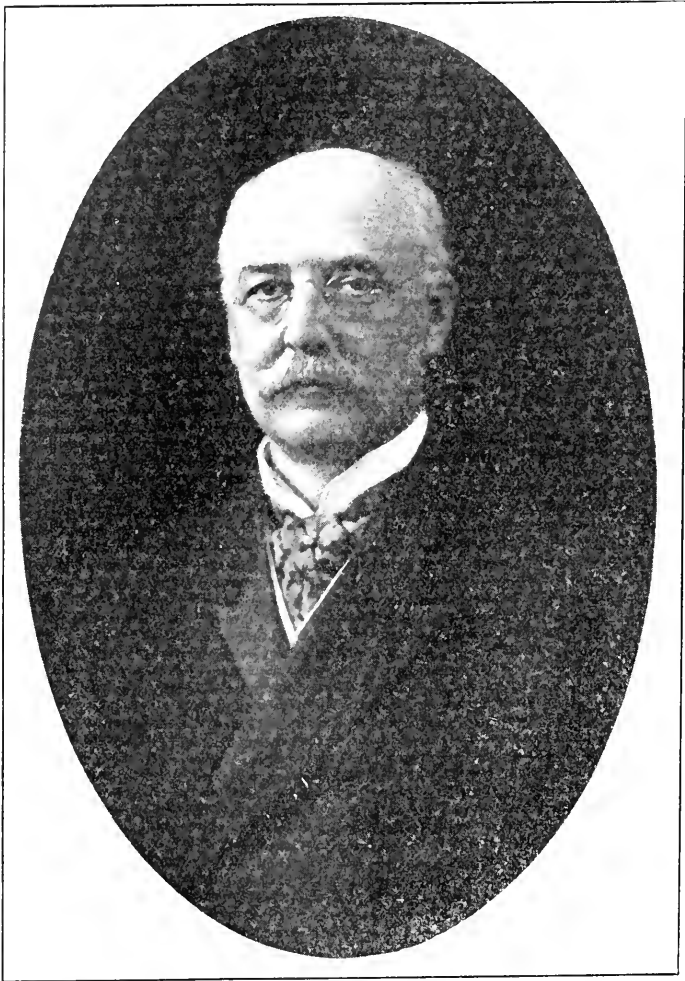
THE NATIONAL EDUCATIONAL ASSOCIATION.

THE National Educational Association held one of its great assemblages on the New Jersey coast during the first week of July. No official report of the registration was given out, but the attendance was estimated at 15,000, some newspapers placing it as high as 20,000. The association has been called an institute for the promotion of summer travel, and this is certainly one of its functions. Favorable arrangements are made with the railways, and teachers with their relations and friends are thus enabled to enjoy a trip of which the meeting is only an incident. Under these conditions the attendance has increased in an extraordinary manner. The registration was only 625 at the Saratoga meeting of 1885. At the previous Asbury Park meeting of 1894 it was 5,915. At the subsequent meetings it has been as follows. Denver, 11,297; Buffalo, 9,072; Milwaukee, 7,111; Washington, 10,533; Los Angeles, 13,656; Charleston, 4,641; Detroit, 10,182; Minneapolis, 10,350; Boston, 34,984; St. Louis, 8,109.

Asbury Park and Ocean Grove offered an attractive place of meeting to those who wished to visit the cities, the seaside or the mountains of the Atlantic seaboard, and in addition to the usual features of the program, addresses were made by the mayor of New York City and the president of the United States. Dr. W. H. Maxwell delivered on the first day the presidential address, which we are able to print in advance of its publication in the proceedings. Dr. Maxwell, who came to this country from Ireland at the age of twenty-two, was assistant superintendent and then superintendent of the Brooklyn schools,

and has since 1898 been head of the public school system of Greater New York. This is the most responsible educational position in the country. There are in New York City nearly one million children of school age, and the annual budget for the public schools is about \$30,000,000. Compared with the vast responsibility of administering this system, the presidency of Harvard University or the commissionership of education is comparatively unimportant. The responsibility is obviously increased by the political conditions and by the fact that in New York City are enormously emphasized the two increasing difficulties of education, to which Dr. Maxwell referred in his address—the crowding into cities and the quantity and quality of immigration.

In addition to addresses by the president of the association, by President Roosevelt and by Mayor McClellan, there were a number of papers presented before the general sessions. Dr. W. T. Harris, U. S. Commissioner of Education, without whom a meeting of the association would be incomplete, read a paper on 'The Future of Teachers' Salaries'; Dr. Andrew S. Draper, state commissioner of education, spoke of 'The Nation's Educational Purpose'; Mr. William Barclay Parsons, the eminent New York engineer, discussed 'The Practical Utility of Manual and Technical Training'; the question of child labor and compulsory education was treated by Mr. George H. Martin, secretary of the Massachusetts State Board of Education, and by Dr. Franklin P. Giddings, professor of sociology at Columbia University, who considered the perplexing topic of the relation of compulsory education and the prohibi-



WILLIAM HENRY MAXWELL, SUPERINTENDENT OF SCHOOLS, THE CITY OF NEW YORK,
PRESIDENT OF THE NATIONAL EDUCATIONAL ASSOCIATION.

tion of child labor to the decrease of the birth rate.

In addition to the general sessions, there was the usual meeting of the National Council of Education, which consists of sixty of the more active members of the association and holds sessions of general interest. There are, further, departments of kindergarten education, elementary education, secondary education, higher education, normal schools, manual training, art training, musical training, business

training, child-study, science instruction, physical education, school administration, library, special education and Indian education, all of which presented programs.

At the meetings of the National Educational Association there is a vast flood of platitudes annually poured out, but when there are practical questions to be discussed, the proceedings become at once more interesting and more scientific. The teachers are taking an increasing interest in all questions con-

nected with administration, and perhaps more especially in those relating to salaries, tenure of office, pensions and the like. At the recent meeting President Carroll D. Wright, of Clark College, presented the report of the committee appointed to consider these questions, giving valuable statistics shortly to be published. There are in the United States nearly 600,000 teachers, and it appears not unlikely that the National Educational Association will develop into a trades union representing their interests. The average salary, including the highest paid for supervision and the like, is said to be \$300 a year. President Roosevelt, in his address which is printed above, told his audience of 10,000 teachers that they were performing an incalculable service by the very fact that they believed ideals to be worth sacrifice and that they were eager to do non-remunerative work. The speaker prefaced these remarks with the statement that he believed in the movement to secure better remuneration for teachers. The rhetorical effect would have been better if the order of the sentiments had been reversed, for the audience cheered continuously for several minutes the first statement, while they listened to the latter in silence; and we are inclined to think that the teachers are right. The illustrations of men such as John Hay and Mr. Elihu Root, who were stated by the president to have sacrificed their material interests for the nation, can only carry a limited weight, when the teachers reflect on the great wealth acquired by these men, in part, at least, as the result of political affiliations.

The Rev. Dr. Nathan C. Schaeffer, state superintendent of public instruction in Pennsylvania, was elected president of the association, and it is expected that the place of meeting next year will be San Francisco. It is understood that in this case the group that manages the association was de-

feated: there is naturally a certain amount of politics in such an institution. Some complaints are heard that the association is not sufficiently democratic, and that the present methods of administration will be made permanent by the charter that it was voted to secure from congress. It is inevitable that an association of this character should be managed by a small group who maintain a permanent interest in the work, and it is also probable that one man will be dominant. So far as we are aware, the group in control has acted wisely, and the democratic character of the association is maintained so long as this group can be defeated or a new group placed in power, should this meet the wishes of the majority. The constitution, which it will be extremely difficult to alter if once adopted as a bill passed by congress, lodges the control in a board of directors, which consists of the officers, the past presidents, certain life-directors, who we believe purchased the position for \$100, and one member elected from each state. These officers are nominated by a committee containing one representative from each state or territory, elected by the active members of each state. There is, however, at least one state with only two active members, and it does not seem entirely democratic to place such a state against the hundreds of members representing New York or Illinois. Further, if a member is not elected by the state, the appointment is made by the president, and hitherto the constitution of the nominating committee and of the board of directors has been dictated by a small group of men. A more democratic form of government would probably be secured if the active members elected their representatives by ballot, which could be sent through the mail, and if the number of representatives were proportionate to the number of active members in each state.



SOME LEADING MEMBERS OF THE NATIONAL EDUCATIONAL ASSOCIATION.

In the center of the group is Dr. W. H. Maxwell, president of the association; at his right, Dr. Irwin Shepard, secretary; on the left of the picture is Dr. F. Louis Soldan, superintendent of instruction, public schools, St. Louis, Mo.; on the right are Albert G. Lane, assistant superintendent of schools, Chicago, Ill. and Dr. James N. Green, principal of the State Normal School, Trenton, N. J.; standing on the left is Charles P. McFeyr, of the State Normal and Industrial College, Greensboro, N. C., and on the right, James W. Crabtree, president of the State Normal School at Peru, Nebr.

THE COLLEGE COURSE.

THAT the question of the college course is not solved is proved by the changes continually being made in the programs of studies. The seven leading universities in the east are Harvard, Yale, Columbia, Cornell, Princeton, Pennsylvania and Johns Hopkins. Harvard has consistently maintained the free elective system and Johns Hopkins the group system, but the other five institutions have recently revised their requirements for the undergraduate course and the bachelor's degree. Cornell has formed one college of arts and sciences and gives the A.B. degree to all students for a free elective course extending through four years. The ancient languages are not required either before or after entrance, and Cornell is thus more consistent than Harvard, where the A.B. degree means that Latin was studied in the preparatory school and the B.S. that it was not. Cornell requires sixty hours of work and insists on four years of residence; Harvard requires fifty-four hours and rather favors three years of residence; Harvard requires the bachelor's degree for entrance to its professional schools; Cornell permits students to take the fourth year of the college course as the first year in the medical or law course.

Pennsylvania now confers the A.B. degree only on students who take both Latin and Greek for one year in college and the B.S. degree on the others. It requires sixty hours' attendance, which may be accomplished in three or four years. Of these hours twenty-two are required, eighteen are group studies and twenty are free electives. One half year of college work may be in the department of medicine. Like Pennsylvania, Yale has altered its program of studies in the direction of the group system. Students of the college must offer Latin at entrance, but need not continue its study. Sixty hours are required for the degree, and they must include two 'majors' and three 'minors.' One year of work may count

for both the professional and college degrees, and the college course may be completed in three years. The Sheffield Scientific School offers both liberal and engineering courses. Curiously enough, Latin is required for entrance, the course is three years, and the degree of bachelor of philosophy is awarded.

Princeton has this year adopted an entirely new program of studies. A third degree, Litt.B., has been added. The arrangement is logical, in so far as candidates for the A.B. degree must take Latin and Greek for two years, candidates for the B.S. degree must specialize in science and candidates for the Litt.B. degree in languages, philosophy, history or art. Latin is required for entrance to all courses. The studies of the freshman year are completely, and those of the sophomore year are partly, prescribed, and the rest of the four years' course is arranged on a group system. The tutorial system of the English colleges is to be introduced. Princeton aims to return to the old-fashioned college, and may be congratulated on the fairly consistent methods that it has adopted. The experiment in one of our larger institutions will be followed with interest.

Columbia has also adopted a new program of studies. A B.S. degree has been established for students who enter without Latin, but no plans have been made for a course in the sciences. The B.S. students take one course in science in place of a course in Latin, but as nearly all A.B. students elect a course in science and very few of them elect any course in Latin or Greek, the only distinction between the A.B. candidates and the B.S. candidates is that the former have probably forgotten the small Latin they once learned, whereas the latter have probably never learned any Latin. An extreme form of the *table d'hôte* system is adopted in the first two years, all freshmen being required to take seven unrelated studies; while in the last two years an

extreme form of the *à la carte* system is adopted, no groups being required except in the professional schools, even the graduation theses being abolished. Students may take the last two years of the bachelor's course in the professional school, and as they may enter at mid-year and receive a credit of one half year on the entrance examinations, they may obtain the A.B. degree for a college residence of one and a half years. Students receive extra credits for high standing and deductions for low standing, the excellent system being thus introduced of letting quality of work as well as hours of attendance count for the degree.

The unstable equilibrium of the college course is doubtless an indication of progress. There is no reason why an institution such as Harvard or Columbia should not adopt the different programs which are supported by good educational authority and maintain them side by side. At the English universities, a student may

take the 'poll' course or an honors course; he may specialize to any extent or elect freely; he may follow a fixed course of tuition or engage in research; he may receive the B.A. degree for work in medicine or engineering; he may be in residence three years or five. There is no obvious objection to maintaining in the same institution the free elective system of Harvard, the culture group system of Princeton, and the special group system of the Johns Hopkins.

THE CULTIVATION OF MARINE AND FRESHWATER ANIMALS IN JAPAN.

PROFESSOR MITSUKURI, of the Imperial University of Tokyo, presented before the International Congress of Arts and Science a paper on the cultivation of marine and freshwater animals in Japan, which has now been printed by the Bureau of Fisheries. Professor Mitsukuri calls attention to the fact that the cultivation of aquatic animals is not only a matter that will have increasing economic importance,

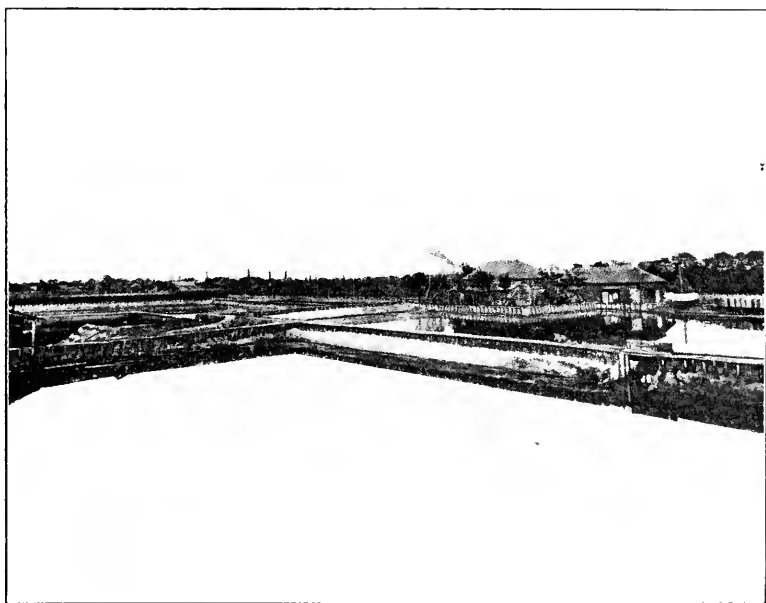


VARIETIES OF GOLD-FISH (FROM JAPANESE PAINTINGS).

Lower left, wakin; lower right (group of three), demé, ryukin, ranchu; upper left (two), ranchu; upper middle and right, oranda shishigashira.

but also opens an opportunity for valuable scientific investigation. Dissection in the laboratory and histological examination can not tell us all that we need to know about animals. This we can easily realize if we consider what our knowledge of man would be if it were confined to the results of the dissecting room. Our bureau of fisheries is in many ways setting an example to other nations, but we shall probably find that in the near future Japan will surpass us and every other nation in the intensive breeding

1874 the number reached fifty, and in the following year breeding was begun. Over one hundred young were hatched the first year, but nearly all of them were devoured by their parents. It thus became necessary to have separate ponds for the young of the first year and of the second year, while those of the third, fourth and fifth years might be mixed. Last year the farm raised about 70,000 turtles, and it is expected that about 60,000 of them will be reared. When three years old, they are sold in the markets of Tokyo for



VIEW OF A TURTLE FARM, FUKAGAWA, TOKYO, JAPAN.

and rearing of animals living in the water. Indeed, in some ways they appear already to have accomplished this. For example, there are complaints of the disappearance of the diamond-back terrapin, but apparently no efforts are made to rear it. In Japan the soft-shelled turtle is reared and sold in large numbers. The accompanying illustration shows the turtle farm of the Hattori family, near Tokyo. In 1866 the first large turtle was caught; by

a price in the neighborhood of forty cents each.

Goldfish have for a long time been bred in Japan, being perhaps the most characteristic oriental fish. The accompanying illustration shows some of the types raised, as depicted by Japanese artists. The extreme plasticity of this fish and the types that are developed by selection are of very considerable scientific interest and would doubtless serve well for the

study of Mendel's law and the mutations of de Vries. The monograph describes the breeding of the eel, the gray mullet, the oyster and other forms. As Professor Mitsukuri says: "While the pasturage of cattle and the cultivation of plants marked very early steps in man's advancement toward civilization, the raising of aquatic animals and plants, on any extensive scale at all events, seems to belong to much later stages of human development. In fact, the cultivation of some marine animals has been rendered possible only by utilizing the most recent discoveries and methods of science. I believe, however, the time is now fast approaching when the increase of population on the earth, and the question of food supply which must arise as a necessary consequence, will compel us to pay most serious attention to the utilization for this purpose of what has been termed the 'watery waste.' For man to overfish and then to wait for the bounty of nature to replenish, or, failing that, to seek new fishing grounds, is, it seems to me, an act to be put in the same category with the doings of nomadic peoples wandering from place to place in search of pastures. Hereafter, streams, rivers, lakes and seas will have, so to speak, to be pushed to a more efficient degree of cultivation and made to yield their utmost for us. It is, perhaps, superfluous for me to state this before an audience in America, for I think all candid persons will admit that the United States, with her Bureau of Fisheries, is leading other nations in bold scientific attempts in this direction."

SCIENTIFIC ITEMS.

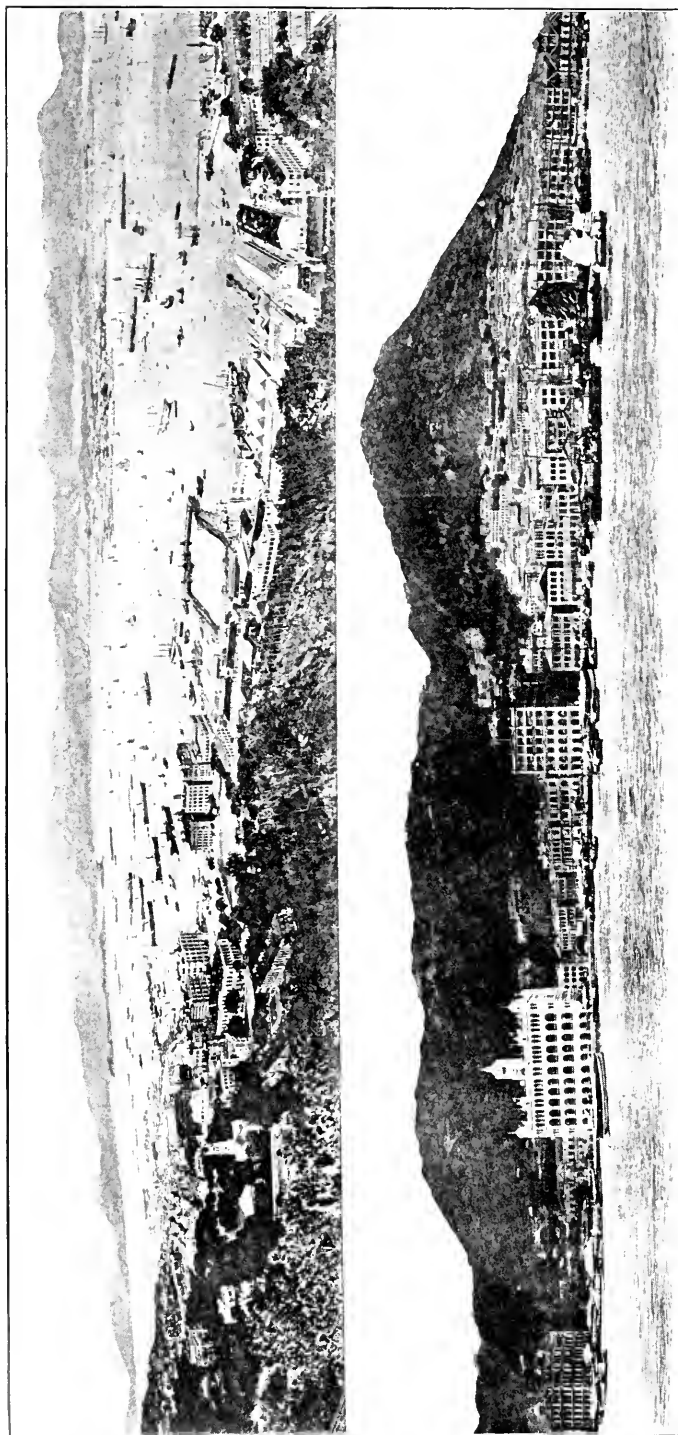
WE regret to record the death of Dr. Wm. Thos. Blanford, F.R.S., the well-known British geologist, and of Mr. Geo. H. Eldridge, geologist of the U. S. Geological Survey.

THE Berlin municipality has appropriated \$20,000 to erect a statue in honor of Rudolf Virchow, which will be placed on the Karlsplatz, close to the Charity Hospital.—The faculty and students of the medical and dental departments of the George Washington University have erected, in the main hall of the department of medicine, a bronze tablet to the memory of their late dean and professor of chemistry and toxicology, Dr. Emil Alexander de Schweinitz.

AT a meeting of the General Education Board, held on June 30, a gift of ten million dollars was announced from Mr. John D. Rockefeller, as an endowment for higher education in the United States. The announcement of the gift was made in a letter from Mr. Frederick T. Gates, Mr. Rockefeller's representative, which reads as follows:

I am authorized by Mr. John D. Rockefeller to say that he will contribute to the General Educational Board the sum of \$10,000,000 to be paid October 1 next in cash, or, at his option, in income producing securities, at their market value, the principal to be held in perpetuity as a foundation for education, the income, above expenses and administration, to be distributed to or used for the benefit of such institutions of learning at such times, in such amounts, for such purposes and under such conditions, or employed in such other ways as the Board may deem best adapted to promote a comprehensive system of higher education in the United States.

Mr. Rockefeller has also given one million dollars to Yale University.



HONGKONG.

The harbor is one of the greatest ports of the world. The commercial gateway to South China and the chief distributing and trans-shipping center in the far east. 'Victoria,' the chief city of Hong Kong, as seen from the harbor; showing how it is limited as well as protected by the mountainous character of the island.

THE POPULAR SCIENCE MONTHLY.

SEPTEMBER, 1905.

CHINA'S RENAISSANCE.

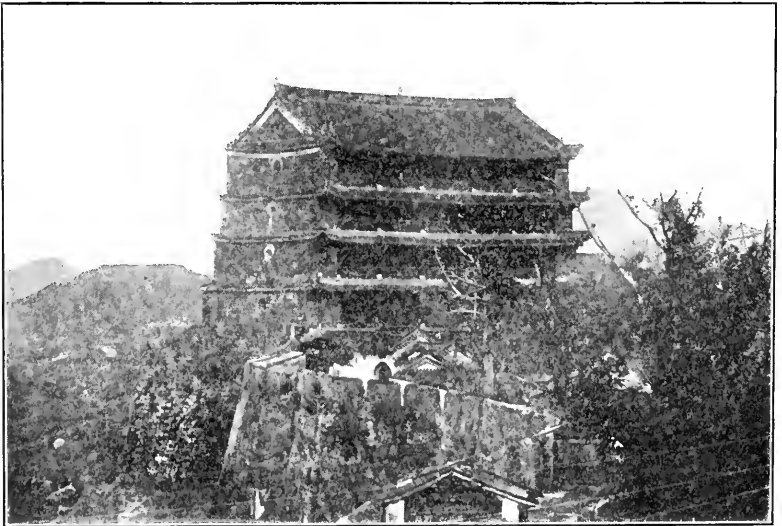
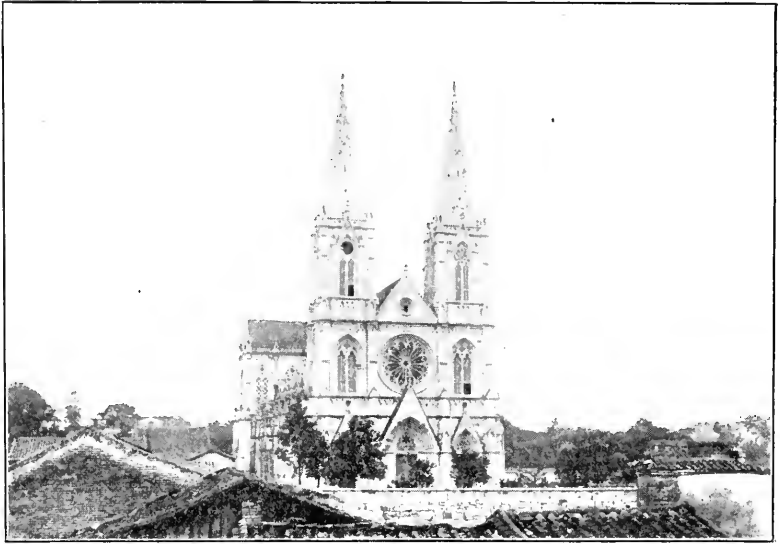
BY CHARLES KEYSER EDMUNDS, PH.D.

CANTON CHRISTIAN COLLEGE.

SO long as constant forces and invariable conditions characterize a phenomenon, it is more or less easy to determine its course. But no matter how regular any known part of the representative curve of coordinates may be, extrapolation is always precarious and fraught with uncertainties. The careful observer is ever on the watch for so-called 'critical points,' times or places when or where entirely new and extraneous forces or hitherto latent internal potentialities begin to operate, and for a time at least, if not henceforth, to dominate the course of events. It is generally true that a comprehensive knowledge of such critical points is far more illuminating as to the real nature of the phenomenon in question than that of any other part of the curve, though of course it is essential to be familiar with the 'normal trend' as well. Many examples could be cited in the realm of physical science, but the one to which this series of papers attempts to call attention is of far more lively interest and pregnant with the destinies of the whole human race.

That China is facing a crisis amid the tramping of armies on her north and amid the increasing murmur of a discontented people within her own borders is clear to all close observers of the empire. The oldest, largest and most conservative nation of the world, with its home in the orient, is awakening under the impact of western ideas in trade, religion and education. Albeit that from the start there could be but one final issue, the progress of events well repays careful study.

This impact began along entirely commercial lines, then religious and hence educational, and finally because of the growth and future



A CONTRAST: TWO CONSPICUOUS LANDMARKS OF CANTON.

THE FRENCH CATHEDRAL, CANTON. Built in 1860 on the site of the native Governor-General's residence, which was destroyed and the ground seized at the close of the Franco-Chinese war, 1856. The steel frame and the windows were brought from Paris.

THE FIVE-STORY PAGODA ON THE WALL OF CANTON. Built some five hundred years ago as a huge watchtower to aid in keeping back the Tartars. Constructed of sawn blocks of red sandstone and hardwood columns and timbers — well preserved to-day. Foreign troops were garrisoned here at the time of China's war with England and France.

possibilities of the first, it has become of wide political import. After noting briefly in this paper the period of beginnings and indicating the present-day aspects of this threefold renaissance, we shall in subsequent papers confine ourselves to a consideration of the educational factors.

The intercourse between China and the West began when the Portuguese sent their first trading vessel to her southern ports, of which Canton is the chief. in 1516, and till 1842 it was a purely commercial relation in which the power and civilization of Europe were represented for the most part by the East India Company, seeking only for the



A TYPICAL STREET SCENE IN VICTORIA, HONGKONG.

advantages of trade and persistently opposing all efforts designed to enlighten the people with whom they dealt. "The attitude of official China during this period was that of supercilious arrogance. China sought no intercourse with outsiders. If they sought trade with her, it was granted as a gracious favor by an officialdom which despised trade and traders too much to attend seriously to the details involved until they became matters threatening international rupture."

The event which began the new order of things was the 'opium war' between Great Britain and China, which, though little to the credit of a righteous nation, nevertheless has served as the origin of what must ultimately be of immeasurable benefit to the more benighted land. By the treaty of peace of 1842 British subjects were permitted to reside at certain important ports along the eastern coast and to trade

with whom they pleased. This was soon extended to subjects of the United States and France, and since then the rights of foreigners in China have steadily increased. There are now over thirty 'treaty ports,' the gateways of Western trade and influence.

American commerce with China began in 1784, the first ship leaving New York on Washington's birthday of that year, and taking fifteen months for the round trip. Our trade with China has been successful from the start, and is greater in importance and value than that of any other nation except Great Britain. With all the rapid developments of modern commerce and the pressure which every commercial nation is exerting in that quarter, our sales to China have quadrupled in the last decade. This rapid growth, together with other recent events in the far east, has warranted the U. S. Department of Commerce and Labor in publishing a quarto volume of some hundred and twenty pages on 'Commercial China in 1904.' Some of the introductory sentences of this monograph are significant in the present connection:

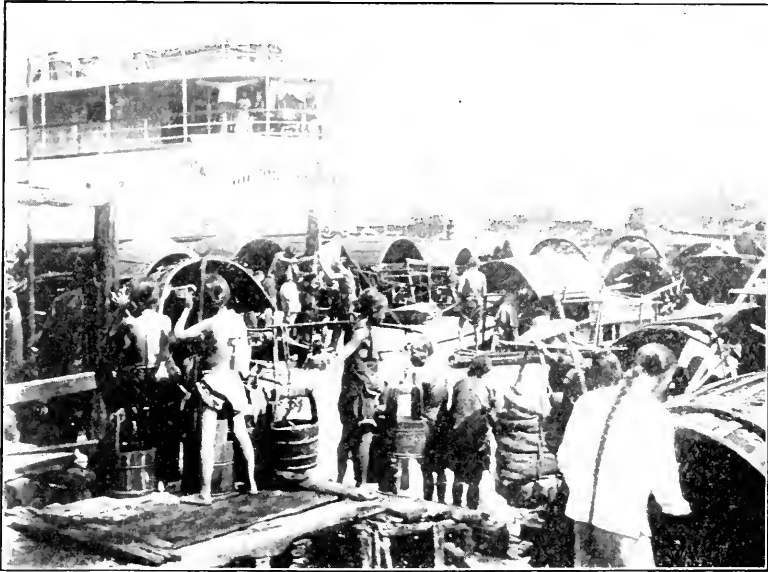
With an area of 4,000,000 square miles and a population of 400,000,000 people, its written history, covering thousands of years, shows that its doors have been firmly closed against foreign trade until within the memory of the present generation, while during the short time in which foreigners have been admitted to its commerce no period has been so marked with important commercial developments as that of the past three years. With hundreds of miles of railway now in operation and thousands of miles projected; with telegraphs connecting its capital with every province and even its far away dependencies and also with the outside world; with steam navigation and foreign vessels penetrating to the very head of its many navigable waterways; with new treaty ports opening upon the coast and far inland, and with foreigners permitted to travel for business or pleasure to the remotest corners of the Empire and carry with them their merchandise and the machinery with which it is manufactured, the changes in conditions are such as to attract unusual attention. *

The expansion of the great powers of the world has culminated in the armed strife on China's northern border which is holding the attention of the civilized world. The issue in the east may be briefly stated, but it concerns hundreds of millions of the human race. 'Shall Japan, Siam, Korea and China be free to work out their own national destinies?'

* Japan and Siam have already made great strides, but while they may seem to be beyond outside domination, their fate is still involved in no small measure with that of China. The issue in the orient is sharply drawn: 'independent national development for China, and continued progress of the other two free Asiatic states; or the subjection of China, and the endangering of all free nationality in Asia.'

The loss of free nationality in Asia would probably be a calamity to mankind. However justly the occidental may pride himself on his mastery of the art of living, however truly he may rejoice in his achievement throughout the whole reach of life, a sane modesty, taught him by his own science, should keep him from regarding western peoples as the

* See 'To Save the Chinese Empire,' by O. D. Wannamaker, *The South China Collegian*, Canton, China, July, 1904.



MODERN HARBOR OF CANTON, where foreign commerce with China first began.

(a) Looking from Honam across the Canton River towards the city. Customs station prominent near center of river front as shown. The tall buildings are pawnshops. White Cloud Mountain appears to the north.

(b) In the rear of a departing river steamer bound for Hong Kong ninety miles away. Native sampans ('three-board') and ma lung tengs ('slipper'-boats) in great profusion and confusion. Note the water-carriers drawing the city's main water-supply. The only pure water obtainable, except rain water, is that brought in buckets from near the top of White Cloud Mountain. Deep artesian wells have not as yet been sunk. This in a city of two million people!

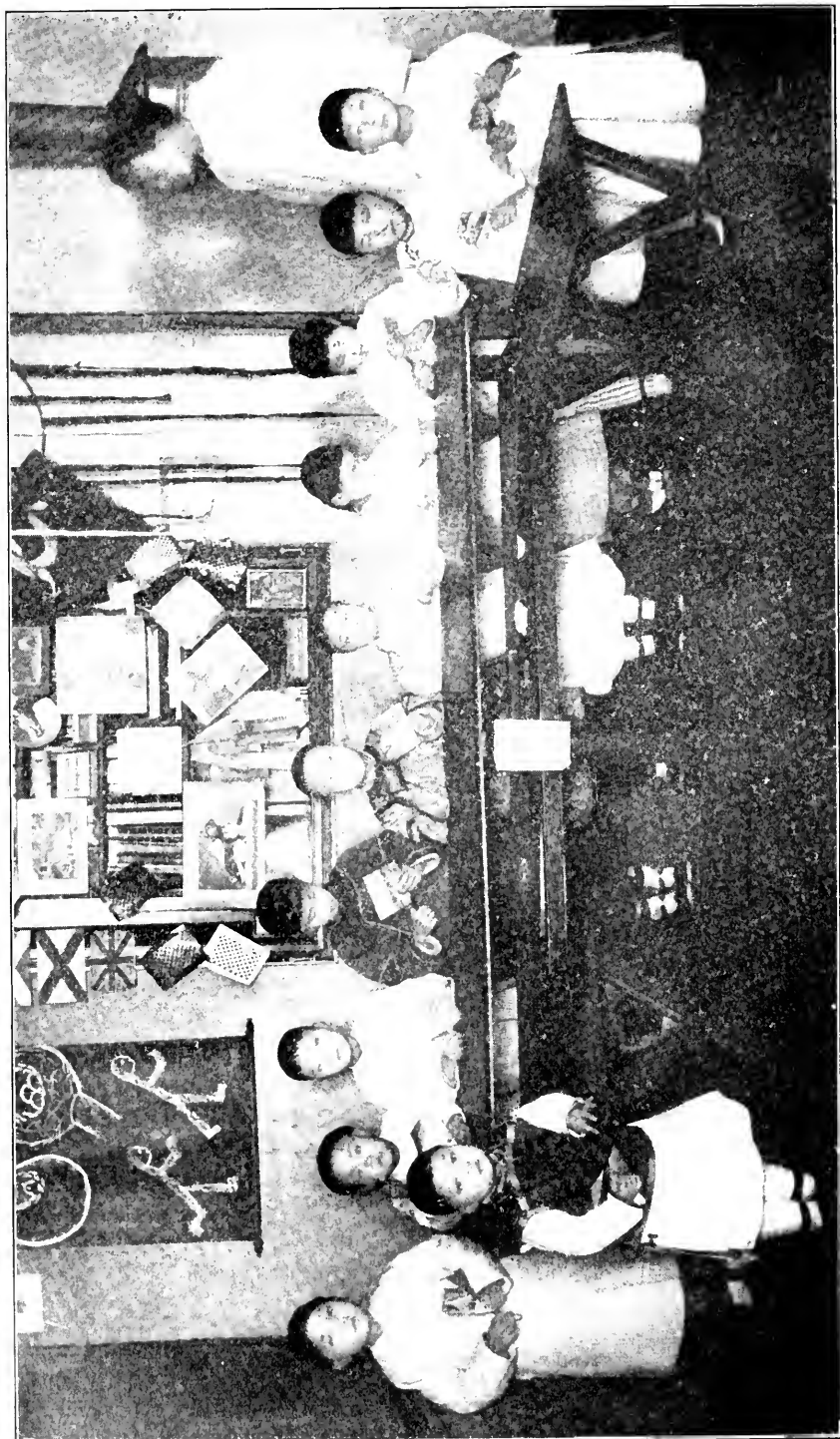
whole race of man, or from looking with scorn upon entire divisions of the race whom his training has not fitted him to appreciate. "A proper reverence for humanity will not allow him to exalt his own position at the expense of the entire east, or to attempt crudely to force upon a whole continent external domination or those forms of civilization which are the product in some part of himself." From the higher level of human development, expansion and domination we may well feel that the world is destined to profit greatly by present events in the far east if they result in restoring to humanity the whole continent of Asia, free to join in making the history of the next hundred years, free to be itself and to supplement, with all of good there is manifest or dormant in it, the strength and goodness of the west.

The shortest road to a partial success in this endeavor to preserve free nationality in Asia is the development of China's material resources, which will not only enrich China and the world, but will help to arouse the people from their age-long sleep; and it may be that military development consequent upon this awakening will serve to maintain the empire's independence.

But China's independence should concern her friends in the west chiefly because such independence is essential to something far more important: true freedom for the Chinese people. "The dormant powers now awaking in this race and promising such a future for it in the commercial and political affairs of the world demand imperatively that there be set in motion, side by side with this material transformation, forces far more subtle that shall bring about a true renaissance of the nation by influencing profoundly the intellect and the soul of the race. Only so can the Chinese people be speedily restored to the modern world."

Without books, newspapers, the pulpit, political debate, general assemblies, etc., China's people have long been groping in the dark. An ignorant people can not be patriotic, nor can there be any steady progress in commerce, agriculture or manufactures among them. These are not due to any extent to differences in government. Democracy among an ignorant people is impossible, or at least dangerous. Although China's scholars of the old school have a superior education in some respects, it is after all too narrow to fit them for lives of service to their fellows. The literati oppose changes because they are ignorant and fear to tread a new path in the dark.

But the ignorance of the people in general or of the literati is not the most dangerous part of China's ignorance; it is the blatant and conceited ignorance of those young men who know little of the foundations of China's civilization and less of western institutions, who wish to tear down the old without knowing how to build up the new. Ignorant of what it means to govern so great a nation as China and to



CHINESE GIRLS IN THE S. SCHOOL AT CHIN KIANG.

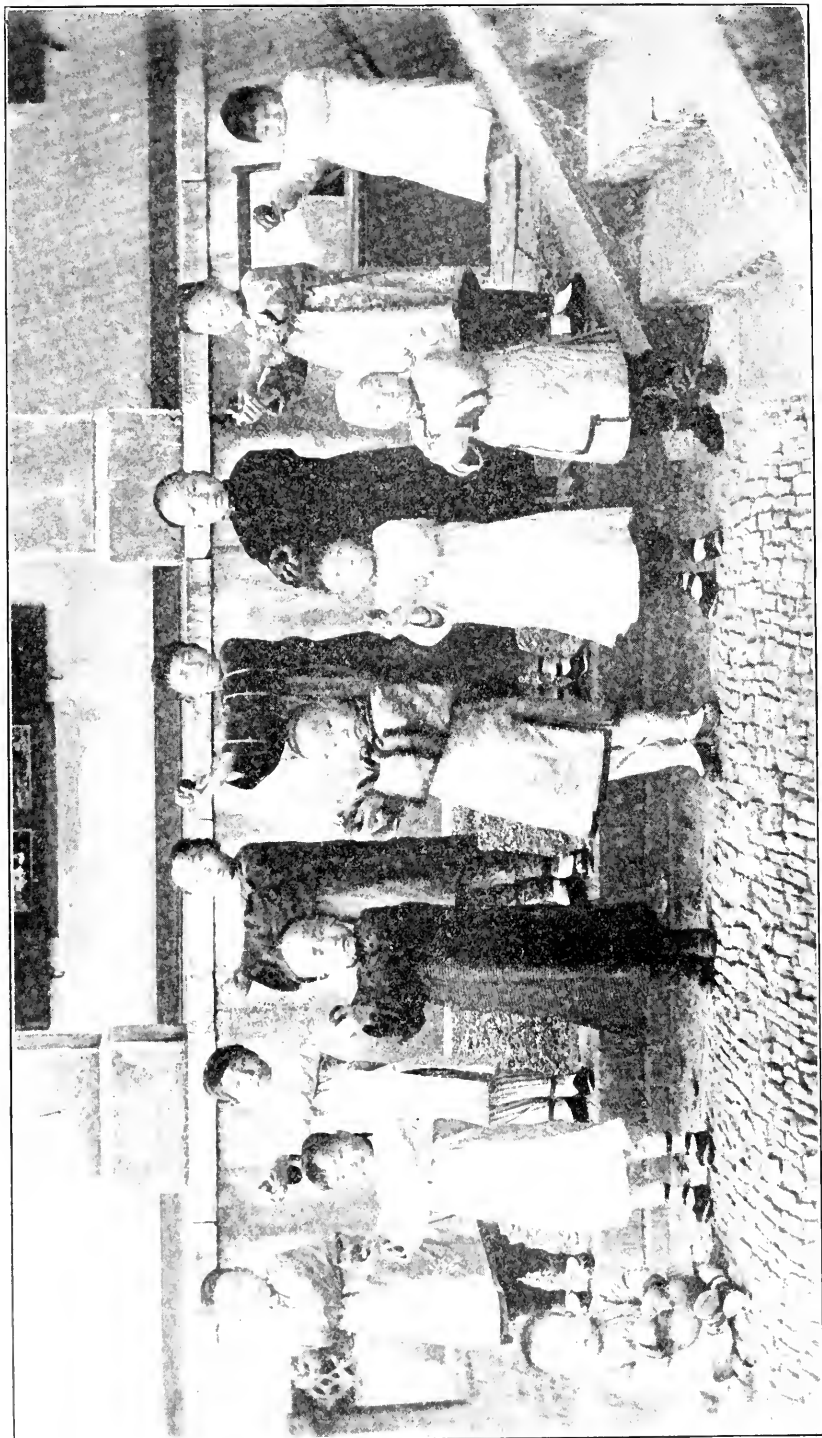
adjust her relations with the world, they wish to plunge at once into anarchy. They are too willing to move because they do not know China, while the literati are unwilling to move because they do not know the world. China needs men who know the institutions of both China and the west, who see clearly the foundations of all real civilizations, and hence can help their nation forward.

From the very beginning of foreign intercourse with China, men have not been wanting whose vision was clear and disinterested enough to lead them to devote untiring energy to dispel the darkness of China's ignorance and superstition. With the opening of the nineteenth century the missionary societies began trying to find an entrance for christianity and modern civilization into the Celestial Empire, but they were obliged, on account of the repellent forces still operative, to content themselves with such work as could be carried on among the emigrant Chinese in the vicinity of the Malay Peninsula, so that during the first period of large commercial intercourse with China (1677-1841), there was no modern educational effort within the confines of the empire. Through the work of the Society for the Diffusion of Useful Knowledge in China, founded in 1834, a beginning of western education within the borders of China was made by the printed page, while as yet the founding of schools within the country was impracticable.

Parallel with official China's arrogance with regard to trade was literary China's proud confidence in the axiom, "What Confucius teaches is true; what is contrary to his teaching is false; what he does not teach is unnecessary." "Confucius lived 2,400 years ago. Theirs was an assurance rooted in undisputed tradition, and fortified by the accumulated conservatism of two and a half millenniums of undisturbed conformity."* The problem was how to teach a nation that had no desire to learn; no desire, not from lack of interest in learning so much as because they believed themselves to have a monopoly of valuable knowledge.

Effective contact of western thought with this colossus of conceited ignorance began on the cession of Hongkong to the British in 1842, when the British government assumed responsibility for the education of the Chinese population of the island. Though numbering only 5,000 at the start, it has since multiplied to 270,000, and considerably more than half a million Chinese pass annually between Hongkong and various parts of the mainland, so that the importance of Hongkong as a distributing center of ideas as well as of material products must not be underestimated, though a frank observer is somewhat disappointed at the inadequate way in which the opportunities for higher education are being improved.

* See 'Western Education in South China,' O. F. Wisner. 'East of Asia,' Special Educational Number, Shanghai, June, 1904.



CHINESE GIRLS IN THE SCHOOL OF CHIN KIANG.

Encouraged by the more liberal atmosphere created by the colonial government and by the contiguity to the great empire to be influenced, the Morrison school, started four years before in Macao, was removed to Hongkong in 1843, followed in 1844 by the Anglo-Chinese College of Mallaca (founded also by Morrison in 1818). Many educational enterprises have since developed in Hongkong, though the results do not measure up to those in most of the schools in central and north China.

Educational work within the actual borders of China began when the treaty ports provided for in 1842 were opened up. Canton was the chief of these, and there as early as 1835 Dr. Peter Parker had opened the Canton Hospital, and this together with other benevolent medical work helped to pave the way for more extensive evangelistic and educational activities by creating a more friendly feeling towards foreigners among the Chinese. Though having its beginnings in the south, this educational work rapidly spread, and there is now scarcely a mission from Canton to Peking without its primary school, day school, intermediate school, night school or college. There are about 2,000 day schools with 35,400 pupils, and 170 higher schools with some 5,000 or more students. A few of these are girls' academies, in which there are courses of study equal to those of schools of a like grade in the United States, and pursued with equal credit. The oldest of these boarding schools for girls is that begun by the Wesleyan mission at Canton in 1861. Among the leading christian colleges, the one which has had the most graduates and the widest influence is the Shangtung College, founded at Tengchow (now at Weih sien) by the Presbyterians in 1864, under Dr. Calvin W. Mateer.

The work of this body of christian educators, small as it has been, has had an immeasurable effect. Awakened under the influence of this silent agency, and more rudely by the results of the China-Japan war and the events of 1899-1900, China's leaders have been made to see that the trouble lies in their faulty system and ideals of education; and have in nearly every case of educational reform called to their aid men hitherto prominent in educational missions. One of the most remarkable indications of the change that is coming over China is the spectacle of such eminent officials and scholars as Chang Chih Tung and Yuan Shih Kai urging upon the younger scholars the necessity of studying western sciences and becoming acquainted with the accomplishments of other nations. The government has begun to adopt measures to facilitate this course. In 1901, while the court was still in exile, a series of edicts was issued commanding a reorganization of the educational system of the empire, calling for changes in the examination system hitherto in vogue, for the establishment of an Imperial University at Peking and a large number of other high-grade institutions in all parts

of the empire. Although the active response of the provincial officials has been somewhat tardy and inadequate in many instances, there are abundant signs that, without doubt, the renovation of the worn-out system of education is at hand. Just what the efforts of the government have been and the results they are producing will be noticed in more detail in a later paper; suffice it now to point out that whereas at first it was a problem of how to educate a people who did not desire enlightenment because they fondly thought they already possessed all useful knowledge, the present problem is how to pass from old ways to radically new ones with the least friction among a people still in great part thoroughly conservative, but embracing numerous individuals thirsting for the newer learning. For realizing that the complete refutation of the age-long methods of the past is China herself, the most progressive officials and many of the young men are becoming sensible not only of the precarious position of their nation, but of their individual poverty and need of education.

During 1903 the new publications of the Society for the Diffusion of Christian and General Knowledge among the Chinese amounted to 11,434,600 pages, while *The Review of the Times*, a Chinese monthly, edited by Dr. Young J. Allen, published 54,400 copies. The corresponding figures for 1904 are 19,256,800 pages of new publications, 45,500 copies of *The Review of the Times* and 80,000 copies of *The Chinese Weekly*, edited by W. A. Cornaby. The total of reprints and new publications has grown from 25,353,880 pages in 1903 to 30,681,800 pages in 1904. Moreover, a conservative estimate puts the piracy of all the best books of this society by various native presses at five times the direct output of the society! During 1903 the Diffusion Society sold 35 complete sets and four supplements of the 'Encyclopædia Britannica' in English, while hundreds applied for it in Chinese. Several legitimate native publishing houses have recently sprung up, the chief of which, the Commercial Press of Shanghai, is literally sending forth volume after volume of new literature, mostly translations of works that have proved their usefulness among other nations. That the high officials are being influenced by the translations of the Diffusion Society is clear from the remarkable changes in the questions set throughout the empire for the literary examinations for the second degree, samples of which will be fully treated in a later article.

THE SCIENCE OF PLANT PATHOLOGY.

BY PROFESSOR FRANK LINCOLN STEVENS, Ph.D.,
NORTH CAROLINA COLLEGE OF AGRICULTURE.

FROM the time men first had interest in plants, knowledge of their imperfections or premature death has existed, without, however, definite conception that the imperfections in question really constitute a condition of disease.

The Bible and the early writings of the Greeks and Romans contain references to what we now recognize as wheat rust, fig blight, insect galls and other of the more strikingly conspicuous plant ailments. Such references are more abundant in the literature of the seventeenth century, and in the latter part of that and the eighteenth century a few papers giving careful descriptions of malformations due to insect invasion appeared. Even the law was invoked to aid in combating the wheat rust in France as early as 1660. Prior to the nineteenth century, however, knowledge of plant diseases can hardly be said to consist of more than mere observation of the fact that such diseases occur, and the little real knowledge that did exist was swamped by rampant superstition.

It is natural that the first attempts to explain imperfections were founded upon climatic and soil relations. Vestigial beliefs prevail to this day throughout the country among the untutored to the effect that the various blights, rusts, rots, mildews, etc., are caused solely by untoward conditions of weather, or the unpropitious position of celestial bodies or some other occult influence.

The significance of one great factor in the production of plant disease, namely the parasitic fungi, remained quite unrecognized until the second decade of the nineteenth century. Fungi had been seen upon the plant and had been described in some detail during the preceding decade, but instead of being recognized as causal agents of disease they were, as was the fate of bacteria in the case of animal diseases, by many regarded as products of disease. Before the study of plant diseases could be scientifically undertaken, the basic facts of plant nutrition were to be discovered, the parasitic habit of the fungi proved, the minute anatomy of the plant disclosed. Epoch-making in the disclosure of these desiderata, which may be said to have given birth to plant pathology as a science in the second decade of the nineteenth century were the investigations of the early Dutch, French, German and English botanists. Like bacteriology, plant pathology is an infant science of the last century, owing its being to the perfection of the microscope.

In the last two decades of the last century, scientific effort concerned itself chiefly with accumulating knowledge concerning fungi and insects. Vast numbers of these were classified, catalogued and described. In other words, the means of diagnosis were perfected and diseases were grouped into natural classes according to their causal agents. Attempts toward the development of methods of treatment by the use of various sprays were more or less effective. Indeed, spraying had been advocated to some slight extent for a century or more as a remedy for insect and other plant diseases. The variety of spraying substances recommended ranged from clay, ashes and cow manure to sulphur, lime, salt, etc. One writer recommended "The applying around the base of the tree; flax, rubbish, sea weed, ashes, lime, sea shells, sea sand, mortar, clay, tanner's bark, leather scraps, etc."—evidently not a homeopathic prescription. The variety of substances recommended raises suspicion that the efficiency of no formula was demonstrated. In 1787 we find the heroic advice, 'just wet the trees infested with lice, then rub flowers of sulphur upon the insects, and it will cause them all to burst.' Some decided progress was, however, made. As early as 1842, a whale soap was used and retained favor; quassi, hellebore and tobacco were standard insecticides as early as 1855. Sulphur was used for the mildews and bluestone for wheat smut.

The last twenty years of the nineteenth century mark the beginning of a new epoch in plant protection. For this there are three reasons: first the increased aggressiveness of a certain fungous disease, the grape mildew, in Europe; second, the rapid spread of the potato bug, somewhat pedantically termed the Colorado beetle, and, third, resulting from these two, revolutionary changes in materials and methods for treating plant diseases, both fungous and insect, in the new world and in the old. It is a matter not entirely without interest that the revolution in European methods may be definitely traced to typical American aggressiveness, inasmuch as the activity arousing fungus was of American importation.

In Europe the invasion of the downy mildew of the grape in 1878 was unchecked by the most vigorous fungicides then used. All are familiar with the story of the great benefit conferred upon humanity through the predatory habits of the French boys in the vineyards that produce the famous Bordeaux wines. The rows lying nearest the roadway were sprinkled with verdigris or a mixture of lime and bluestone, to give the impression that the fruit was poisoned. In 1882 Millardet, of the faculty of the sciences, noticed that the vines thus treated held their leaves while others succumbed to the mildew. He ascribed this effect to its proper cause, and conducted carefully systematized experiments, which resulted in giving to the world *bouillie*

bordelaise, *Bordelaiser Bruhe*, or Bordeaux mixture, a proved fungicide of great efficiency; one that has not yet been surpassed.

In the new world the extension of the potato belt westward connected the eastern potato belt with the region of the native food plant of the familiar potato bug. Finding the potato plant a more abundant and wholesome food than the wild solonaceous plants that it had formerly fed upon, the potato bug began its eastern migration. In 1859 it was found east of Omaha City, in 1868 it had reached Illinois, in 1870 Ontario, in 1872 New York and in 1874 it was upon the Atlantic seaboard. The potato bug ate ravenously and man was stimulated to new activity in the search for more effective means to overcome insect pests. The use of Paris green and London purple followed as a direct result of this stimulus.

The development of efficient fungicides and insecticides in Europe and America led naturally to the perfection of the machines used in applying these mixtures, and not the least important part played in the development of a practical plant pathology is concerned with the evolution of spraying machines. The first sprayer consisted of a bunch of switches. This was dipped into the spraying mixture which was distributed over the foliage by vigorous shaking. It gave place to an improved spraying broom or brush with hollow handle, the liquid flowing from a reservoir to the brush, from which it was applied to the leaves. Sprayers and pumps followed in turn. Then came the improvement of the nozzle.

We may recognize two periods in the development of plant pathology: the first or embryonic period extending from prehistoric times to the beginning of the truly scientific investigations in the middle of the eighteenth century, and contributing chiefly observations, collections, descriptions; the second or formative period, during which the foundations of the science were laid, the chief factors of it determined, and the chief lines of future progress marked out.

It is in no way my purpose to call attention to the part the Carolinas have played in botany as a science, yet I can not refrain in passing from mentioning that prominent place in the history of American mycology is assured to de Schweinitz, a minister of Salem, N. C., who in 1818 published the first important paper on American fungi; to M. A. Curtis, a tutor in Wilmington, N. C., who in 1830, with Berkeley in England, described many fungi of the Carolinas; to Ravenal, of South Carolina, the first to publish exsiccata of American fungi, and to Louis Bosc, of South Carolina, who published a descriptive list in 1811.

The embryonic and formative period prepared the way for the third period, beginning about 1885, which may be called the period of growth. It is marked by the development and perfection of the

rudimentary principles and discoveries of the preceding periods. It was during this period that the most spectacular conquests were made; that popularization and extension of methods occurred. So great, so numerous, so wonderful were the advances made during the past decade, that we frequently see the statement that little or no progress had been made in plant pathology prior to 1885. The present day student should, however, bear in mind that it was the persistent, arduous, patient work of the preceding years that rendered possible the progress of the closing years of the century.

My denomination of this period as 'the period of growth' indicates the nature of the changes which it inaugurates; growth in every direction and concerning every phase of the subject. There has been growth in the list of plant maladies. New diseases have been discovered by scores, and old diseases have been found to affect new plants, and diseases hitherto insignificant have taken prominent places as dangerous foes. The alteration of the plant constitution by high selection and breeding, the bringing of plants into new climatic or soil relations, the more intensive cultivation, the bringing of a susceptible plant into a region where a parasite is already growing upon one of its botanical relatives, thus exposing it to a possible new foe, are conditions that operate to admit of the evolution of new diseases. The growing of plants in large quantities in solid blocks, rather than sparingly in scattered gardens, brings about a congested condition comparable with the crowding of our cities, and favors the development of epidemics* by furnishing abundant material for the parasitic organisms to attack, abundant nutriment upon which they may multiply, and abundant opportunity for them to reach new hosts and spread the contagion. With potatoes, for example, raised merely as garden crops, the probability of an epidemic affecting the majority of gardens is not so great as when potatoes are raised in vast fields. A single field crop, once infested, so contaminates the air with spores that other fields are almost sure to become infected. The contagium becomes sufficiently multiplied to break the quarantine, and a general epidemic results. Any factor which tends to increase the occurrence of epidemics may quickly raise a given disease from obscurity to a position of commanding importance. So too does the increase in value of hitherto comparatively insignificant crops. The pecan and cranberry are at present objects of particular solicitude by the plant physician.

With the importation of plants from foreign countries and the transportation of plants from one part of the country to another comes

* The use of the word epidemic in relation to plant diseases while etymologically incorrect, seems justified since no other word conveys the desired meaning and the meaning of this word is clear to all.

the possibility of increased disease transference. Recent years have seen the San José scale spread from the Pacific to the Atlantic; the asparagus rust from the Atlantic to the Pacific; the hollyhock rust has invaded us from Europe; the chrysanthemum rust from the Orient; the watermelon wilt is now moving northward and the peach yellows southward. In nearly all cases where the soil is diseased the affected region is annually enlarging, so that soil diseases a decade ago insignificant in the territory of their occupation are fast assuming control of alarmingly large regions. The growing of plants in larger quantities also increases the amount of germ-bearing refuse to the ultimate end that the very air and soil become germ laden.

Civilization, higher culture and community life, especially if it verge upon congestion of population, exacts an inevitable forfeiture by increased mortality. Thus does the list of diseases that comes within the horizon of the practical men enlarge. Wonder, often skepticism, is expressed at the existence of unfamiliar diseases of man, other animals and plants, as though these afflictions were conjured up by the imagination of the over zealous practitioner. The increase of affliction is more apparent than real, as it is in the case of appendicitis, which is now recognized, named and cured, consequently, heard of, whereas under the old régime it was not recognized as a distinct disease, therefore it was unheard of, though the patient died. Parallel cases might be cited among the plants.

The work of DeBary on polymorphism among the fungi is being extended. Knowledge of the life histories of various pathogenic fungi is being slowly expanded. Summer forms are connected with winter forms, and thereby the hibernating condition, often the most vulnerable point of attack, exposed. The discovery of heteroecism in the rusts, the alternation from wheat to barberry, from apple to juniper is of classic antiquity in the annals of plant pathology. It emphasized the need of close study of life histories of all parasites. Such study has given abundant fruit, notably in disclosing the relation between the apple cankers and the ripe and bitter rot of the apple, and revealing the winter condition of the brown rot of the peach. The lead so fortunately made in the discovery of the Bordeaux mixture has been assiduously prosecuted. The original Bordeaux mixture has been greatly modified, changed, indeed, from a thick paste to a thin solution, and so thoroughly tested in all its modifications, that it has now probably reached its ultimate perfection. Hundreds of other chemicals, both dry and wet, have been tested as fungicides, with the adoption of a few adapted to special conditions, *e. g.*, sulphur and sulphides for powdery mildews and the ammoniacal copper carbonate for use as the fruit ripens, thus avoiding unsightly spotting. A happy combination of insecticide and fungicide has been found in the various

sulphur washes. There has been very remarkable growth in the perfection of spraying appliances; pumps and dusters of many kinds are upon the market. Particularly is the improvement in nozzles to be noted. Nozzles constructed upon scientific principles, capable of applying the liquid in the form of the finest spray to the tops of the highest trees. In the place of the old hand pump and pail, we find barrel pumps on wheels, tanks on wheels with pumps operated by gearing attached to the wheels, and finally for the larger fruit farms and for municipal care of shade trees are multiple pumps driven by steam power.

The treatment of seeds to kill adhering spores has been improved upon in many details. It illustrates especially well the nature of the development during the present epoch of plant pathology. Originally the treatment for wheat smut was based purely upon superstition. Pliny, for example, says that 'if branches of laurel are fixed in the ground the disease will pass from the field into the leaves of the laurel.' Tull in 1730 says that there are but two remedies proposed, brining and changing the seed. The avoidance of certain kinds of manure because of their effect upon the host plant and because they carried the smut spores was also advocated about that time. The scientific demonstration by Brefeld that the plant is susceptible only when very small, gave rise to the thought that by hastening the early growth the period of susceptibility could be shortened, and methods of planting and tilling in accord with that idea were advocated. In addition to cultural methods mechanical treatment of seeds, such as passing the wheat loosely between millstones, violent fanning, etc., were suggested about 1786. The chemical treatment of seeds, says Tull, was accidentally discovered about 1660 by the sinking of a shipload of wheat at Bristol, and afterwards, finding it unfit for breadmaking, it was used for seed wheat. The following harvest in England was very smutty except in the case of this accidentally brined seed, which made a clean crop. Then followed brining with liming and liming without brining, soaking in lime, arsenic, salt, arsenic and lye, and various other treatments, none of which, however, came into general use. Accident coupled with acumen again aided in hastening a discovery. Provost while attempting to germinate some spores placed some of them in water distilled in a copper vessel. These failed to germinate, though similar spores placed in water which had not touched copper germinated well. Following this lead he and numerous other investigators experimented extensively with copper compounds during succeeding years.

Such is the history of the development of a treatment effective for smut of wheat and barley, but not for that of oats. The next marked advance was made by Jensen, a Dane, who in 1887 developed the famous Jensen hot water treatment, a treatment which though re-

quiring considerable accuracy of manipulation was thoroughly effective. This method, if no easier were to be had, was well worth to practical agriculture all that the experiment stations of the world have ever cost. Within only a few years, however, the Jensen treatment was supplanted by the formalin treatment; a treatment so simple, inexpensive and effective that, save for minor improvements of detail, the end seems to have been reached in the search for preventives for the particular diseases to which the method applies.

Growth of knowledge concerning bacterial diseases has occurred, beginning with the pear blight which baffled all horticulture prior to the assertion of its bacterial nature by Professor Burrill. The proof that bacteria can and do cause plant diseases has been definitely adduced, and a large number of such diseases have been recognized upon many plants. Not only from the scientific side have these ailments been studied, but from the practical as well, and preventive and palliative measures have in many instances been found.

The soil is often spoken of as the living earth. Not only may it live, but it also partakes of those chief accompaniments of life, viz., health, sickness and death. A healthy soil may, from an agricultural point of view, be regarded as one capable of fulfilling all its vital functions; a sick soil, one in which some such functions are impaired. Of only one class of soil sickness may I speak, namely, that which results in producing sick plants by harboring pathogenic germs. The cotton wilt, the Texas root rot, the watermelon, tobacco, tomato and cabbage wilts, the cabbage club foot and the onion smut are conspicuous examples of disease so propagated. Diseases of this type not only destroy the crop, but they preclude the possibility of successful culture of the plant in question, or of its close botanical relatives for many years. Such foes to agriculture have completely destroyed the possibility of tobacco growing on many farms otherwise eminently adapted to this crop and ill adapted to any other, resulting in great depreciation in the value of the land. This encroachment upon valuable soil will proceed yearly, and with geometrically increasing rapidity, until means of prevention are discovered, as they have now been in some instances, and the method of prevention becomes common knowledge. Soil diseases, the most dreaded of all dangers to the plant, are prevalent to much greater extent in the south than in the north. One field is known to exist in South Carolina upon which neither melons, cotton nor cowpeas can be grown. It is conceivable that many other germs could infest one and the same field, but no greater affliction concerning such staple crops seems possible.

Growth in popular appreciation of the importance of plant diseases and of the value of remedial and prophylactic measures is perhaps the most striking characteristic of plant pathology in the last twenty years.

At the beginning of this period spraying was in no wise general. It was of rare occurrence. Man suffered unresistingly the attacks of the molds, mildews, rots and blights. The circulation of thousands of state experiment station bulletins and similar bulletins from the national department of agriculture, the vigorous campaign of farmers' institutes, farmers' reading circles, farmers' extension courses, and the extended use of farmers' periodicals and agricultural papers have served to bring the latest discoveries of science to the use of him who will heed. As is to be expected, it is the man who most closely studies his business, he who has most at stake, the large specialist in the culture of any crop, who first embraces the offered aid. The large orchardist or vineyardist leads the way in the adoption of new methods and new machinery. The revolution looking toward recognition of the value of plant treatment is now so thoroughly inaugurated that the treatment of such diseases, both insect and fungous, in the case of fruit and trucking crops is of general occurrence. The movement, too, is world-wide.

The practical outcome of all the investigation and propaganda up to the present time is that many hundreds of plant diseases have been recognized; for a hundred or more have been prescribed remedial or preventive measures, many of which are eminently successful; witness, the treatment of cereal smuts, the peach curl, the grape black rot, the powdery mildews. The saving occasioned by any one of these, as is true of scores of others, would amply suffice to pay all the expense of investigation and propaganda incurred in the development of the whole field of plant pathology. By oat smut alone the estimated damage in the United States yearly is \$26,766,166, a loss avoidable by an annual expenditure of less than four cents an acre. The saving actually made in Dakota, Minnesota and Wisconsin in one year is placed at \$5,000,000.

The future problems of plant pathology are manifold. The period of growth must continue long before the work now undertaken is done. Many diseases of even the cultivated plants are not yet recognized. The diseases of wild plants, particularly the weeds, must too be studied to ascertain the possibility of intercommunication of diseases between weeds and crop plants. The life histories of all disease producing fungi must be closely studied, particularly to determine their hibernating condition. As yet the merest beginning has been made. The interrelation of host and parasite must be studied, the periods, points and modes of infection made known. The biology of the fungi, their life habits, conditions of spore formation, characters of growth, relation to light, heat, moisture, nutriment, etc.; their resistance to adverse conditions, their longevity under various conditions of environment are all problems of ultimate practicality. The question of species is unsettled and the

recent demonstration of biologic varieties among the rusts, mildews and fusariums opens a large and important field of research. The agencies operating as disease distributors, the wind, insects, soil, man, water or what not must be known that such distribution be more readily controlled. The causes of resistance and susceptibility to certain diseases rest in obscurity, except in a few cases where the responsibility has been fixed upon some particular structure or chemical. The breeding of plants resistant to specific diseases not readily amenable to other means of control must proceed. Such work is now in progress with cotton, melons, tomatoes, tobacco, grains, flax and other plants. The relation existing between many root fungi and bacteria and the roots they inhabit remains to be studied. Aside from parasitism there is also mutualism, a kind of beneficial disease falling to the province of plant pathology. It needs much further study.

Specific problems also abound, the peach yellows and rosette, the mycoplasma theory of rusts, the grape Brunnisure. Differences of opinion now exist or the technique or scientific data are insufficient for an adequate solution of these questions and many other similar ones. Work on timber protection, while not strictly a question of disease, but rather a post-mortem problem, falls to the lot of the pathologist for the want of a more appropriate place. That intensive study of a disease, however thoroughly it may seem to have been studied before, may lead to important development is well illustrated in the case of the familiar pear blight, which, though known for ages and the topic of masterly classic research, has recently, under trained observation and critical interpretation and experimentation, revealed new secrets leading to more masterful and complete control. The large fields of plant pathology, grouped under the term 'physiological disorders,' are still practically unworked; diseases due to false nutrition, absorption or assimilation, or to impaired carbon assimilation owing to improper environment, to crowding or shading or to hereditary inabilities. A start has been made sufficient to show the importance of the results awaiting.

The recent discovery of the so-called ultramicroscopic organisms or filterable enzymes which has robbed the bacteria of the distinction of being the smallest of living things opens a new field in both plant and animal pathology comparable in kind, though probably not in magnitude, with the creation of bacteriology by Pasteur. It is yet unknown whether we have to do here with organisms or enzymes, and contemplation of the problems awaiting in this realm places us in a position to appreciate more fully than ever before the great controversy of spontaneous generation as fought in the sixties. The announcement in a recent periodical of the discovery of soluble protoplasm emphasizes the existence of a vast unknown covered by the words protoplasm,

enzymes, invisible organisms. Is it coincidence of fate that with the growing importance of the problem of the invisible organism there comes the invention of a microscope of surpassing excellence with which the seeing of molecules is a hoped for possibility?

The science of plant pathology is indeed young. It has yielded much, and it is still full of promise. In the achievement of the results to come draught will be made upon the sister sciences even more than in the past. Plant physiology waits upon chemistry; plant pathology upon plant physiology, and chemistry in return receives valuable contribution from both. Mathematics, physics and geology all contribute to the general upbuilding. The sciences, though becoming more divergent instead of becoming more independent, are yearly becoming more dependent, each using the discoveries of the others to gain new foothold or new tools in the search for truth. Often it is the frontier territory lying between two sciences which, belonging distinctively to neither, is least worked, and therefore presents most promising territory for conquest. Such is the history of the comparatively new sciences of physical chemistry, physiological chemistry and biometrics.

Nor does the field belong exclusively to either the devotee of pure science, so-called, or of applied science. The study of problems seemingly most remote from any practical ends has often proved fundamental in the upbuilding of vast industrial growth. Bacteriology was born of crystallography. The father of galvanic electricity was derided as the frog's dancing master. Nor does the avowed object in view give a sure key to the ultimate outcome. Alchemy, though never attaining the end sought, hastened immeasurably the era of industrial chemistry. Nor may it be said that applied science is inferior, for without the application the fundamental principles are of no avail in the promotion of the welfare of man.

Intensive laboratory study with no object other than the increase of knowledge of molecular construction has led to the commercial production of many important compounds. The present oat smut treatment by formalin owes its practicability equally to pure science in the chemical study that rendered the production of formalin practicable at moderate cost, and to pure science of the botanist who from mere interest in fungous growth discovered the nature of parasitism, and to the practical scientist who applied the knowledge of the chemist and the botanist to the solution of a definite agricultural problem. The distinction between pure science and applied science is invidious. It is not a difference based upon the nature of the knowledge; rather upon the motive of the worker. All true science is practical, either remotely or directly, and the man of applied science is but completing the work of the pure scientist. Especially does the future of plant pathology rest with both.

SLEEP AND ITS REGULATION.

BY DR. J. MADISON TAYLOR,

PHILADELPHIA, PA.

SLEEP as a factor in physical economics ranks in importance with respiration and digestion. Those who live normally, who throughout all ordinary exigencies maintain a natural attitude toward life, its strains and responsibilities, may expect to enjoy a full measure of this restorative function. How much each one needs is not to be determined by dogmatic rules or precedents, nor does each one require the same amount under every condition or circumstance. There must be enough, daily and weekly, and of suitable character, to restore the balance of neural energy reduced by whatsoever of fatigue follows upon daily activities; otherwise the sensorium resents this deprivation in one way or another. Individual needs vary and can only be determined inferentially, giving due weight to generally accepted requirements.

Sleep, being the completest form of rest, is needed most by the youngest and least by the oldest. Most sleep is required by the weakest and least by the strongest. During childhood and exhaustive states too much sleep is rarely possible. For those in full tide of vigor too much sleep is often distinctly hurtful. Many modifications will immediately suggest themselves to those who are wise or learned in the science of bodily growth, development and disorders. Experience always counts for much. Variants, sometimes wide, are often permissible. Large errors will arise when these qualifications are marred by caprice, taste, prejudice; and harm follows, of one sort or another, sometimes of serious degree, by obscuration of sane reasoning on what may seem to be obvious and simple facts.

Physical efficiency depends chiefly upon the kind and amount of effort expended. Rest is an inevitable corollary. Relaxation is the starting point of all effort. For example, the strongest blows, the most accurate thrusts, can only proceed from an arm in thorough equipoise. Equipoise presupposes a full quantum of energy. Animal energy depends upon adequate rest as much as on force-giving foods. Complex acts, conditional always upon harmonies between intact central nervous dynamos, and well-adjusted mechanisms, can only be performed in their completeness when forces are at the norm.

Sleep is an absolute necessity for conscious beings. There are those who oppose this view, and some require relatively little, and that,

too, for long periods. Some sleep lightly, retaining in greater part their consciousness. Occasionally we hear of an individual who has lived for a long time without sleep, so far as can be determined, and yet has continued to maintain good health. Sufferers from one form or another of nervous exhaustion are often compelled to forego sleep temporarily. Vigorous persons of pronounced personality and highly developed consciousness have the least need for sleep, at least while at the zenith of their powers and in the full flower of energizing.

The maintenance of conscious life demands an expenditure of energy so intense that the processes of nutrition and reconstruction of cellular waste can not be carried on without sleep. Complete repose of the consciousness is demanded for the plastic nutrition of the organism and the accomplishment of vegetative life. Consciousness is the highest of our faculties, rendering possible moral and scientific ideation; it demands the greatest efforts of our organism. In its absence sleep is less required.

All the internal organs are, during sleep, relatively less filled with blood because then the skin is in a state of hyperemia or gorged with blood. The sweat glands act more energetically at night whether we are asleep or awake, hence the danger of chills is then greater. All the organic activities continue, but are less vigorous at night, and during sleep, whereas during sleep in daylight hours these proceed with little alteration. When animals or men feel the desire to sleep they instinctively seek a quiet sheltered spot, as free as possible from light and noise, thus avoiding whatever impressions from the external world are liable to be subjectively translated into sensations. The eyelids are lowered; a position is sought wherein the muscles can be fully relaxed. The sensorial organs are capable of acting during sleep and continue to transmit impressions into conscious sensations.

With the pallor of the brain, which occurs in sleeping animals, the cortex ceases to react so readily to mechanical, photic, electric or other stimuli. The spinal cord and sensory nerves do not sleep, yet sensations of pain are then lowered. The nerves transmit painful impressions, but the consciousness of the sleeper perceives them incompletely. The voluntary muscles become quiescent during sleep, but retain their power, as shown by the normal subject in changing position, arranging the bedclothes, even walking; soldiers are able to march or ride while asleep. The brain is the chief part which sleeps, but it is not wholly inactive, exciting inhibitions which check the formation of reflex movements. If stimuli are applied of sufficient intensity to overcome the protective states of the somnolent consciousness the subject awakes, recognizing the cause more or less certainly.

Sleep is not an absolute arrest of cerebral activity; the brain then retains always partial energy. In deprivation of sleep it is the brain

which suffers most, while in deprivation of food it is the brain which preserves longest the integrity of its structure and function. In young animals, abundantly fed and cared for but kept awake, there follows serious lesions of the organism which soon become irreparable, and death results.

There have been many theories and hypotheses advanced to explain the phenomena of somnolence. The physiologists have here, as so frequently elsewhere, exhibited far more academic than practical interest in the matter. There is no subject, however, of greater importance, since it is a prime factor in all the reparative phenomena of life, standing at the foundation of nutrition; yet no research work has been done on the nature of sleep commensurate with the gravity of the subject. Psychologists have written extensively on one phenomenon of sleep, viz., dreams. Normal sleep has attracted so little attention that we do not know exactly how to modify it in accordance with common conditions of bodily derangements. Inferentially certain facts seem established which not only account for the phenomena of sleep, but enable us to reason from them and thus to regulate the state in great measure; sometimes sufficiently. It is probable that during sleep there is a diminished resistance in the surface vessels, inducing lowered blood pressure, hence smaller amounts of blood pass through the brain. As sleep approaches the cerebral vessels grow relatively less filled with blood for an hour or more after full somnolence has come. After reaching its minimum tension the brain circulation remains practically constant for one or two hours or more, gradually returning to normal as the time for awakening nears.

After having attained a fair idea of what sleep is, whereby we can better appreciate a reasoning from our individual standpoint, we may proceed to discuss its regulation. For the young, who may be assumed to be in possession of full neural and circulatory balance, whether in or out of health, the regulation of sleep is a simple matter, one which will in most instances adjust itself if the subject be placed under normal conditions.

We may fix our attention most profitably upon the status of sleep in those of middle or late life. Here a number of causes conspire to disturb equilibrium of body cells, sometimes slightly, and at others it will be found that effects have been insidiously wrought which may suddenly obtrude upon our attention, causing great distress, often impairing the integrity of our judgment, hence our working efficiency. Therefore a double peril assails. Mere inability to sleep naturally, or as heretofore, or as each one assumes as a right, is, especially among men (who shrink from admission of physical weakness), seldom regarded as worth their seeking the advice of a physician. Whereupon the simplest remedy is to hunt about for something which will obtund

the consciousness. Often this is a form of alcohol. A friend will advise a glass of whiskey at bedtime, may be two or more; beer is popular for this purpose; some special form of wine is often recommended, and (deplorable as it may seem) too often by the physician.

The entering wedge is so easy, and in the main agreeable in its primary effects, that the habit of tipping is thus readily established. Or again the chemists' shops are filled with 'simple harmless remedies for insomnia.' The sign boards in all public places glisten with advice. Every acquaintance is ready with counsel, especially those numerous well intentioned women with little else to do but to prattle of their shallow convictions on matters coming within the narrow range of their experience, medical, spiritual or social. It is never safe to play with drugs; to trifle with agencies often hurtful to a profound degree in their ultimate effects. Idiosyncracies exist, too, whereby what may harm one not at all produces in another far-reaching derangements of vital organs. One of the most dangerous lunatics I ever saw was a man possessed by sudden homicidal tendencies. He would have remained so had not it been discovered, by providential accident, that he was accustomed to use habitually moderately large doses of some bromide. The obsession promptly and permanently disappeared by total withdrawal and the use of an antidote. We physicians, especially those who see many instances of nervous derangements, are constantly coming in contact with the deplorable derangements caused by hypnotic drugs, many of which are ordinarily classed as innocent. The action of narcotics presents none of the characteristics of normal sleep except the temporary arrest of consciousness; hence narcosis is not true sleep. It does not refresh and regenerate vigor as does normal sleep. To be sure, drug unconsciousness may and often does pass into sleep. Again there are those who have become so accustomed to narcotics that, when deprived of them, they can not sleep. This would seem to prove a sort of antagonism between the drug effect and natural sleep. In brief, whatever agents inhibit cerebral activity, inducing local anemia, hence permitting sleep or narcosis, are harmless provided they do not derange nutrition or cause other ill effects. All narcotic drugs invite these evil effects in varying degrees and hence are to be avoided, and only used in extreme cases and under guidance of a competent physician.

The other peril lies in the fact that derangements of sleep often foreshadow serious structural damage of the heart, arteries or other organs or tissues. Hence unless the phenomena be estimated intelligently, in the light of other than obvious data only to be secured through careful medical examination, a deadly disease process may escape detection until too late to accomplish full repair.

To secure regular consecutive sleep it is best to assume that posi-

tion which is most natural and best suited to invite the least disturbance of the functions of the great organs. To use the analogy of the four-footed animals, and by such facts we can secure the safest guidance, the best position is on the abdomen or nearly so. Habits may, and do, vitiate our instincts here as elsewhere, and we can accustom ourselves to many departures from natural and advisable operations. This is especially forceful while in vigorous health, but we are speaking here of securing the best rest with the least tax upon our organism, hence it is well to determine those means which are normal, and employ them. The body should lie as nearly as possible on a level, head and feet as well as body, on the side inclined toward the abdomen, adjusting arms and legs in such a fashion as shall not permit undue pressure upon nerves and bloodvessels, direct or indirect.

To lie on the back is objectionable for the reason that long continued pressure on the tissues adjacent to the vertebral column, which are innervated by the posterior primary divisions of the spinal nerves, exerts a continued irritation through vasomotor connections to the viscera, disturbing the circulation in the segments. Here are the cell bodies of the vasomotor nerves, which thence pass to the organs and beyond parts, thereby governing function. Thus, dilatation is induced and maintained in the blood vessels of the viscera. Also certain results follow directly by effect of gravity. Pressure on the abdominal organs, and their varying contents, is exerted upon the great vessels, arterial, venous and lymphatic, the sympathetic plexuses, and the ebb and flow of fluid in them is deranged. Hence function and nutrition of these structures are influenced unfavorably. Man is the only animal which sleeps on the back. This attitude should only be assumed for short periods. During extreme weakness this position is often taken, but it is the duty of attendants to urge a frequent change to the side, otherwise several hurtful effects may follow, among which the least grave are nightmare and evil dreams. The poisons of katabolism circulating in the blood tend to be deposited in the outlying tissues; hence arise pneumonia and bedsores. Not only is this true for those who are suffering from one or another form of disability, but for those in robust health, especially when sleeping on the back after full meals. Many obscure forms of digestive or circulatory disorders may have been initiated in infancy through lying too long upon the back.

In animals, among whom such disorders are rare and whose spinal column is constantly horizontal, there is little or no change in the relative positions of the great organs at any time. In man, who is constantly altering the relationships of these viscera by lying, standing, stooping, the blood supply and venous return are subject to frequent interruptions, and strains are exerted upon the supporting structures

of the blood vessels and thus the vasomotor mechanisms are taxed heavily. The head should be permitted to rest as nearly upon a level as the feet, though most people prefer some support. The blood should be encouraged to reach all parts of the body equally, hence the limbs had best be extended, not flexed; the habit of extending the arms above the head is a particularly bad one.

To secure the most perfect repose the temperature of all parts should be equalized before retiring. Cold feet induce delay in securing sleep and it is then shallow when attained. The bladder and bowels by weight of their contents will interfere with repose, hence they should be previously emptied. It is most unwise to overfill the stomach before retiring; this disturbs sleep almost as much as hunger, but moderate eating before sleeping is not hurtful, and is often salutary.

Sleep is only a function; therefore, whatever disturbs it depends on structural derangement of some sort. Disorders of sleep are manifold. The commonest are psychic exaltations or depressions, worries, brooding on the cares of the day, continuing to dwell on the waking problems. Habit is ever forceful. A well-trained mind will promptly shut off or readily let go of the thought processes. Unnatural activity of the sensory and association centers causes dreams; that of the motor centers results in shocks, starts and spasmodic phenomena. Control of the visceral centers may become inhibited, permitting unconscious discharges from the bladder, intestines or sexual organs; innervation of the lungs or heart being thus deranged, palpitation or dyspnoea is induced. Sensory centers being over-stimulated, sensations of light follow, or of sound, also pain or vertigo. "In fine, the ordinary smooth current of the subconscious activities breaks against some pathologic states and now one symptom, now another, is thrust out and so unpleasantly that the sleeper awakens" (C. L. Dana).

A review of Dana's remarks on the disorders of sleep will be useful to achieve an understanding of the varieties and phenomena of insomnia; a better term perhaps would be difficulties of sleep. Some people, especially those of middle age, fall asleep easily, but wake in the small hours and thereafter only doze fitfully. This may be due to beginning degenerative changes in the arteries, connected with the effects of worries and strains, or only a habit, or echo of youthful customs of early rising, or an acquired weakness or irritability of the heart. Others fall asleep readily, but are soon disturbed by little explosions of motor, sensory or psychic forces. The body or limbs start or jerk; sleep follows, but these nervous explosions may be repeated two or three times. It is usually the result of exhaustion, psychic or muscular over-tension, physiologic irritability, indigestion, nervous fatigue, or may foreshadow some serious derangement. Sudden awakenings often betray emotional distress, fear or disorders of ideation.

Weir Mitchell has written fascinatingly of disorders of sleep, making absorbing reading for the profession as well as the laity. He it was who described first the sensory shocks, strange feelings passing along the body, culminating in some abrupt explosion, noise, odor or vision. Vertigo is occasionally thus experienced, especially by those who have felt it before. That mysterious malady called 'migraine' sometimes occurs suddenly while asleep 'and hales the sufferer from profound sleep to waking hours of misery.'

Morbid or perverted sensations, numbness, 'pins and needles' formications and such like mild neuroses appear at times during sleep. Limbs may seem 'dead,' sensation being temporarily lost and not in any way which follows upon marked pressure interrupting the flow of nervous impulses, but purely a phenomenon of sleep. These are more common in the later hours of night, when the motor cells are restored in part, losing irritability, the sensory cells being still excitable. These discomforts may be referred to interruptions in the conductivity of the spinal cord. Nocturnal psychoses, the night terrors of children, nightmare, strange mental vagaries, changes in intellectual and emotional balance, are of such wide variety that they can only be alluded to; each person of rich experience is able to recall instances. In these conditions of distress much folly can be committed, and frequently is; evil thoughts are thus engendered, which too often influence action later. Sometimes imperative impulses arising in slumber drive one to commit questionable or silly deeds. The imagination in some is thus stimulated to utter weird statements, or to put on record what are falsely estimated to be thoughts of deep significance. I recall reading an incident in the early official life of Bismarck, who often thus awakened in the night with the conviction that he had solved perplexing problems. On reducing to writing the ideas thus excited he found, on perusal next day, that they were altogether fanciful. It is true, valuable ideas do come in dreams or in real temporary waking states.

The sleep of early life is peculiarly sensitive to irritations of the organs below the diaphragm, digestive or genital; in later life to those above, of the heart, blood vessels or lungs. In this connection we may refer to dreams. The suspension of brain activity in sleep is only partial; there prevails a certain amount of psychic life. Every nervous stimulus, sensation or idea leaves an impression, a trace, in the cerebro-spinal system. Obscure motions, influences, irritants generated in the organism, may afterward revive temporarily under some impulsion of consciousness, as by afflux of blood. Each cell of the body is endowed with more or less memory (Henle), for by this means are preserved hereditary influences, the transmission of psychic and mental characteristics, the after images of sensations. In this manner many sounds, sights, feelings, which are partially conveyed to the sensorium,

may become revived and variously interpreted to the consciousness. Predormital sensations, thoughts and movements are thus capable of inducing multiplication and diverse auto-interpretation. Dreams grow luxuriantly when the state is one of partial wakefulness. The influences of the day are then woven into fanciful pictures more or less reflecting actual life.

If sleep be profound the imagination is no longer dominated by actualities and there arises the phenomenon of a special world, that of dreams. Mental activity is really physical activity; hence we may experience consequential fatigue. At the bottom of the emotion may be found a subjective excitation of the peripheral nervous apparatus. This form of reflected life constitutes the basis of dreaming, the imagination, hallucinations, the realm of fancy. Dreams have their origin in those parts of the organism most active in the waking state, in eyes, ears, the tactile, temperature and muscular sense. The same obtains as to hallucinations in the insane. A very deep sleep does not permit of dreams, or the waking memory can not recall them, whereas in very light sleep dreams are frequent and can be remembered.

Dreams are more numerous and picturesque among intellectual people, and during certain exhaustive states, and less among those of lower mentality. The more primitive, young and intellectual the person, the more illogical, disjointed and elementary are the dreams. In old age, and profound depressive states, dreams are most rare; they serve many useful purposes. To the physician certain features of dreams possess a valuable significance. They exercise a salutary influence upon otherwise unused areas of the brain and permit the excursions, or, may be, formation, of the faculty of imagination (Manacienne). They act as a defense against the monotonies and trivialities of real life, for without them we should grow old much more rapidly (Novalis). Many writers, poets, scientists, philosophers, musicians, etc., testify to the value of dreams in piecing out their concepts, idealizations, weaving a woof of imagination invaluable to the completed thought.

It will be seen that the regulation of impaired sleep reaches back to causes most varied. Some are slight and superficial; others are due to deep-seated derangements or lesions, beginning or established. In practise, however, certain plain simple procedures usually suffice to bring about happy results. Beyond what these can accomplish, skilled medical aid should be sought and a careful search made for definite disorders, and systematic measures instituted to remove them consonant with the difficulties encountered. It is well to remember that the causes of wakefulness may be highly complex; slight factors often acting with equal forcefulness with those which theoretically should be greatest.

We are concerned in our efforts to regulate the resting period of

the consciousness, with possible morbidity in two directions; too much or too little. Ordinarily it is assumed that the more one gets of sleep the better. This view is so generally accepted that the custom of some physicians, especially those who see much of illness in the extreme periods of life, to order food or employ active measures at regular hours, involving the waking of the patient, verges upon the danger line. Judgment must be exercised, and is well within the capabilities of a good nurse. Serious exhaustion has often followed needless interruptions of repose during exhaustive states.

It is entirely demonstrable that a variety of disorders may result from, or are indicated by, excessive somnolence, partly of developmental and partly of degenerative origin. During infancy sleeping must predominate over waking states, the unconscious reflex life over the conscious intellectual life. It should be remembered, however, that consciousness requires exercise for development. Monotonous measures, such as rocking, swinging, unmusical lullabies, may serve a salutary purpose occasionally, but can readily be carried too far, to the point of lowering normal temperature, inducing excessive anemia of the brain and disturbances of circulation. Sleep should come by opportunity, comfortable position and customary environment. Habits should be formed sufficient in themselves to invite repose. It ought not to be interrupted needlessly, nor forced by measures or drugs which obtund the consciousness. Normality of sleeping capacity is the product of intellectual equipoise. Stupid folk are proverbially dull, lethargic, with large capacities for deep sleep. Some part of this is no doubt the result of over indulgence. The consciousness is often enfeebled by disuse in young or old. In the young the impetus to exercise the faculties demands encouragement; also, as age enfeebles the brain structures, mental stagnation, hence degeneration, is invited by overmuch time spent in unconsciousness. Nutritive balance, the expenditure of energy, can not be maintained indefinitely. Renewals must occur, and it is shown that inordinate somnolence makes for exhaustion of body and mind; the kidneys suffer, their vessels become distended and hence enfeebled. In the aged the tone of the tissues, especially of the vessel walls, tends to become devitalized, leading to a stasis in lymph and blood vessels and to various forms of organic derangement. In deep sleep, long continued, this stasis of blood and lymph is unduly encouraged, sometimes to the point of paralysis. The bile becomes thickened, stagnated; the bowels, the intestines, suffer from a surfeit of sleep, impairing the machinery of peristalsis, hence follows constipation. The urinary organs also share in this derangement of elimination and gravel, calculi, may form. Anemias are often unaccountable, but it will be found that chlorotics usually sleep too much and are the better for its regulation.

There is no simple fact more forcefully borne in upon the writer than that early rising and movement in the open air before breakfast is a measure of vast importance in a large array of chronic ailments, especially those involving gout, dyspepsia, constipation, obesity and disorders of the sense organs. Many people aver that they are made miserable by rising early, stirring about before taking food, and consequently suffer from headaches, nausea, prostration and the like. These phenomena are the results of some derangements in the circulatory balance, most probably due to a morbid quality of sleep, which for the most part is remediable. In proof of this statement is the fact, usually clearly demonstrable, that if the physician can secure fair cooperation, with persistence all this wretchedness will disappear. Particularly is this shown if circumstances compel the patient to alter his habits for the better. Abundant illustrative instances could be cited. Weir Mitchell in his recommendations for the rest treatment, so valuable in the repair of profound conditions of exhaustion, compels a fixed hour for wakening, usually seven A.M. Often it has been the writer's duty to soothe and explain to Dr. Mitchell's patients, who resented being awakened, the reason for this regulation.

Disuse of muscle is followed by atrophy; so of other tissues. Strength can only grow by judicious, continued use. Witness the pitiable spectacle of steady degeneration in the tissues, in mental and physical aptitudes, commonly displayed in those of advancing years, who, through withdrawal of normal stimuli to exertion, permit their organs and their structures to fall into disuse. Prosperity, interpreted so often to mean cessation of energies, is often fatal to physical and mental efficiency. The antidote is simple and most effective, the retention of habits of usefulness applied all along the whole line of normal activities.

The whole range of bodily derangements and diseases can be interpreted through variations in the blood supply. This again depends upon the incidence of diverse irritants, infections from without or poisons generated within; or such as are the products of changes in the blood plasma effecting oxygenation.

Sleep being the relaxation, suspension, of the consciousness, the brain being the center of consciousness, it naturally follows that, as evidence shows, the circulation in the brain is, during sleep, at the lowest normal tension. Whatever disturbs sleep, therefore, probably induces an afflux of blood to the brain. It is evident that to sleep peacefully and continually it is important that the blood pressure shall be as nearly as possible normal. If this be markedly above or below par sleep is interfered with. Plethoric folk, however, supposedly of over-tense vessels, often sleep better than the feeble and weakly; yet they are more likely to slumber heavily, are difficult to wake, and on

waking suffer from morning confusion and headache; in short, are far less refreshed by their slumber and require longer to acquire waking balance than frail beings whose sleep is shallow, interrupted and seemingly insufficient.

All these facts and reasonings from vascular tone constitute a long, somewhat technical, story; suffice it to say that, in order to secure comfortable natural sleep there is demanded a careful regulation of blood supply and distribution. Where a careful regulation of life fails to accomplish this, help must be sought of a wise physician, who will promptly determine what is amiss. The difficulty may be found to be due to faulty skin action, cold extremities, intestinal accumulations, or visceral poisons, organic derangements, a weak heart, an overtired body, an overwrought brain or other physical disorders, the province of the physician. Interference with matters out of the realm of our experience is usually followed by punishment. Among the most dangerous things a person can do is to take a shot in the dark in medical procedures, swallowing medicines on blind guesses. Damage must almost inevitably result, first by deranging digestion, perhaps already at fault, and next achieving stupor, not true sleep, or encouraging the brain to demand meretricious, unsuitable soporifics.

While it is most desirable that sleep should be taken in regular amounts, at a suitable time, and this during the hours of darkness and continuously, still it is possible that various habits may be formed, seemingly peculiar, which suffice for ordinary requirements. These may be acquired to meet some temporary demand, or become habitual for years. For instance, mothers of young babies commonly form the habit of sleeping and waking readily and frequently, and yet continue to enjoy excellent health. Trained nurses acquire even more complex, yet systematic, habits of sleep and wakefulness; a regular irregularity, yet productive of little or no exhaustion, at least for a time. Persons engaged in diverse strenuous occupations secure a power of seizing sleep when they can get it, notably sailor men by 'watches' of four hours each, twice a day.

Sleep, being the chief restorative agency for the consciousness, the desideratum is chiefly to achieve enough repose in sufficient completeness to effect repair of brain cells and other centers of energy. In those whose lives are full of repeated and emphatic demands upon them for concentration of attention, the habit of taking short naps is found to be most refreshing and invigorating. Many physicians, some lawyers, and other professional men who pursue literary work, find it satisfactory to secure a brief sleep some time during the day, often in the middle of operations, when an opportunity offers. Thus a short sleep in a chair, or preferably lying down on the back on a bench or lounge, will rejuvenate the powers and permit intellectual work far

into the night. While a certain number of hours of consecutive sleep are imperative for full health, these can not be dogmatically determined except by carefully weighing circumstances, which vary. Lumber men on the 'drive' maintain excellent health on the smallest amount of sleep, during the most trying circumstances, after intense physical exertion so long as the spring daylight lasts, often wet to the skin, with little or no bedclothes or protection at night from freezing weather and fed irregularly, often insufficiently. Armies, exploring parties and others have similar experiences, and suffer no distress for days and weeks, the men often actually gaining in health, seldom losing. If the circumstances be cheerful, such competition, overcoming the forces of nature, is salutary. If peril, strained attention or tyrannous officers complicate the conditions, ill health may appear early and is then often severe.

When to sleep is again a matter of opinion. Early rising is by common consent a salutary custom, especially when the day comes early, not otherwise. It is agreed that more sleep is required in winter than in summer. The best sleep is had during the hours of darkness. The mind is clearest in the early morning, and those who can utilize this period for intellectual work are capable of turning out the best products. Some can not do so, or think they can not, and yet furnish excellent results.

The sleeping room should be cool, abundant air being always admitted. This should not be interpreted to mean that the room may safely remain intensely cold. In the modern treatment of tuberculosis fresh air is recognized to be imperatively needed all day and all night. Artificial heat can, and should, be supplied along with the fresh air, till the temperature of the room be at or near 50° F. or 55° F., for some even 60° F. Above this no one in health is likely to sleep in perfect comfort. Babies and invalids need a heat of from 60° F. to 70° F., even more at times, yet all require the fresh air, or fullest ventilation.

Fever patients, even those suffering from pneumonia or bronchitis, may sleep with safety and great advantage in a thoroughly ventilated cool room and with no more covering on them than is needed for protection from sudden changes of temperature which might send their body heat down below normal. It is needless to particularize as to the offensiveness, deleteriousness, of the body and lung exhalations emitted by those asleep. This is more than apparent, it is actually greater by far than when awake, and demands prompt removal and an abundance of good air to replace that which is vitiated. There are those who still cling to the shred of demon influence which causes them to 'dread the night air' when spirits range and goblins weave evil spells; when diseases come wafting in at open windows, keyholes

and other joints in the harness of defense. Since the pestiferous mosquito has been proved the chief carrier of mephitic paludal diseases, insect nettings are deemed sufficient to ward off evil nocturnal influences. Sleeping in a close exhausted atmosphere is so promptly and painfully punished by discomforts, that it would seem there could not be two minds on the matter. Yet many refined and educated folk still prefer the shut windows. Curiously enough some woodsmen, farmers and others who live much in the open air incline to a hot room for sleeping. To my sorrow, I have often been compelled to experience this prejudice.

Body clothing at night should be loose, not dense, permitting the ready passage of air, never of wool next to the skin. Bed clothing should not be too close of texture, blankets being preferable to dense 'comfortables' and not 'tucked in' too closely. Air should be allowed to pass occasionally under the sides at least as one turns about more or less freely. I have proved this in open camps in bitter temperatures, thus using less clothing than those who slept in bags. Indian guides often sleep with their heads covered and their feet bare to the fire. Even on the long trail I prefer pajamas to close fitting day underwear at night. Under these circumstances, too, occasionally rising and warming by a fire gives better rest than to stay close in a sleeping bag all night long. As to beds the firm mattress with springs is vastly better than soft clinging surfaces.

Some people sleep with a profundity, a completeness, from which they can only be aroused with difficulty. They occasionally wake unrefreshed with confusion, headaches, stiffness and soreness of limbs. This is unfortunate and usually betokens some abnormality in health which should be corrected. Such deep somnolence is not so restorative as the lighter forms of slumber. Again limbs become cramped, hence nerves and blood vessels suffer hurtful pressure, by long remaining in one position; the integrity of the internal organs likewise is imperilled. Sleep is invited by darkness. Light, even though the eyes be closed, penetrates the lids and stirs the consciousness through these most delicate of sense organs. Hence it is wise to exclude light if one must sleep after the sun has risen. A useful device is to cover the eyes with black cloth or even a handkerchief folded, or use a screen, rather than to exclude daylight from the entire room, which too often means exclusion of air as well. Those whose heart and arteries lack tone may give attention to this to secure or to maintain sleep. Day drowsiness and night wakefulness indicate often a cardiac weakness demanding attention. Conversely, high pulse is usually present in those who sleep over heavily.

A complete circulatory balance is needed for those who would sleep most refreshingly. One of the best means to secure this is by exercise

at bedtime, enough to distribute the blood to the surface and muscles, hence to relieve the tension in the vessels of the brain. High vascular tension is often a cause of insomnia; it may be continuous or only due to psychic causes, worries, morbid tension, over-excited circulation or toxins. Hence the common device of the hot foot bath, hot entire bath, or even a cold bath inducing reaction, may suffice. To execute some systematic movements with little or no clothing on is better; in cold weather with extra clothing on, such as a sweater. Certain movements, especially those of the neck and shoulders, are particularly useful. A series of movements I devised in treating a chronic neurosis put many patients promptly to sleep. Also certain manipulations of the neck, especially a distributed pressure over the posterior occipital nerves, have in certain cases of obstinate insomnia in my hands been followed by complete cure. One man who claimed he had not slept a full night for thirty years was thus put to sleep in my office and after a course of treatment he remained free from this distress. That admirable instrument, now unfortunately out of fashion, the bicycle, cured scores of insomniacs by affording patients the means of prompt lowering of blood pressure by a ride just before bedtime. Few measures are more prompt, certain and permanent.

Eating some light food is often of value, but the overfull stomach is frequently a cause of shallow or distressed sleep. There are many forms of digestive derangement, liver troubles, toxemias, etc., which impair sleep in those who are under the impression they have powerful digestions. Nothing wakes some people so certainly at evil hours as an over-acid stomach, relievable by a simple alkali or charcoal. The bowels are best evacuated before bedtime; if full they may cause much loss of sleep. In short, as Emerson says of all health, of which sleep is a major item, it is not to be bought, it must be *earned*; and wisdom, frugality, self restraint, industry, perhaps all cardinal virtues, contribute to this boon.

STATE UNIVERSITY SALARIES.

BY C. W. FOULK AND R. F. EARHART.

FROM time to time the question of the relatively low pay of members of the teaching profession is brought to the foreground in the public press. The statements made are as a rule only general in character, or if any actual figures are given for a large group of teachers they usually relate to those in the public schools. It has happened, however, that during the last half year certain comments have been made on the remuneration of college and university professors. Sir William Ramsay, the eminent English chemist, remarked during a recent visit to this country on the absence here of any great academic prizes, positions of high standing and large salary together with leisure for carrying on research. An article in the *New York Evening Post* of recent date has also been widely quoted. This purports to give a brief account of the salaries paid at Harvard. From it one learns that, roughly speaking, the average salary of a professor there is \$4,000, of an associate professor \$3,000, of an assistant professor \$2,000, of an instructor \$1,000, while an assistant must content himself with from \$250 to \$400. The *Post* intimates that the situation at Harvard is better than at any other American university. Whatever may be the real state of affairs, these figures may certainly be looked upon as being among the highest. Indeed, to anticipate one of the chief items in the statistical part of this paper, it may be said that the average salary of the professors in the state universities of the middle west is \$2,315. This, whether it be too low or not, is certainly lower than \$4,000.

The question at Harvard is receiving its full share of attention, for it has been noted in a recent number of *Science* that \$1,800,000 of a fund of \$2,500,000 has been raised to be devoted 'to increase the present totally inadequate amount available for the salaries of the teaching staff.' The Carnegie pension fund is another item of interest in the matter. In THE POPULAR SCIENCE MONTHLY of December, 1904, an article under the title 'Status of the American College Professor' has much to say of the financial side, and in the *Atlantic Monthly* for May of this year an anonymous writer discusses in detail the necessary expenses of a college professor. These exceedingly pithy articles will be found to have an added interest in the light of the statistics brought out in this paper.

But if this question of university salaries is to be discussed at all

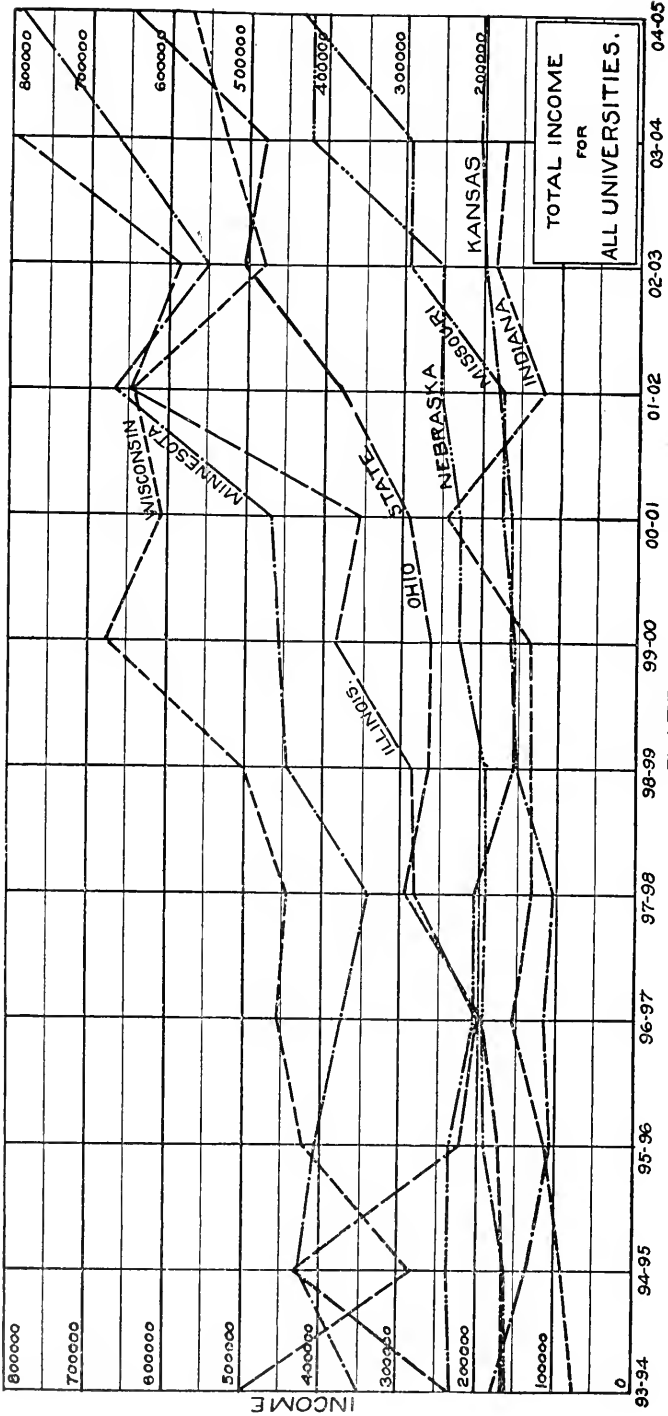


PLATE I

Incomes year by year from 1893-4 to 1904-5.

intelligently, the starting point must be comprehensive statistics showing exactly what the situation is. To get such statistics is not an easy task. Though most institutions of learning have published reports giving details of their business management, these reports are not always easy to find, and, when found, certain kinds of information are not always easy to obtain from their pages. In taking up the matter, the authors saw that with the time at their disposal only a limited number of institutions could be studied. In selecting this small number, it seemed desirable to take a representative group of some well defined type so that the figures would have wider application. In choosing the type the state university of the Middle West was selected, for the reason that in this large section of the country it is the most important type, not in numbers, for in this particular the small denominational college outranks it thirty to one, but in wealth, number of students and rapid rate of growth.

The actual group of which a discussion is to be found in the following pages consists of the universities of Wisconsin, Minnesota, Nebraska, Kansas, Missouri, Illinois, Indiana and Ohio. Effort was also made to secure similar data from the universities of Iowa and Michigan, but without success.

These eight universities may certainly be looked upon as representative. They have shared in the development of the region in which they lie. The equipment, the attendance and the number of instructors have increased to a remarkable extent, and, finally, there is in them an almost entire absence of traditions of the past. In such institutions, if anywhere, one would expect to find the normal salary and the normal rate of change of salary. That is, the increase in the incomes of these schools, as well as other conditions of a secondary influence, has been such that a greater or less increase in the salaries paid has been largely a matter of policy, to be followed or not as their various boards of trustees have seen fit; and it is therefore reasonable to suppose that whatever state of affairs in regard to salaries exists in these institutions more nearly represents the rating of the positions on the part of the people than can be found in other universities and colleges.

In the following pages then will be found an account of the salaries paid at these eight institutions. No discussion of the conditions prevailing at the several schools will in any sense be attempted. The data as obtained from the published, or soon to be published, reports are given and the important items are pointed out by references in the text. Whatever local conditions may exist for explaining this or that peculiarity are beyond the scope of the paper, which aims solely at a presentation of the facts in this group of representative institutions, the authors believing that such a presentation should be preliminary to any change that may come.

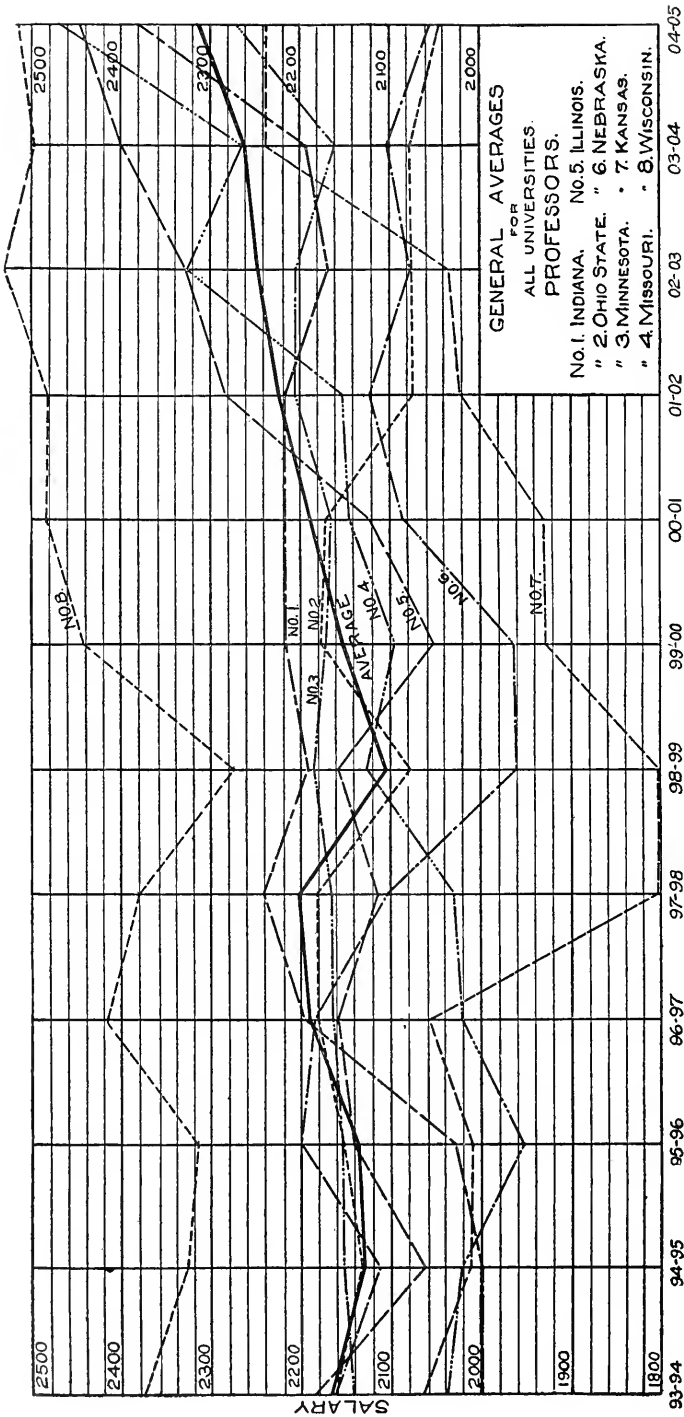


PLATE II

A graphical scheme has been chosen as this presents at a glance the general situation from year to year. A large amount of data was, however, collected that will not admit of simple graphical treatment; for instance, the maximum and minimum salaries, the number of men of a given rank from year to year, the number receiving a given salary, etc. To have presented all this would have multiplied unduly the number of plates, and therefore no such presentation will be attempted.

Most of these figures, as was mentioned above, were obtained from the published reports of the institutions. Those for the last two years, however, were kindly furnished by the executive departments of the universities.* In addition, all the data for each university were referred back for correction, if necessary, and therefore may be looked upon as official. Only data relating to the salaries of professors, associate professors and assistant professors are given, for the reason that to have included the large number of instructors, assistants, etc., would have demanded too much time.

This shows the total income of each university during the past twelve years, that for the current year being, of course, estimated. At present Minnesota heads the list with an income of approximately \$800,000. Ohio, Wisconsin, Missouri, Nebraska and Kansas follow in the order named, with Indiana and Illinois not given.

In connection with this it ought to be said that both Kansas and Indiana support two institutions of higher learning; each state having in addition to the university an agricultural and mechanical college. In the other states these subjects are not given in separate schools, but make a part of the university curriculum. In this paper only those institutions officially designated as state universities are considered. This of course will greatly affect the relative income, but should in no sense affect the salaries.

This shows the average salary from year to year paid at each of the universities to men holding the rank of professor. The heavy line on this plate marked 'average' gives the average salary of professors in the eight institutions. It was obtained by treating the eight universities as one and dividing the total amount paid each year to professors by the number of men of this rank in the eight schools.

Two notes of explanation are required in regard to this plate: (1) Many men in the professional schools of law and medicine hold the rank of professor, but inasmuch as they give only a small part of their time to teaching they receive relatively low salaries. Obviously they represent professions other than that of teacher, and all such are

* The authors wish in this place to thank the presidents of these eight universities for their ready aid, which made possible the collection of the data for the more recent years. They feel especially indebted to Dr. W. O. Thompson, of Ohio, through whose kind assistance the interest of the others was enlisted.

accordingly omitted. (2) In some places the deans of the several colleges in the university receive extra compensation owing to the executive work required of them. They have, however, been included in the averages because their work is entirely within the university and educational in character. This paper aims solely at a discussion of the pecuniary side of the positions in these state universities, aside from that of president, and therefore it seemed fitting to rate the deans with the professors, rather than to make a separate list.

The noticeable features in the average salary curve are the high points at the years 1896-7 and 1897-8, the sudden drop at 1898-9 and the steady upward trend from that time to the present. An inspection of the tabulated data from which the curves were compiled shows that during the year 1895-6 there were in the eight universities 187 professors at an average salary of \$2,139. In 1896-7 the number increased to 196, but increases in salary raised the average to \$2,193. During the next year, 1897-8, the number rose to 202, while the average salary reached \$2,202. In the next year, 1898-9, however, something seemed to happen. There appears to be evidence that in some institutions, at any rate, salaries were actually cut. The number of professors reached 224. The average salary fell in four universities, remained constant at a very low mark in one and rose in three. This was the low water mark, for from that lean year to the present there has been a steady increase, the curve being almost a straight line. Great differences are, however, to be noted during this period in the several universities. In four of them, Wisconsin, Illinois, Kansas and Missouri, the rate of increase in the average salary is more rapid than that of the general average for the eight. In two of them, Indiana and Minnesota, there is an increase, but at a less rapid rate than the average for all. One of them, Nebraska, increased rapidly during the first three years and then suddenly declined. One of them, Ohio, shows a decline since 1899-1900. Advance reports of the Ohio salary list for 1905-6 show an upward trend, the averages for that year being as follows: professors, \$2,200; associate professors, \$1,580; and assistant professors, \$1,347. In 1898-9 the average salary was \$2,106. At present, 1904-5, it is \$2,315.

This period of seven years, beginning with 1898-9 and ending with the present academic year, is peculiarly suited to a study of the salary question. During this period, times in general have been good and the universities themselves have prospered, as an inspection of Plate I. will show. The time embraced is sufficiently long to warrant general conclusions, and it is therefore reasonable to suppose that whatever changes may have taken place may be looked upon as more nearly normal than in the preceding period.

It is gratifying to note that the average salary has increased in a substantial manner, it being now practically ten per cent. more

than in 1898-9. The increased cost of living, however, during this time should be taken into consideration before a final conclusion is reached in regard to the real state of affairs.

Before leaving the discussion of this the most important of the plates, the reader should be warned against ascribing too great significance to the ordinary ups and downs of the curves. In the first place, the arithmetical mean leaves much to be desired as a single expression for giving an idea of a set of numbers that differ much among themselves. Secondly a rather slight change in number and salaries of the professorial staff of an institution will in some cases change the average out of proportion to the actual change. The scheme of giving the averages is, however, the best that can be used, and when the trend of the curves for a period of years is taken into consideration, it is believed that they very fairly represent the situation.

Naturally an inspection of the complete data from which the curves were plotted reveals many interesting and important points which the curves themselves fail to show. For instance, one interesting feature that presents itself is that in the majority of the institutions there appears to be a 'normal' salary for men of full professorial rank; that is, a sum which all professors receive unless there be a special reason for their getting more or less. This is inferred from the following figures taken from the data for 1904-5, but typical of the whole period: In Kansas 57 per cent. of the professors are receiving \$2,200 each; in Nebraska 47 per cent. receive \$2,100; in Minnesota 48 per cent. receive \$2,400; Indiana pays 53 per cent. \$2,500; and in Ohio 40 per cent. get \$2,250. (In 1905-6, 36 per cent. will receive \$2,500.) In Wisconsin 33 per cent. receive \$2,500 and 20 per cent. \$2,000. Wisconsin has apparently two 'normal' salaries, a condition not presented by any of the others. In the cases of Missouri and Illinois no considerable proportion of the faculty receive the same salary. These so-called 'normal' salaries do not coincide with the average salary, they being sometimes higher and sometimes lower and differing in maximum by over \$200 from the average.

In regard to high salaries, Wisconsin heads the list. In this institution, in 1904-5, ten deans and professors are receiving from \$3,000 to \$4,500. The lowest recorded salary, \$1,000, is also on Wisconsin's list. Illinois and Missouri are the only other universities of the eight that pay a professor more than \$3,000. All of them are paying some men \$2,500 and in four of them this is the highest salary paid. All but one, Indiana, pay some of their professors less than \$2,000. It should be borne in mind that these figures refer to salaries of men of full professorial rank and do not include associate and assistant professors.

Taking the period beginning with 1898-9 and closing with the present academic year, 1904-5, it is seen from the complete data that

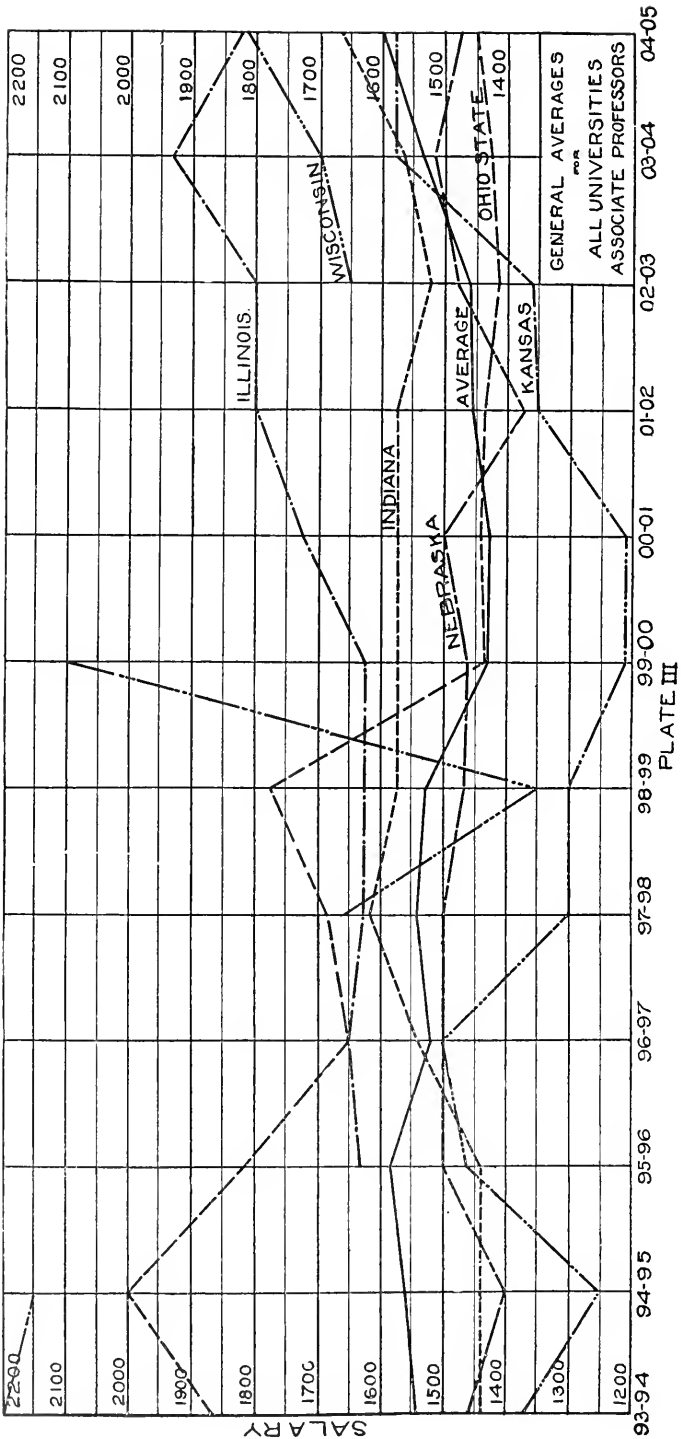


PLATE III

in these eight universities the number of professors receiving \$2,500 or more has increased from 40 out of a total of 224, or about 18 per cent., to 89 out of a total of 285, or 31 per cent. On the other hand, the number receiving less than \$2,000 has decreased from 21 per cent. in 1898-9 to less than 12 per cent. at present.

Among the several universities there are very great differences.

At present Wisconsin pays 60 per cent. of her professors \$2,500 or more; Indiana, 53 per cent.; Missouri, 44 per cent.; Illinois, 43 per cent.; Nebraska, 16 per cent.; Kansas, 10 per cent.; and Ohio 5 per cent. In 1905-6, Ohio will pay 36 per cent., \$2,500. As to the number receiving less than \$2,000, the percentage ranges from 0 in Indiana to 31 in Ohio.

Here is shown in a manner similar to that for professors the averages for associate professors.

This title does not exist in the University of Missouri, and at Wisconsin there have been periods—indicated by the omitted parts of the curve—when no one held it. The University of Minnesota, in sending data, classed associate professors and professors together.

The interesting feature brought out by an inspection of the data is the relatively small number of men holding this title. It has, however, increased with fair uniformity from 18 in 1893-4 to 49 in 1904-5. Among the several institutions there are great differences, Ohio and Kansas being in the lead. The figures for 1903-4 represent very well the relative numbers during the last five or six years and are accordingly given. In that year Wisconsin had 1; Minnesota, 0; Nebraska, 6; Illinois, 3; Indiana, 9; Missouri, 0; Kansas, 14; and Ohio, 19 associate professors.

In a general way the average salary curve for men of this title follows the trend of the curve for professors. At present it is \$1,600.

This gives the averages for assistant professors. These have increased steadily in number from 61 in 1893-4 to 159 in 1904-5. The general average curve shows the same trend as the preceding ones, the average salary being now \$1,374.

Previous to 1901 the title of assistant professor did not exist in the University of Nebraska, the lowest professorial grade being adjunct professor. Since 1901, however, assistant professors have been added, thus making four grades with the title of professor.

Inasmuch, however, as the adjunct professors represented the third grade of professorial rank which in position at least corresponds to assistant professor in the other institution, they were rated as such on Plate IV. until 1900-1, the advent of the assistant professor.

The Nebraska curve then is really that of the adjunct professors till 1900-01, after which it refers to the assistant professors.

Having now obtained the exact data in regard to salaries, the question may arise as to whether the professorial position does not carry

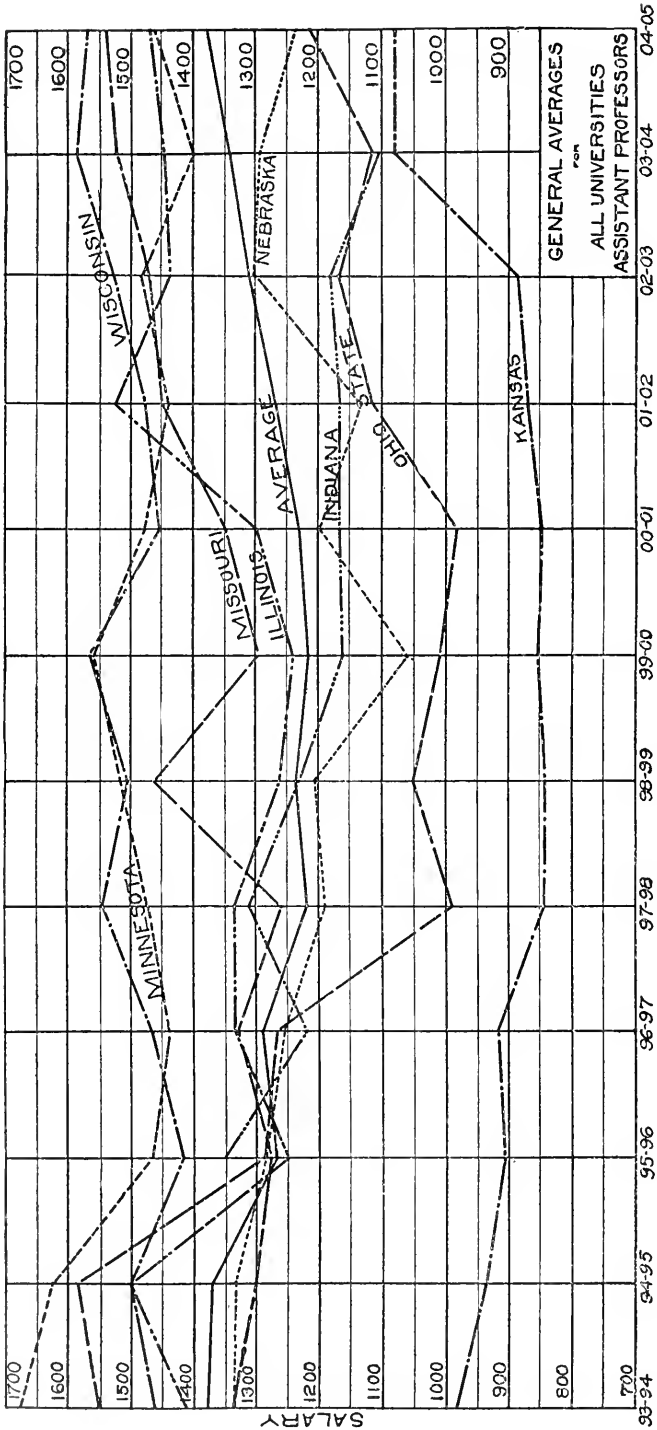


PLATE IV.

with it, in many cases at least, certain perquisites in the way of rooms, board, etc., in the university buildings; and if in an indirect way opportunities are not offered for large fees for expert consultation work, etc., thus very materially raising the real income.

In regard to the first of these items relating to house and board, it may be said to be entirely negligible. In some of these eight institutions the president receives his house in addition to his salary, but no professor is thus favored. A discussion of the second item, sources of income attracted by the position, is impossible because of lack of data. Some few professors do receive at times large fees for expert work. Others, to eke out a meager salary, do a certain amount of routine work. Still others receive something in the way of royalties on their books. An estimate of the general average addition to the income through these sources would, however, be nothing but a guess and will therefore not be attempted. It should be said, though, in regard to all such work, that it is done in addition to the regular duties and is to be looked upon as that much extra labor accomplished oftentimes by taking time from much needed vacation periods.

Looking back over the above figures, it is seen that the average pecuniary attraction in the field of state university work is \$2,315 per year plus an indefinite amount that may be made by extra work. It is further seen that this sum is increasing, but at such a slow rate as to leave it an open question as to whether the increase is keeping pace with the increased cost of living. In comparison with the salaries or incomes of men of like training, age and experience in other professional lines such as law, medicine, engineering, etc., it is small, being perhaps not more than one third or one fourth as much. Some of this great difference might be accounted for by the fact that the university man enjoys longer vacations; but, assuming that no work at all is done during the time the university is not in session, and that the vacation time includes one fourth of the year, the salary of the professor would still be small in comparison with that of other professional men. In making these comparisons, it will possibly be objected by some that the average of the whole number of professors is compared with the incomes of the more successful men in other lines. To this it may be said that the salaries of all professors are not so compared. These eight universities are all large and rich institutions. Were one to collect statistics of the 150 to 200 small colleges in this region where the salaries are far lower than in the state universities, the general average professorial salary would undoubtedly drop to less than \$1,800. It must be borne in mind then that it is entirely fair to compare the salary of the state university man with that of the more successful men in other lines.

In very intimate relation with the income to be expected is the cost of preparation. It is doubtful if in any other line so much is spent in preparing for the work. After completing the four years undergraduate course the aspirant for professorial honors must spend at least two or three years in graduate work in some large university. On completing this he will be fortunate if he obtains even an assistant professorship. More usually he becomes an assistant or instructor at \$600 to \$700 a year.

The manner of living required in any position is also closely related to income received. Here, too, the professor has nothing to his advantage, for he is compelled to keep up appearances. He must dress well, and his house must be in a good neighborhood. In order to meet other men in his line he must attend the meetings of technical societies, where these men come together. Finally he is supposed to be a patron of the arts and sciences and the owner of a fine library, all of which costs money.

The sentimental side of the question, the compensations coming from love of the work, seeking for truth, pursuit of ideals, in short, the things that are worth more than money, the authors will not discuss, feeling that it would be without the scope of the paper. They do not wish to be understood, however, as taking so sordid a view as to place money compensation above everything else. Still, the subject can not be left without this reflection: other professions also have their ideals. Because the lawyer or surgeon or engineer receives more salary, it scarcely follows that he has no ideals, does not love his work and takes no thought of service to his fellow men. Can it be shown that these are not worth as much as the ideals of the teacher? If it can not, it follows that the teacher pays too high a price for the privilege of following his chosen work.

Finally, one other question will be raised. Does not the low salary exert an influence on the kind of men who go into the profession of university teaching? It is sometimes flatly stated that the best men do not enter the profession because of this fact. This point, also, the authors, who are just entering the professorial ranks themselves, obviously do not want to discuss, hoping that in presenting the facts of the situation they have contributed their share and made the way easier for wiser minds to follow.

NATURE AND MAN.*

BY EDWIN RAY LANKESTER, M.A., HON. D.SC., F.R.S.,

HON. FELLOW OF EXETER COLLEGE, DIRECTOR OF THE NATURAL HISTORY DEPARTMENTS OF THE BRITISH MUSEUM, LATE LINACRE PROFESSOR IN THE UNIVERSITY OF OXFORD.

IT is the pride of our ancient universities that they are largely, if not exclusively, frequented by young men of the class who are going to take an active part in the public affairs of the country—either as politicians and statesmen, as governors of remote colonies, or as leaders of the great professions of the church, the law and medicine. It would seem, then, that if these universities attached a greater, even a predominant, importance to the studies which lead to the knowledge and control of nature, the schools would follow their example, and that the governing class of the country would become acquainted with the urgent need for more knowledge of the kind, and for the immediate application in public affairs of that knowledge which exists.

It would seem that in Great Britain, at any rate, it would not be necessary, were the universities alive to the situation, to await the pressure of democracy, but that a better and more rapid mode of development would obtain; the influential and trusted leaders of the community would set the example in seeking and using for the good of the state the new knowledge of nature. The world has seen with admiration and astonishment the entire people of Japan follow the example of its governing class in the almost sudden adoption of the knowledge and control of nature as the purpose of national education and the guide of state administration. It is possible that in a less rapid and startling manner our old universities may, at no distant date, influence the intellectual life of the more fortunate of our fellow citizens, and consequently of the entire community. The weariness which is so largely expressed at the present day in regard to human effort—whether it be in the field of politics, of literature, or of other art, or in relation to the improvement of social organization and the individual life—is possibly due to the fact that we have exhausted the old sources of inspiration, and have not yet learnt to believe in the new. The ‘return to nature,’ which is sometimes vaguely put forward as a cure for the all-pervading ‘taedium’ of this age, is perhaps an imperfect expression of the truth that it is time for civilized man not to return to the ‘state of nature,’ but to abandon his retrospective

* Concluding part of the Romanes Lecture, delivered in the Sheldonian Theatre, Oxford, on June 14, 1905.

attitude and to take up whole-heartedly the kingdom of nature which it is his destiny to rule. New hope, new life will, when he does this, be infused into every line of human activity: art will acquire a new impulse, and politics become real and interesting. To a community which believes in the destiny of man as the controller of nature, and has consciously entered upon its fulfillment, there can be none of the weariness and even despair which comes from an exclusive worship of the past. There can only be encouragement in every victory gained, hope and the realization of hope. Even in the face of the overwhelming opposition and incredulity which now unhappily have the upper hand, the believer in the predestined triumph of man over nature can exert himself to place a contribution, however small, in the great edifice of nature-knowledge, happy in the conviction that his life has been worth living, has counted to the good in the imperishable result.

If I venture now to consider more specifically the influence exercised by the University of Oxford upon the welfare of the state and of the human community in general, in view of the conclusions which have been set forth in what has preceded, I beg to say that I do so with the greatest respect to the opinions of others who differ from me. When I say this I am not using an empty formula. I mean that I believe that there must be many here present who are fair-minded and disinterested, and have given special attention to the matter of which I wish to speak, and who are yet very far from agreeing with me. I ask them to consider what I have said, and what I have further to say, in the same spirit as that in which I approach them.

It seems to me—and when I speak of myself I would point out that I am presenting the opinions of a large number of educated men, and that it will be better for me to avoid an egotistical attitude—it seems to us (I prefer to say) that the University of Oxford by its present action in regard to the choice and direction of subjects of study is exercising an injurious influence upon the education of the country, and especially upon the education of those who will hereafter occupy positions of influence, and will largely determine both the action of the state and the education and opinions of those who will in turn succeed them. The question has been recently raised as to whether the acquirement of a certain elementary knowledge of the Greek language should be required of all those who desire to pursue their studies in this university, and accordingly whether the teaching of the elements of this language should form a prominent feature in the great schools of this country. It seems to us that this is only part of a much larger question; namely, whether it is desirable to continue to make the study of two dead languages—and of the story of the deeds of great men in the past—the main if not the exclusive matter to which the minds of the youth of the well-to-do class are directed by our schools and universities. We have come to the conclusion that this form of educa-

tion is a mistaken and injurious one. We desire to make the chief subject of education both in school and in college a knowledge of nature as set forth in the sciences which are spoken of as physics, chemistry, geology and biology. We think that all education should consist in the first place of this kind of knowledge, on account of its commanding importance both to the individual and to the community. We think that every man of even a moderate amount of education should have acquired a sufficient knowledge of these subjects to enable him at any rate to appreciate their value, and to take an interest in their progress and application to human life. And we think further that the ablest youth of the country should be encouraged to proceed to the extreme limit of present knowledge in one or other branch of this knowledge of nature so as to become makers of new knowledge, and the possible discoverers of enduring improvements in man's control of nature. No one should be educated so as to be ignorant of the importance of these things; and it should not be possible for the greatest talent and mental power to be diverted to other fields of activity through the fact that the necessary education and opportunity in the pursuit of the knowledge of nature are withheld. The strongest inducements in the way of reward and consideration ought, we believe, to be placed before a young man in the direction of nature-knowledge rather than in the direction of other and far less important subjects of study.

In fact, we should wish to see the classical and historical scheme of education entirely abandoned, and its place taken by a scheme of education in the knowledge of nature.

At the same time let me hasten to say that few, if any of us—and certainly not he who now addresses you—would wish to remove the acquirement of the use of languages, the training in the knowledge and perception of beauty in literary art, and the feeding of the mind with the great stories of the past, from a high and necessary position in every grade of education.

It is a sad and apparently inevitable accompaniment of all discussion of this matter that those who advocate a great and leading position for the knowledge of nature in education are accused of desiring to abolish all study of literature, history and philosophy. This is, in reality, so far from being the case that we should most of us wish to see a serviceable knowledge of foreign languages, and a real acquaintance with the beauties of English and other literature, substituted for the present unsuccessful efforts to teach effectively either the language or literature of the Greeks and Romans.

It should not be for one moment supposed that those who attach the vast importance which we do to the knowledge of nature imagine that man's spirit can be satisfied by exclusive occupation with that knowledge. We know, as well as any, that man does not live by bread

alone. Though the study of nature is fitted to develop great mental qualities—perseverance, honesty, judgment and initiative—we do not suppose that it completes man's mental equipment. Though the knowledge of nature calls upon, excites and gratifies the imagination to a degree and in a way which is peculiar to itself, we do not suppose that it furnishes the opportunity for all forms of mental activity. The great joys of art, the delights and entertainment to be derived from the romance and history of human character, are not parts of it. They must never be neglected. But are we not justified in asserting that, for some two hundred years or more, these 'entertainments' have been pursued in the name of the highest education and study to the exclusion of the far weightier and more necessary knowledge of nature? 'This should ye have done, and yet not left the other undone,' may justly be said to those who have conducted the education of our higher schools and universities along the pleasant lines of literature and history, to the neglect of the urgently-needed 'improvement of natural knowledge.' Nero was probably a musician of taste and training, and it was artistic and high-class music which he played while Rome was burning: so too the studies of the past carried on at Oxford have been charming and full of beauty, whilst England has lain, and lies, in mortal peril for lack of knowledge of nature.

It seems to be beyond dispute that the study, firstly of Latin, and much more recently of Greek, was followed in this university and in grammar schools, not as educational exercises in the use of language, but as keys to unlock the store-rooms—the books—in which the knowledge of the ancients was contained. So long as these keys were needed, it was reasonable enough that every well-educated man should spend such time as was necessary in providing himself with the key. But now that the store-rooms are empty—now that their contents have been appropriated and scattered far and wide—in all languages of civilization, it seems to be merely an unreasoning continuation of superannuated custom to go on with the provision of these keys. Such, however, is the force of habit that it continues: new and ingenious reasons for the practise are put forward, whilst its original object is entirely forgotten.

In the first place, it has come to be regarded as a mark of good breeding, and thus an end in itself, for a man to have some first-hand acquaintance with Latin and Greek authors, even when he knows no other literature. It is a fashion, like the wearing of a court dress. This can not be held to justify the employment of most of the time and energy of youth in its acquirement.

A second reason which is now put forward for the practise is that the effort and labor expended on the provision of these keys—even though it is admitted that they are useless—is a wonderful and incomparably fine exercise of the mind, fitting it for all sorts of work. A

theory of education has been enunciated which fits in with this defence of the continued attempt to compel young men to acquire a knowledge, however imperfect, of the Latin and Greek languages. It is held that what is called 'training the mind' is the chief, if not the only proper, aim of education; and it is declared that the continuation of the study of those once useful, but now useless, keys—Latin and Greek—is an all-sufficient training. If this theory were in accordance with the facts, the conclusion in favor of giving a very high place to the study so recommended would be inevitable. But the facts do not support this theory. Clever youths are taken and pressed into the study of Greek and Latin, and we are asked to conclude that their cleverness is due to these studies. On the other hand, we maintain that though the study of grammar may be, when properly carried out, a valuable exercise, yet that it is easily converted into a worthless one, and can never in any case take the place of various other forms of mental training, such as the observation of natural objects, the following out of experimental demonstration of the qualities and relations of natural bodies, and the devising and execution of experiment as the test of hypothesis. Apart from 'training' there is the need for providing the mind with information as well as method. The knowledge of nature is eagerly assimilated by young people, and no training in mental gymnastics can be a substitute for it or an excuse for depriving the young of what is of inestimable value and instinctively desired.

The prominence which is assigned to a familiarity with the details of history, more especially of what may be called biographical history, in the educational system favored by Oxford, seems to depend on the same causes as those which have led to the maintenance of the study of Greek and Latin. To read history is a pleasant occupation which has become a habit and tradition. At one time men believed that history repeats itself, and it was thought to be a proper and useful training for one who would take part in public affairs to store his mind with precedents and picturesque narratives of prominent statesmen and rulers in far-off days and distant lands. As a matter of fact it can not be shown that any statesman, or even the humblest politician, has ever been guided to useful action by such knowledge. History does not repeat itself, and the man who thinks that it does will be led by his fragmentary knowledge of stories of the past into serious blunders. To the fashionable journalist such biographical history furnishes the seasoning for his essays on political questions of the day. But this does not seem to be a sufficient reason for assigning so prominent a place in university studies to this kind of history as is at present the case. The reason, perhaps, of the favor which it receives, is that it is one of the few subjects which a man of purely classical education can pursue without commencing his education in elementary matters afresh.

It would be a serious mistake to suppose that those who would give a complete supremacy to the study of nature, in our educational system, do not value and enjoy biographical history for what it is worth as an entertainment; or further, that they do not set great value upon the scientific study of the history of the struggles of the races and nations of mankind, as a portion of the knowledge of the evolution of man, capable of giving conclusions of great value when it has been further and more thoroughly treated as a department of anthropology. What seems to us undesirable is, that mere stories and bald records of certain peoples should be put forward as matter with which the minds of children and young men are to be occupied, to the exclusion of the all-important matters comprised in the knowledge of nature.

There are, it is well known, not a few who regard the present institution of Latin and Greek and so-called history, in the preeminent place which they occupy in Oxford and the great schools of the country, as something of so ancient and fundamental a character that to question the wisdom of that institution seems an odious proceeding, partaking of the nature of blasphemy. This state of mind takes its origin in a common error, due to the fact that a straightforward account of the studies pursued in the university during the last five hundred years has never been written. Our present curriculum is a mere mushroom growth of the last century, and has no claim whatever to veneration. Greek was studied by but a dozen or two specialists in Oxford two hundred and fifty years ago. In those days, in proportion to what had been ascertained in that subject and could be taught, there was a great and general interest in the university in the knowledge of nature, such as we should gladly see revived at the present day. As a matter of fact, it is only within the last hundred years that the dogma of compulsory Greek, and the value of what is now called a classical education, has been promulgated. These things are not historically of ancient date; they are not essentials of Oxford. We are therefore well within our right in questioning the wisdom of their continuance in so favored a position, and we are warranted in expressing the hope that those who can change the policy of the university and colleges in this matter will, at no distant day, do so.

It is sometimes urged that Oxford should contentedly resign herself to the overwhelming predominance given to the study of ancient elegance and historic wisdom within her walls. It is said that she may well be reserved for these delightful pursuits, whilst newer institutions should do the hard work of aiding man in his conquest of nature. At first sight such a proposal has a tempting character: we are charmed with the suggestion that our beautiful Oxford should be enclosed by a ring fence and cut off for ever from the contamination of the world. But a few moments' reflection must convince most of us that such a treatment of Oxford is an insult to her and an impossibility. Oxford

is not dead. Only a few decades have passed—a mere fraction of her lifetime—since she was free from the oppression of grammar-school studies, and sent forth Robert Boyle and Christopher Wren to establish the new philosophy of the invisible college in London. She seems, to some of us, to have been used not quite wisely, perhaps not quite fairly, in the brief period which has elapsed since that time. Why should she not shake herself free again, and give, hereafter, most, if not the whole, of her wealth and strength to the urgent work which is actually pursued in every other university of the world as a chief aim and duty?

The fact that Oxford attracts the youth of the country to her, and so determines the education offered in the great schools, is a sufficient answer to those who wish to perpetuate the present employment of her resources in the subvention and encouragement of comparatively unimportant, though fascinating (even too fascinating), studies, to the neglect of the pressing necessary knowledge of nature. Those who enjoy great influence in the affairs of the university tell us with pride that Oxford not only determines what our best schools shall teach, but has, as a main preoccupation, the education of statesmen, pro-consuls, leaders of the learned professions, and members of parliament! Undoubtedly this claim is well-founded, and its truth is the reason why we can not be content with the maintenance by the university of the compulsory study of Greek and Latin, and the neglect to make the study of nature an integral and predominant part of every man's education.

To return to my original contention—the knowledge and control of nature is man's destiny and his greatest need. To enable future leaders of the community to comprehend this, to perceive what the knowledge and control of nature are, and what are the steps by which they are gained and increased, is the duty of a great university. To neglect this is to retard the approach of well-being and happiness, and to injure humanity.

I beg, finally, for toleration from those who do not share my opinions. I am well aware that they are open to the objection that they partake more of the nature of dreams of the future than of practical proposals. That, perhaps, may be accepted as my excuse for indulging in them on such an occasion as the present. There are, and always have been, dreamers in Oxford, and beautiful dreams they have dreamed—some of the past, and some of the future. The most fascinating dreams are not, unfortunately, always realized; but it is sometimes worth while to tell one's dream, for that may bring it a step nearer to 'coming true.'

GENERAL EDUCATION FOR ENGINEERS.

BY PROFESSOR CHAS. D. MARX,
STANFORD UNIVERSITY.

THERE has been of late years a large increase in the number of students of engineering in our colleges and universities. An investigation made by Professor Raymond, of the Iowa State University, shows that the attendance in arts and science courses has increased in four years 15 per cent., in engineering courses 102 per cent. This tendency on the part of the young men to take up the study of the more practical lines of work in preference to the so-called more liberalizing studies is viewed with grave concern by some. 'Are we to be merely a nation of shopkeepers and engineers?' has been asked from this platform. While not sharing the fear implied in this question, I must admit that because of the tendency of the young men of the country to take up engineering studies, the proper training of the engineer is a matter of vital importance to the commonwealth. The extent to which engineering enters into some of the most vexing problems of our national and municipal life is perhaps fully realized only by men who have an engineering training. The correct solution of these problems can in many cases be given only by engineers; but these must be men trained on broad lines. The charge is brought not infrequently that the professional structure which we rear on the foundation laid in our public schools is a narrow one, lacking in windows from which to gain the necessary outlook for surveying even one's own field, let alone that of one's neighbor. The charge is well founded, but may with equal justice be brought against students in other lines of work.

The graduate from a high school who takes up engineering studies should be required to broaden his intellectual horizon before beginning his professional work. The difficulty of bringing this about is great, and the introduction of the elective system has certainly not helped matters. The tendency toward early specialization is constantly increasing, and one-sided narrow linguists, historians and scientists are as much a menace to the commonwealth as one-sided engineers. For it must be borne in mind that the work which the engineer is called upon to do is in the world, implies contact with men and things and is in its nature broadening. It is cultural in the best sense of the word, and must, therefore, react on him. This does not hold true to the same extent for the other lines of work mentioned. In a democracy

it is of the highest importance that every man realize that the noble duties of citizenship devolve upon him, that he has responsibilities other than those of merely providing the daily bread for himself and his. We have a community of interests only as long as we have common points of contact; we have the latter only as we have a broad common subsidiary training.

Admitting that the high school course of the embryo engineer should be rounded out with additional work in language, science, history and economics, the question arises where shall this knowledge be acquired?

For the training of our engineers we have, broadly speaking, two types of schools in this country—technical schools pure and simple, such as the Massachusetts Institute of Technology, the Rensselaer Polytechnic Institute and others, and engineering departments either in our colleges of engineering and mechanic arts, or in our universities. I group the last two named, because in both of them some of the general culture studies mentioned as necessary for the broadening of the engineer's training are presented merely from the standpoint of the specialist.

In the schools of the first type there is a recognition of the fact that the general culture courses must be adapted to the needs of the technical student. There is a frank acknowledgment that these broadening studies may be made to serve a useful purpose, even when they are not an end to themselves, and that this does not detract from their value. The fact is recognized by teachers of these subjects in purely technical schools, that because the student is to be a specialist in some line of engineering, he can not at the same time be a specialist in ancient and modern languages, in history, economics and the pure sciences. From the engineer's standpoint, as regards the acquirement of this supplementary general training, there is much to be said in favor of the autonomy of technical schools. This, too, is the view at which the German Society of Engineers has arrived. As in this country, there has been a very large increase in the number of students in the technical courses in Germany. So large has this increase been that for a time at least foreign students in mechanical engineering were barred at Berlin. Existing institutions are still so crowded that the establishment of new technical schools is contemplated. The suggestion was made, that in those places where universities existed and technical schools were needed, the latter might well be incorporated in the university. At a meeting held in Munich in September, 1904, which was attended by representative teachers from the technical schools, the universities, the preparatory schools and by engineers of standing in practise, the following resolution was submitted: "It is not desirable in place of establishing new technical high schools, to add technical facul-

ties to existing universities, because both institutions differ in their character and method of instruction." Those assembled, after laying stress on the fact that members of the engineering profession should be judged by the same educational standards as other educated professional men, adopted the above resolution in substance, but, in deference to the university men, the last clause of the resolution was not emphasized; I think, though, that the correctness of the statement is generally admitted.

In spite of these conclusions we find in this country at least a tendency in the opposite direction. In our strongest state universities and in others built on private foundations, we find either engineering departments or colleges. The union of Harvard University and the Institute of Technology is under consideration. Something can, therefore, undoubtedly be said in favor of this arrangement. Of course, the presence of the 'sublimated tinker' in the university has been deprecated, but not by the leaders of educational thought in America.

It is recognized that the presence of a body of hard working, straight thinking young men in a university, even if they intend to make some practical use of their education, is a good antidote for intellectual snobbishness. On the other hand, it must be conceded that the technical student, too, is benefited by being thrown in contact with men in other lines of work, many of which have no direct practical application. Students become acquainted with one another, learn to appreciate one another's point of view, and mutual respect and goodwill result.

While fully recognizing the benefits which come in a general way to the engineering student from this environment, it must, nevertheless, be asserted that, as our universities in their development follow in the wake of the German universities, they too, like them, become unfitted for doing the general culture work, not only for engineering students, *but for all students*. The tendency toward specialization in subjects and subdivisions of subjects leads to the offering of many undoubtedly valuable courses. But they are courses for the specialist, fitted for his needs, and capable of being understood by but few. The giving of general culture courses is discouraged; and there is some justification, as long as the aim of many so-called students is merely to get hours enough to graduate. The summing up of the results in any given line of work and its presentation, so that the non-specialist may get a general view of the field, are dangerous, because of the 'little learning' thus imparted, which, of course, is 'a dangerous thing.'

Even in poetry: "The learned guardians of these treasures insist that they can not be appreciated unless there has been much preliminary wrestling with a 'critical apparatus' and much delving among 'original sources.'"

If the engineering student is to acquire that general cultural training the lack of which is often made a reproach to him, and if the technical school is to find its full development in the university and not as a separate institution, then the university must make provision for this much needed instruction, unless it can be provided for all students elsewhere. It will and should lead to the giving of courses differing in character and differing in method of presentation from those now offered to the specialist, but they may be none the less both useful and inspiring.

It is necessary for the specialist to know the methods of study of his specialty; it is necessary for the general student to know the results of such study. Therefore, to be both useful and inspiring, such courses must be given by men who are past masters in their line of work.

This will be held by many to be a plea in favor of superficiality, and if getting a general view of another line of work is superficiality, why it is a superficiality of which many specialists might well be guilty. The objectors to this kind of general knowledge lose sight of the fact that no one who is thoroughly grounded in his own line of work is likely to be damaged intellectually by such general information. Conscious of the limitations of his knowledge in his own field after years of study, he is not likely to assume that he has mastered another field as the result of a general lecture course in that subject. The chances are, however, that the effect will be to broaden his views, to enlarge his sympathetic understanding of the work of the specialist and to create an atmosphere of mutual respect and consideration for one another's line of work. In order to give such courses there must be an increase in the teaching force in the various lines of work in our universities. Certainly the work of the specialist, upon which progress in any given field depends, must not be stinted for the sake of the seeker after general knowledge. This is one reason why consolidation of the technical school with the university, if the tendency toward specialization in the latter continues, can not bring about economy in instruction. Justification for such consolidation must be sought elsewhere, as shown above. Not only engineering students, but all students pursuing special studies in a university need general courses, and though it may not be possible for us to become a nation of engineers, it is eminently desirable that all educated persons should have at least some general knowledge of engineering. Surely he can not be held to be truly educated who is ignorant of the conditions which surround him, of the methods by which his daily intellectual and physical needs are met. This training is not for the purpose of making more half-baked experts, prepared to pass snap judgments on matters beyond their ken, but for the purpose of teaching them the importance of solving the problems of manufacture, distribution and transportation correctly. These problems trans-

lated stand for the providing of material and mental food for the masses, the betterment of their conditions of living, for healthy homes, for the pure air, the pure earth, the pure water of the sanitarian, for the intellectual growth which is made possible by freeing man from soul- and mind-killing drudgery. Public service is what engineering stands for, and perhaps the cultural effect of such work will be admitted. The work is as altruistic as that of the physician, as that of the minister. For the spirit of acquisition, for corporate greed the profession of engineering is not responsible. There has been no fear expressed of our becoming a nation of physicians or even of lawyers. The danger to the commonwealth from a superabundance of lawyers may be greater than that from a superabundance of engineers. There need be no danger from either if the lawyers and engineers are men of the right stamp.

Moral integrity does not necessarily go with cultural training so called. Men with the broadest of cultural training may be found in the pay of corporations striving for illegal franchises. Political bosses with no cultural training may be found abetting them. Engineers may probably be called upon to carry out the work. The danger to the community lies not in the character of the work, but in the character of the man; and a nation is in no danger even if it be largely a nation of engineers, as long as these men are men of character. Such men our engineering schools are trying to train and send out into the world. Some of them as yet may be lacking in general training, but no one feels this shortcoming more keenly than these very men. If others were as conscious of their own shortcomings, of their woful lack of knowledge of the engineering of to-day, it would be well indeed. That these engineers, sent out by our schools, are making their presence felt in the world can not be gainsaid; that they have contributed to the mental and moral uplifting of this nation, no one who thinks deeply will deny.

QUACKERY.*

BY DUDLEY F. SICHER,

YALE UNIVERSITY.

WHAT impresses one in reviewing the literature, is the extent and ancient origin of quackery, and the ineffectual fight against it. Eight pages of the 'Index Catalogue of the Library of the Surgeon-General's Office' are taken up with a bare list of books, pamphlets and addresses, exploiting quackery or aiming at last to deal it the long-evaded death-blow. As early as 1605 we find good Dr. Guybon riding out to the charge with 'Beware of Pickpockets. Or a Caveat to sick folkes to take heede of unlearned phisitions and unskilfull chyirurgians'; but neither this heavy artillery nor the unbroken fire of subsequent English doctors could daunt the brave hosts of mountebanks who have marched on through the decades, healing the well and making the sick remember their pains. English sovereigns down through Queen Anne continued to exercise the 'Royal Touch'; in 1665 one Valentine Greatrakes successfully laid claim to this same healing power; a certain Dr. John Ward gloriously humbugged King George the Second; somewhat later, Elisha Perkins (1741-1799), of Norwich, Conn., son and father of Yale graduates, enthralled two continents—laity and physicians alike—with his Metallic Tractors. Then, in the early nineteenth century, *floruit* (on pickings estimated at fifteen thousand pounds per annum) suave John St. John Long, of whom Dr. Francis R. Packard says: 'The list of his patients reads like a directory to the fashionable quarter of London.' These are only a few, the more gigantic, vermin from out the dirty swarm. Everywhere and everywhen we meet with exploiters of secret remedies, unfailing panaceas, advanced treatment (*sic*), and all other alleged cures which stand as quackery (in the words of Dr. A. T. Schofield) 'when used by unqualified men, or if they are advertised or puffed unprofessionally, or connected with any fraud or wilful exaggeration.' But it was left for the modern era to furnish that strangest chapter—of an enormous spread of quackery, along with progress in scientific medicine and the growth of education. Berlin, capital city of the world's least hysterical people, reports an increase of 1,600 per cent. in the number of resident quacks since 1874. For England the roll-call is answered by *The British Medical Journal*

* Paper read before the Yale Biological Club, March 23, 1905.

thus: "John Bull, for all his boasted common sense and hatred of humbug, is still more quack-ridden than any member of the human family except his cute Cousin Jonathan." And as for 'cute Cousin Jonathan's' America—Champe S. Andrews, counsel exclusively retained by the Medical Society of the County of New York to expose medical frauds, is authority for the estimate that in New York City alone there are, against six thousand regular practitioners, twenty thousand quacks. In view, therefore, of its ancient origin, persistence and recent spread, it is not enough to account for quackery on the basis of the Irishman's observation that 'there were always fools in this world; in fact, there must have been some lying around, waiting for the world to begin.' . . . Rather is quackery a well-defined phenomenon, grounded on effective causes. Why it should exist at all, how the worst empiric enjoys custom, often from the cultured, and what measures may be aimed against this social evil are questions which invite examination.

At the very bottom lies the insufficiency of orthodox medicine. Not even the long strides of the last century have brought it to the full rank of an exact science. The doctor must stand by, and, only half intelligently, assist *vis mediatrix naturæ*; until quite recently at least, he could in no wise control her, like the chemist and the engineer. Rather has he been somewhat in the position of the philosopher, who must work, more or less, in the mist, and between uncertain boundaries. That explains not only the early rites of the medicine-man, but the whole belief in proffered panaceas. The alchemist sought the *one* agent which should turn all the baser metals into gold; the philosopher still seeks the *one* truth which shall uncover heaven's mysteries. Is it not equally natural that men should lend a credulous ear to every announcer of the much-sought cure-all?

Then, to this prospect of a universal medicine we must add the call of the new—always so strong in unsettled provinces. I mean, that something in a wide-awake community or a growing sphere of knowledge which sees salvation in the novel. We recognize this tendency in the fad-worship of Indian occultists, in the rapid succession of new systems of philosophy, in the passing dominance of scientific theories and in the brief vogue of methods in therapeutics. Out of this same phenomenon grows the ready acceptance of Quack A's 'Absolutely New Method of Treatment. No Drugs. No Knife' or Empiric B's 'Radical Invention. All Diseases banished without Fail.'

Remember, moreover, the omnipresence of disease, its agonies and the common dread of it. With this monster the doctor is asked to triumphantly close, whereas he can only pelt it at a distance. When the suit is lost, it is usually the law, not the lawyer, on which the vials of bitterness are poured; how seldom comes a fatal sickness for whose

sad issue some doctor isn't blamed! Consider what large proportion of quack remedies is for cancer and incurable female complaints: 'The doctors all gave me up,' writes Figment A; 'I know you have tried the physicians in vain,' blares Humbug Z. It is here, upon affections which scientific medicine confesses it can not help, and also upon maladies born of shrewd playing on one's fear of disease, that the empiric waxes fat. Why shouldn't the invalid take heart and believe? Often the loud assurances act as anodyne; occasionally, they even effect a cure. Or, how can the neuropath and the valetudinarian escape the hypnotism of the quack's terrorizing? For the quack wields a deadly weapon in what psychiatrists recognize as 'the power of the unconscious mind over the body.' He forces credence by calculated emphasis and careful insinuation. He works you into a mood where the mind 'autosuggests,' at times the throwing off of a disease, more usually, belief in a cure or the assumption of imaginary sickness. It is, of course, a familiar fact that the typical medical student goes through the whole calendar of diseases. 'Autosuggestion' is the technical word for this mysterious process; it is what the hypnotist employs, but never to stronger purpose than the superior quack.

Given, on the one hand, this set of causes—the limitations of scientific medicine, the pain and dread of disease, and the power of 'autosuggestion,' and, on the other hand, depraved humanity, hard-driven in the struggle for existence, but cunning in the knowledge of men, and you have the essential parts which, with a few minor pieces, make up into the smooth engine of quackery.

Every newspaper and magazine reader knows how well the quack makes capital out of the limitations of scientific medicine. When the regular practitioner is puzzled, he admits, or when the case transcends cure, he gravely shakes his head. The quack now steps in and begins where the other left off. He 'especially solicits obstinate cases'; 'welcomes the doubter and the skeptic.' He realizes the persuasive value of bold assertion and big promises; how the exclamation-point and the period may appeal more strongly than the careful interrogations of the honest physician. He talks much of the 'thousands who testify to its success,' and thus swaggers himself into the confidence of the poor invalid, whom the doctors, in good conscience, must acknowledge beyond their aid. With so many broken-hearted witnesses of the insufficiency of evolved therapeutics, almost any knave can steal a living by brazenly opposing some dominant practise in medicine—as surgery or the use of drugs. These 'methods' nowadays have a pseudo-physiological basis; with a speciousness it is often hard to confute, tracing all disease back to 'inside nerves,' 'sluggish circulation,' and the like, they impress by the sweep of their assertion and their tone

of scientific explanation. It is scant wonder that the pompous logic moves the incurable, whom neither 'knife' nor 'drugs' can save, vapid ladies of fashion, and the smart shallowpate of 'a little learning.'

But the quack does not depend solely on the agony of disease and the inability of scientific medicine completely to cope with it. He swells the total of victims by magnifying minor ailments and imposing imaginary ones. By cooked mortality statistics he frightens the individual into noticing and treating some indisposition, which the family doctor, generally to no effect, laughingly pronounces not worth bothering about; and then, conversely, by the same process of 'autosuggestion,' a few months' trustful application of the vaunted nostrum brings back the patient's assurance and draws his mind from the ailment. Or, the quack will address himself to the social weakling, and by skilful insistence ascribe failure to 'pelvic disease,' 'nerve exhaustion,' 'and all that,' as Pope says. The poor numskull and the unattractive girl are quick to seize the hope; yes, not deficient endowments, but dissipation or insidious disease has caused their defeat—good Doctor Slyfox, A.B., M.D., member of six medical institutes and nineteen learned societies, will raise them out of the slough. Again, along this same line of 'autosuggestion,' the quack enlarges his levée by invitations to self-diagnosis. With a subtle mastery of rhetoric he sets forth such an array of 'symptoms' that no diligent pupil need feel he is cast into outer darkness. Follow the fraudulent guide—and yesterday you had consumption; to-day varicocele fastens you in its fangs; to-morrow your kidneys will be fatally weak—and so the falsehood runs.

It may be supposed that caution so palpably absurd would rouse more ridicule than credence. But the hypochondriac, the neuropath, the person of weak judgment (ignorance is no indispensable factor) do not reason in such matters. We are almost led to accept as genuine the testimonial in which it is written, 'I had tried *all* the medicines.' With such people, the high-sounding swagger, pretended altruism and adroit description of past achievements drown out the voices of common sense. Even the normal reader can hardly turn to the quack's advertisement day after day, in a non-critical mood, without experiencing at least a passing influence. The fulsome notices of books and plays, in fact, the whole psychology of advertising, rest on this very principle of 'autosuggestion.' So all the quack requires is a hearing. Given a hook-and-line and a pond of fish, he understands baiting too well, not to land a heavy catch.

Of course, there are contributory factors. The quack has other resources. Notable is his use of that universal weakness, the basis of get-rich-quick schemes and the shopper's bargain,—I mean the fascination of getting something for nothing. The doctor will send you a heavy bill on the first of January or July; the quack offers: 'No Pay

till Cured,' 'Send for Sample Bottle. Free.' How the charlatan manages never to lose out would make a realistic novel in itself. Suffice it to indicate his crafty reliance on creating 'the habit'; one bottle with its high content of alcohol will inevitably 'tone you up,' or admixed opiates may be the 'irresistible pain-killer,' to which you will want to turn again. Quacks are among the largest customers of wineries and distilleries. Recent analyses (by the Massachusetts State Board of Inquiry) have developed the possibility that the druggist's show-case may hold more alcohol than the cellar of the saloon opposite, and many a temperance advocate, quite unknowingly, has drawn inspiration for his lecture from that after-dinner glass of nerve tonic or stomach bitters.

With such instruments at his disposal, restrained by no Hippocratican oath or sacred reputation, left free to run riot, by criminally lax laws, deliberately dead-lettered, the *genus* Quack swarms out over the land. Its species are unnumbered, being marked by every device deceitful ingenuity can conceive. Psycho-therapeutics and knowledge of human nature constitute the quack's entire outfit; all he really needs is moral atrophy and the instincts of a cheap drummer. Such is the baleful etiology of medical quackery.

If confirmation of this diagnosis is desired, it may be sought in the recent spread of quackery and its especial vogue in America. Paradoxical as it sounds, the growth of education, while compelling the quack to improve his methods, has greatly extended his field. Formerly, he seldom worked farther than his voice or circular might carry; now, every literate is a potential victim. His wares are displayed in almost every piece of print that strikes your eye; for the publisher and 'the press' he has subsidized and suborned. So-called family magazines (messes of popular fiction and indecent advertisements) are distributed gratis at the instance and backing of the quack, for whom they are so much purchased propaganda. To the same end he sustains the whole modern plethora of magazines and newspapers. Without his lucrative patronage periodicals, representing the real excess of supply over demand, would end their artificial existence, and so, wherever there is a struggling paper, manhood slumbers and the editor accepts the proffered bribe. How else explain the significant truth that the sectarian press ranks among the worst offenders? The 'yellies,' too, depend as much upon the quack as upon scandal; and the most prosperous of them all affords the grossest example. The editorial columns of a certain evening journal will, no doubt, to-night, blare its owner's championship of the people, while almost every page invites the trust-ground toiler to hand up his savings to swindling men specialists and venders of alcoholic cure-alls. In fact, with a few notable exceptions, such as *The Outlook*, *Life* and *The New York*

Evening Post, the whole press unblushingly sprinkles its columns with the charlatan's cards. Nearly every New York daily on January 24 reported, at lengths inversely proportional to its abatement of quackery, the exposé of Dr. Henry Kane's Radium-Cure swindle; in the January 22 issue of one of the most reputable of them, I find a conspicuous advertisement of this same discomfited wonder-worker. Shameless self-interest never could have played so slavishly into the quack's hands until the growth of education made publishing a fiercely competitive business.

At the same time, not only has the growth of education placed a megaphone to the empiric's lips, but it has sensitized the public to his call. There is a wider interest in hygiene and therapeutics; people think more about their health and more readily take alarm. 'Health journals' enjoy large circulations; too often nothing more than elaborate handbills of the editor's particular book, 'system,' or hygienic contrivance, and, at best, running wild with 'hints to health' and philippics against the doctors, these magazines only succeed in leaving their readers the shuttlecock of every battledore in quackdom. Similarly, the broadcast discussion of medical problems, in response to the interests of an educated public, creates a kind of diathesis to imaginary disease. Then, vaguely bound up, perhaps, in widespread education is the modern stress of life, hysteria, high nervous tension and susceptibility to fads.

As a final (undetached) cause we must recognize the passion for untrammelled personal freedom, so characteristic of latter days, especially in England and America. It is that attitude which one writer savagely describes as 'jealously safeguarding to every citizen the sacred right of going to the devil in his own way.' Fearing to dispense undue privileges and unjust fetters, framers and executors of the law, notably in the United States, have virtually thrown open the delicate art of healing to almost any person too crack-brained or dishonest to earn an honorable living. Not only does quackery thus recruit directly, but wild-cat schools are permitted to dump upon an overcrowded profession graduates sadly lacking in capacity and training. Most of these must end up as charlatans, in much the same way as the manufacturer, shut out from the restricted trade in the genuine article, caters to the public taste with cheap and tinsel imitations; or, at best, such half-baked doctors impair the efficiency of their brotherhood and shake confidence in it. It is not bare accident that America is at once the 'home of quackery' and the 'home of the free.'

These, therefore—growth of education and the modern spirit of liberty—are the specific forces behind the recent spread of quackery; and America stands as arch-victim, just because they have been at their strongest here.

Even from the foregoing generalizations it must appear that quackery is a seated evil, which the community, in self-defense, ought promptly to weed out. Yet the roots, as we have seen, spread out so variously, that past effort has been without effect, and the future will do no better unless exceptional measures are applied. In this case, it seems, diagnosis is easier than treatment, for the social physician is blocked on every side. Surely, the requirements should be everywhere approximately as high as the better states and countries have set, yet every step towards restriction of practise, even to the safety-point, meets with wrangling opposition. The cry of paternalism is raised, and even the disinterested see in such measures only an attempt at extending the alleged 'Medical Trust.'

Quarantine is proper; government exposure of food adulteration is only right; of course, the state should protect its citizens against fraudulent investment schemes, and every enforcement of these safeguards calls out general praise. But it is ruinous paternalism to save the unwary public from unconscious alcoholism, medical extortion and dangerous malpractise!

Of the same caliber, it seems to me, is that other plea against state interference, to the effect that variance from orthodox practise is not enough to brand a method as quackery. It is urged that progress consists in dissidence, and that the traditional school has no right to sit in judgment. 'The prophet is never believed in his own country,' you know. Such argument—and it is very common—sounds too much like the prattle of those 'advanced thinkers' who would do away with the moral code on the ground that all standards are relative and arbitrary. Further, the records fail to show a single instance where scientific medicine has drawn profit from quackery, nor is the modern broad and progressive attitude likely to cheat any honest radical of an adequate hearing.

Just so long, however, as this repugnance for state interference with medical quackery obtains, it is folly to seek help in that quarter. *Existing* postal laws and statutes on fraud are themselves sufficient to blackeye quackery, and their total failure stands as a pathetic proof of the scant likelihood of ending quackery through the toils of the law. Mr. Andrews reports that a wellnigh insuperable obstacle to his vigorous work is the difficulty of obtaining witnesses; persons are rather diffident about exposing frauds of which they have been the stupid victims. Besides, even in clear cases of fraud, it is often impossible to lay hands on the real culprit; or, if caught, after paying his fine or serving his sentence, the quack can start up the old business in another section under another name; the salutary restraints of public opinion play no part with him. After all, what boots it to crush a dozen or even fifty out of the unnumbered swarm? The press will not em-

phasize the prosecutions, and so their effect is lost. Similarly, the postal department could, quite legally, I believe, stamp out the evil alone, if it dared exclude from the mails every periodical containing a single fraudulent quack advertisement; but how prove its case, and where is the administration which could survive the ensuing clatter about 'usurpation of authority' and 'freedom of the press'?

Legislation, therefore, can only be secondary to ventilation and the education of public opinion. But how educate public opinion, when its educator, the press, is itself irretrievably allied with the forces of evil?

First, obviously, such papers as have not prostituted themselves must agitate; they should expose their brothers' shame and the people's consequent losses. Editor Bok's recent appeal (in *The Ladies' Home Journal*) to the women of the land not to let their babies suck in with their milk the alcohol or opium of 'motherhood' nostrums, and to tear down from fence and barn the quack's advertisement, is the kind of measure that counts. Here, too, is a chance for those wealthy yellow journals, forever bruiting their own altruism, to whom a 'scoop' is more necessary than the quack's gold, to expose typical quacks; they make easier handling than the gas and the beef trust, and the attack, no doubt, would yield even richer sensations than the divorce court. Then, public-spirited men of all professions should everywhere organize—as has just been done in Germany—a systematic campaign against quackery. The recent example of an English workingman's society should be followed, and illuminating tracts be circulated by unions and employers. Perhaps the school boards may be free also to level a blow. I know the tendency is to overcram the curriculum, to attempt to arm the child with a petty smatter against every need in life; but if we are going to teach hygiene at all, if the possible consequences of alcohol and tobacco are to be pointed out, why not lay some stress on a curse just as extensive and no less harmful, one which rests on no natural appetite, but on ignorance and absence of forewarning? At any rate, superintendents of board of education free lectures can include in their admirable courses a few talks on quackery by such qualified experts as Champe S. Andrews, Esq.

Against measures of this sort the press hardly dares raise its voice, and effective legislation will soon follow as the expression of the popular will.

Such procedure, it is hoped, may limit the future annals of quackery, and hasten that golden age when even the doctors can almost agree with Mrs. Eddy that there is no such matter as disease.

HOW CANADA IS SOLVING HER TRANSPORTATION PROBLEM.

BY LAWRENCE J. BURPEE.

OTTAWA, CANADA.

IN Canada the main lines of transportation run east and west, much more decidedly than they do in the United States. The Dominion is, roughly speaking, a vast parallelogram, three thousand five hundred miles long by perhaps a thousand miles deep. Climatic conditions have in the past confined, and probably will continue to confine, the bulk of the population to the lower or more southerly half of the parallelogram. The problem confronting the people of Canada is, therefore, how best to provide adequate transportation facilities for a population scattered over a relatively narrow belt of country three thousand five hundred miles long. That they have already to a considerable extent solved the problem, the remarkable prosperity of the Dominion at the present time clearly shows; for transportation facilities are an essential of national prosperity in any country, and especially so in one of such formidable distances as Canada.

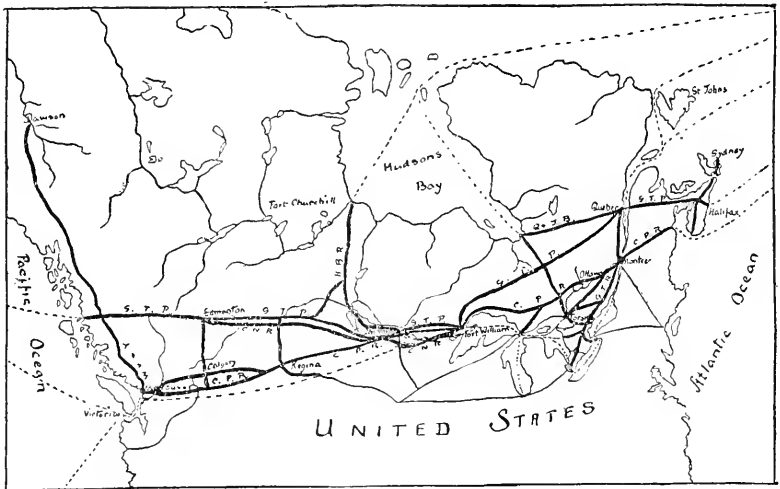
But these facilities must keep pace with the industrial development of the country, and the industrial development of Canada is rapidly outdistancing its means of transport. To bring these two great factors of national prosperity into line, and keep them there, is the question of the hour in Canada, and the statesmen of the country are devoting themselves to its solution with a largeness of view and far-sightedness which augurs well for the future of the young Dominion.

A glance at the map will show that in the facilities afforded for transportation, nature has been on the whole very kind to the people of Canada. She has provided, in the first place, an unrivaled system of water transportation extending from the Atlantic to the head of Lake Superior—almost half way across the continent; and, as if this were not enough, an alternative and shorter route is furnished from Lake Huron to the St. Lawrence, *viâ* French River, Lake Nipissing and the Ottawa. West of Lake Superior we find a system of lakes and rivers extending, with inconsiderable breaks, from the head of the Great Lakes to the foothills of the Rockies, to Hudson's Bay and to the mouth of the Mackenzie River on the extreme northern boundary of the Dominion.

While nature placed formidable obstacles in the way of Canada's first transcontinental railroad—the Canadian Pacific—both along the north shore of Lake Superior and in the Kicking Horse Pass through

the Rocky Mountains, she has provided for the country's second trans-continental a route, farther north, remarkable for its exceptionally low gradients, and including the easiest pass to be found in the whole length of the Rockies.

The natural waterways of the Dominion have been developed and improved systematically for many years past, until this great work has come to be regarded as a fixed national policy, which no government, even though it were so inclined, would have the hardihood to abandon. Up to the present time Canada has spent upon her canals over one hundred and seven millions of dollars, and is likely to expend many



TRANSPORTATION LINES OF CANADA.

times that amount in the years to come. The history of Canadian canals goes back even to the French *régime*, when small canals and locks were built to overcome the Lachine and other rapids on the St. Lawrence. These were but canals in miniature—ditches, 6 or 7 feet wide by perhaps 2½ feet deep, designed to meet the needs of the fur traders' canoes. A similar canal was constructed by the Northwest Fur Company, at Sault Ste. Marie, in the eighteenth century—the earliest progenitor of the gigantic twin canals, American and Canadian, of the present day, through which passes annually a much greater tonnage than that of the Suez canal. The 2½-foot Lachine canal of two hundred years ago has grown to a depth of 18 feet on the sill, 45 feet wide and 270 feet long, in each of five locks, the entire length of the canal with the approaches being eight and a half miles.

From the earliest history of the country the east and west trend of transportation has been marked. The first railways of the country were built to connect a handful of small towns, villages and settlements,

strung like beads on a wire along the north shore of Lake Ontario. Gradually the rails were pushed east and west; east to Montreal and the French-Canadian towns on the lower St. Lawrence, and west to the Niagara peninsula and along the north shore of Lake Erie to the international boundary at Detroit. Then, when the scattered colonies of British North America were at last confederated in the Dominion of Canada, the Intercolonial—Canada's national railroad—was built from Halifax, on the Atlantic seaboard, to Levis, opposite the city of Quebec; subsequently being extended to Montreal.

Finally, with a courage and faith in the country's future which the succeeding years have fully justified, the Canadian Pacific railway was built (subsidized with twenty-five million dollars out of the treasury of the young Dominion, and twenty-five million acres of land), and Canada at last had a railway from ocean to ocean, throughout her entire length, making accessible the vast fertile plains of the northwest, with their incalculable agricultural wealth, and providing transportation facilities between eastern Canada and the new province of British Columbia. Up to the present time Canada has expended on her railways in the form of cash subsidies, irrespective of the value of land grants, and irrespective also of the cost of the Intercolonial (\$77,000,000, including rolling stock) an aggregate—enormous in view of the comparatively small population of the country—of two hundred and forty million dollars.

When the first Canadian Pacific train crossed the prairies of western Canada, not quite nineteen years ago, that land of promise held only a handful of white settlers. To-day there are six hundred thousand, and new settlers are coming in increasing numbers every year. A few years ago men would have laughed to scorn the idea that western Canada might some day become the granary of the British empire. To-day it is accepted as a self-evident proposition, to be realized within a very few years. In 1904 this western country yielded, in spite of adverse conditions, 60,000,000 bushels of wheat valued at \$40,000,000, besides other grains worth another \$10,000,000. This year it is estimated that the wheat crop will pass the hundred million mark; and hard-headed business men, not given to idle boasting, confidently predict that within the next quarter of a century western Canada will produce half a billion bushels of wheat annually. The acreage this year under wheat will exceed four millions; but this constitutes but a fraction of the acreage actually available in Manitoba and the territories for profitable wheat raising. With an available acreage estimated at over one hundred millions, and a rapidly increasing population, he would be a bold pessimist who would deny the coming greatness of the Canadian west as a dominant factor in the world's wheat markets. Under such conditions, it is well that the government of

the Dominion rests in the hands of a strong administration, led by a statesman of commanding ability and exceptional breadth of view. Courage and wisdom to build not merely for the present were never more vitally necessary to the well-being of Canada. The government in its transportation policy is showing the same broad faith in the destiny of the country revealed by its predecessors in connection with the building of the Canadian Pacific.

The rapid development of the west, and the increasing difficulty experienced in handling the grain crops of Manitoba and the territories, made it apparent two or three years ago that provision must be made—and made at the earliest possible moment—for additional transportation facilities between eastern and western Canada. The situation was partially relieved by the construction, through the enterprise of a couple of energetic Canadians, of the Canadian Northern Railway, which provides an additional outlet from the western wheat-fields to the head of navigation at Fort William, where connection is made with the steamers running to Owen Sound, Collingwood and other ports on Lake Huron. Even this rapidly growing system has, however, only partially met the situation. The real solution of the problem is being found in the great project for building another transcontinental road across Canada from ocean to ocean.

The Grand Trunk Pacific is the fruit of the brains of two very remarkable men, Sir Wilfrid Laurier and Mr. Charles M. Hays, general manager of the Grand Trunk railway. One saw the project from the point of view of national statesmanship; the other developed it as a practical business proposition. Briefly, the agreement between the Canadian government and the Grand Trunk Pacific is this: The new transcontinental is divided into two sections. The eastern section, from Moncton, New Brunswick, to Winnipeg, *viâ* Quebec, is being built by the government at the public expense, and upon completion will be leased to the Grand Trunk Pacific for fifty years, with the privilege of renewing the lease for a further period of fifty years. The western section, from Winnipeg, *viâ* Edmonton and the Peace River Pass to Port Simpson on the Pacific, is being constructed directly by the Grand Trunk Pacific Railway Company, the Dominion government guaranteeing the bonds of the company to an amount equal to seventy-five per cent. of the cost of construction. When the entire road is completed, from Moncton, N. B., to Port Simpson, it will be operated by the Grand Trunk Pacific from ocean to ocean, and the railway will be supplemented, as in the case of the Canadian Pacific,* by lines of

* It may be noted here that the Canadian Pacific has arranged for the construction of several new vessels for their Atlantic service which are to have a guaranteed speed of twenty knots an hour and are expected to reduce the time from Merville to Rimouski to five days and four hours.

steamers plying from Quebec or Halifax on the Atlantic to Liverpool, and from Port Simpson to Japan, China and perhaps Australia. At Moncton the Grand Trunk Pacific will make connection with the Intercolonial, over which it will have running rights to Halifax and St. John.

No more forcible evidence could be presented of the keen interest now taken by Canada and the Canadian government in the adequate development of the transportation facilities of the country, than the fact that within the last year or two no less than three official commissions have been created to deal with different phases of the same wide subject. These are, the commission on transportation, the board of railway commissioners and the national transcontinental railway commission. The members of each commission are men of the highest standing, chosen because of their special knowledge and experience in regard to transportation.

The first of these commissions is charged with the duty of investigating every branch of the transportation problem in Canada. The commissioners are to study the best available rail and water routes; the improvement of lake, river and ocean ports; the improvement of the St. Lawrence route; the adjustment of freight rates; foreign competition in transportation; and other questions of a like nature. The commissioners have already accumulated a mass of invaluable data, gathered by personal examination, and supplemented by the views of practical railway and shipping men and others connected in one way or another with the transportation interests of the country. When these facts and figures have been digested, the result will be submitted to the government, with recommendations from the commission covering a broad and comprehensive plan of transportation development by rail and water, designed to meet the large needs of a rapidly growing country.

The board of railways commissioners is a permanent department of the federal government, with offices at Ottawa. The commissioners are, however, continually moving about the country, from Cape Breton to Vancouver Island, hearing and adjusting disputes of all kinds—as to freight rates, station accommodation, the distribution of rolling stock, and a host of other questions at issue between municipalities or individuals and the various railway corporations. The board is vested with very large powers, and their decisions have so far been characterized by a spirit of conciliation and common sense, which have commended them to not only the people at large, but also to the special interests affected. The decisions of the board may be overruled by the privy council, but in practise the commissioners have fortunately a free hand, and the results so far have been of immense benefit to the country. Much of the initial success of the board in the settlement of disputes between the people and the railways was due to the wide familiarity with

the questions involved, the shrewd common sense and the recognized impartiality of the first chairman of the board, Hon. A. G. Blair, formerly minister of railways and canals in the Dominion cabinet. Under his control the board was instrumental in settling, by a policy of conciliation and mutual concession, and with reasonable satisfaction to all parties, a multitude of disputes which had been sources of bitterness and irritation in the districts affected. Mr. Blair's resignation, shortly before the last Canadian elections, was felt at the time to be an irreparable loss, as his was by all odds the master mind of the commission. Fortunately the government has secured, in Mr. Justice Killam, of the Supreme Court of Canada, a successor who possesses much of Mr. Blair's shrewdness and tact, as well as the alert mind and legal knowledge of an eminent jurist.

The third of this remarkable triumvirate of transportation commissions is charged with the location and construction of the eastern half of the new Transcontinental railway.

There are to-day in Canada some 170 railways, twenty-five of which are amalgamated in the grand Trunk system and thirty in the Canadian Pacific. The rest, with the exception of the Intercolonial and the Canadian Northern, are comparatively short, local roads. The total railway mileage of the country is now about twenty thousand, of which the Canadian Pacific accounts for nearly one half, and the Grand Trunk, some 3,200 miles. Of the existing roads, the Canadian Northern is growing with the greatest rapidity. It is expected that by the coming autumn the rails will be laid as far as Edmonton—making a second through line from Fort William almost to the foothills of the Rockies. But the men who are behind the Canadian Northern are by no means satisfied with this program. They look forward to a much wider development for their road, and confidently expect to make it the third Canadian transcontinental. At present the main line extends from Fort William to the neighborhood of Battleford. Then in the east the Canadian Northern interests control the Great Northern, from the city of Quebec to Hawkesbury, on the lower Ottawa; and they are now applying to parliament for authority to construct the intervening link between Hawkesbury and Fort William, *via* Ottawa and north of the Great Lakes. When this link is completed, and the western end of the railway carried to Edmonton and the Rockies, and thence to the Pacific coast, the Canadian Northern will have a through line from Quebec to the Pacific.

With the completion of the Grand Trunk Pacific, and the Canadian Northern, Canada will have three distinct transcontinental railways, and eventually these will in all probability be increased by one and perhaps two others. One at least of these will run through the

far north, probably as far north of the Grand Trunk Pacific as that is beyond the Canadian Pacific. The continuation of such a road has already been seriously considered in Canada, a group of Canadian, American and English capitalists having projected several years ago what was to be known as the Trans-Canada railway. This line was to run from Chicoutimi on the Saguenay River, or the city of Quebec, in a practically air line through northern Ontario and Quebec, north of Lake Winnipeg, and through the upper parts of the territories of Saskatchewan, Alberta and Athabaska* to the Rockies, and thence to the Pacific. The company had even made some little headway with surveys of the proposed route—which was to include a branch to James Bay, and another from Edmonton to Dawson—and was negotiating with the federal government as to a subsidy, when the floating of the Grand Trunk Pacific project, backed by the powerful Grand Trunk interests, and with the certainty of early construction, knocked the Trans-Canada scheme on the head, for the time being. There is small doubt, however, that this line, or one following the same general route, must eventually be built to meet the needs of the country, as the tide of settlement pushes gradually to the northward.

The importance of the Canadian transcontinental routes is not confined to Canada or Canadian interests. These routes are of course designed primarily to build up the Dominion, and facilitate inter-provincial as well as international commerce. Incidentally they become a factor of increasing importance in the opening up of new markets for Canadian products beyond the eastern and western seas. But there is a further and wider field in which they are a feature, the significance of which is seldom recognized. As a link in the chain of transportation between the heart of the British Empire and its outermost boundaries, especially for the carriage of troops and war materials, it would be impossible to overestimate the value of the present and prospective transcontinental lines across Canada.

In eastern Canada, the Canadian Pacific and the Grand Trunk are, and have been for many years past, great rivals. In the west the Canadian Pacific had until lately a monopoly of the traffic, but the advent and rapid development of the Canadian Northern has put quite a new face upon the western situation, and has resulted, for one thing, in a lowering of freight rates from all points in the Canadian wheat belt to Lake Superior ports, which has been of very decided advantage to the farmers of Manitoba and the northwest. One still hears an occasional grumble from the western Canadian farmer on this score, but as a matter of fact freight rates on both the Canadian Pacific and

* Now the Provinces of Alberta and Saskatchewan.

Canadian Northern are now considerably lower than obtain on the Great Northern and Northern Pacific for the same distances.

It seems at first sight rather hard lines that the Canadian Pacific, after fighting alone through the long lean years of western traffic—when the pessimistic prediction that the Canadian Pacific railway would never earn enough to pay for its axle-grease seemed about to be verified—should now, on the threshold of the fat years of western growth and prosperity, be faced with the competition not merely of one, but of two great rivals in the west. As a matter of fact, however, the Canadian Pacific has suffered very little loss of traffic from the competition of the Canadian Northern, and is not likely to suffer eventually from the competition of the Grand Trunk Pacific. Western Canada is growing faster than the railways; the two existing roads in the west have already pretty well all the traffic they can conveniently handle, especially during the harvest, and by the time the Grand Trunk Pacific is completed there will probably be more than enough for all three.

The completion of the Grand Trunk Pacific, and the impetus that will thereby be given to settlement in the northern half of the great Canadian wheat belt, must inevitably lead to a demand for another transcontinental still farther north. It is a curious but indisputable fact that as wheat cultivation is extended north, the limits of the wheat zone are pushed forward,* and the total acreage available for cultivation increases from year to year. There will be ample room for another railway, and perhaps two, north of the route of the Grand Trunk Pacific, and still well within the wheat belt. When grain or other shipments reach Fort William from the west, they have the choice of either a rail or a water route. At present the Canadian Pacific offers the only rail route, but within a few years the Grand Trunk Pacific and the Canadian Northern will both have through lines from Fort William east.

The water routes east of Fort William are practically identical until Lake Huron is reached. There they branch out to a number of Canadian and American lake ports, where connection is made with the Grand Trunk, the eastern lines of the Canadian Pacific, and other roads leading east or south. Another route traverses Lakes Erie and Ontario, *viâ* the Welland and St. Lawrence canals, to Montreal. In time two alternative and shorter water routes will be available from Lake Huron to Montreal; the first, *viâ* the Trent Valley canal, now in course of construction, and on which the government has built an enormous hydraulic lift lock, the only one in America; and the other by way of the Georgian Bay canal. This latter project has been

* It is estimated that the hard wheat belt is receding northward at the rate of fifteen miles every year.

under discussion in Canada for a number of years. It was first proposed to build the canal as a private undertaking, a strong company of Canadian and English capitalists having been formed for the purpose. The company asked the federal government to guarantee their bonds; but after some hesitation it was decided that if the work were to be done it would be preferable to do it at the public expense, and make it part of the great canal system of the country.

Last session the Canadian parliament voted a generous sum to provide for a thorough survey of the whole route, and most of this preliminary work has already been completed. The original project only contemplated an 8 or 10 foot channel; but as the discussion dragged on from year to year, the rapid increase in draft of lake shipping made it apparent that such a canal would be next to useless. The proposed depth was accordingly increased to 12, and then to 15 feet. Finally the projectors came out boldly for a 20-foot ship channel, sufficient to accommodate all lake shipping, and making possible the ambitious dream of shipping men for a route which would enable ocean-going vessels to load their cargoes at Fort William, Duluth or Chicago, and proceed to Liverpool without breaking bulk. The estimated cost of such a channel runs all the way from \$75,000,000 to \$100,000,000; but it is now realized that no smaller project would meet the needs of the country, and it is understood that the Dominion government intends eventually to build the canal with a 20-foot channel.

One other Canadian water route must inevitably be opened up in the next few years—that is the Hudson's Bay route. Several exploration parties have at different times been sent out from Ottawa by the government to examine into the possibilities and advantages of this route, and especially the period of navigability of Hudson's straits. The reports received have been rather conflicting, and as a matter of fact none of the vessels have remained long enough in and around the straits to finally decide the question. Mr. A. P. Low, on the *Neptune* expedition of 1903-4, went fully into this matter, and although his official report has not yet been made public, it is understood to be very favorable. An examination of the earlier reports, taken in connection with the favorable opinions of such authoritative men as Dr. Robert Bell, director of the Geological Survey, and Mr. A. P. Low, leads one to the opinion that the straits are safely navigable for such a period each year as would be quite sufficient to make the Hudson's Bay route commercially successful.

That the people of Manitoba have every confidence in the vast possibilities of this route is proved by the significant fact that the Manitoba government is now agitating for the extension of the provincial boundaries to the shores of Hudson's Bay, the intention being, when this has been accomplished, to build a railway, out of the pro-

vincial revenues, or with a heavy provincial subsidy, from Winnipeg to Fort Churchill.

When this railway has been completed, and a line of steamers placed upon the route from Fort Churchill to Liverpool, it is not difficult to foresee that within a comparatively short time a very large proportion of the wheat of the Canadian northwest available for export will gravitate toward this route; and it would not even be too much to predict that a considerable portion of wheat from Minnesota and the Dakotas would also find its way to Europe *viâ* Hudson's Bay. A very small difference in cost of transportation is sufficient to swing wheat from one route to another; the difference depending partly upon distances, and partly upon rail or water routes, water transportation being of course cheaper than rail. The following table will show at a glance the advantages of the Hudson's Bay route over existing routes to the Atlantic seaboard, so far as distances are concerned:

Winnipeg <i>viâ</i> Hudson's Bay to Liverpool.....	3,626 miles.
Winnipeg <i>viâ</i> Montreal to Liverpool.....	4,228 miles.
Duluth <i>viâ</i> Hudson's Bay to Liverpool.....	3,728 miles.
Duluth <i>viâ</i> New York to Liverpool.....	4,201 miles.
St. Paul <i>viâ</i> Hudson's Bay to Liverpool.....	4,096 miles.
St. Paul <i>viâ</i> New York to Liverpool.....	4,240 miles.

It will be seen that the advantage in favor of the Hudson's Bay route amounts to 600 miles in the case of Winnipeg, nearly 500 miles in the case of Duluth; and 150 miles in the case of St. Paul. When you add to this the fact that the Hudson's Bay route involves only a comparatively short haul by rail, as compared with the existing routes, it will be seen that the advantage is overwhelmingly in favor of the former.

Reverting to the proposition first laid down—that the main Canadian rail and water routes run east and west, it will be seen that this is substantially correct. The only exceptions of any importance are likely to be more in the nature of subsidiary lines than main arteries of transportation. The proposed line from Winnipeg to Fort Churchill is a case in point; another is the suggested branch from Edmonton north and northwest to Dawson. Probably the most important of all will be a line from Vancouver, the western terminus of the Canadian Pacific, *viâ* Port Simpson, the western terminus of the Grand Trunk Pacific, to Dawson and the Yukon. One other possibility of the future is a railway from the city of Quebec, along the north shore of the St. Lawrence, to the strait of Belle Isle; thence across the strait to Newfoundland, where connection would be made with the existing Newfoundland railway to St. Johns. This would give the shortest possible ocean voyage for Canadian and American passengers to England and Europe, and would be of immense advantage for the transport of the mails and of freight, where time is an important object.

THE ANCESTORS OF THE BIG TREES.

BY EDWARD W. BERRY,

PASSAIC, N. J.

THE big trees, or sequoias, have furnished a theme for song and story and have been a Mecca for the tourist for so long a time that any remarks regarding the size or longevity of the far-famed trees of Mariposa and Calaveras would seem trite. Their present isolation—for they are but few in number and do not seem to be holding their own in the struggle with the surrounding vegetation or with the cupidity of civilization—but adds to their majestic grandeur.

To the traveler who journeys to California and for the first time stands in their mighty presence many questions may suggest themselves. How long has it taken these giants of the forest to reach up some four hundred feet above mother earth? Were they created thus? Were they just entering upon a career before the red man's fire or the pale-face's ax checked them, or are they the survivors of a long existing line, struggling to maintain themselves in their last stronghold?

The records of their descent are locked up in the rocks and clays of the world, bits of twigs, cones, and occasionally large pieces of trunks that floated down to the ancient seas and were entombed in the sand and mud, to become preserved as fossils for the edification of later ages. Exploration has unearthed a part of this record. Sequoia remains have been found at almost every locality where Mesozoic fossil plants have been discovered; the cones, especially, because of their hard woody structure, being admirably adapted for preservation. In fact the fossil cones were described away back in the first quarter of the nineteenth century, even before the big trees of California had been described.

So we learn that death has played sad havoc in their noble line. Some have been dead, say, seven million years, with thousands of feet of rock lying vertically over their graves. Fig. 1 gives a diagrammatical summary of sequoia evolution, with the accompanying changes in geological, climatic and floral conditions. The left-hand column shows an ideal geological section, with the ages and periods, and their probable durations expressed roughly in years. In the middle column the procession of changing physical conditions are shown, together with the accompanying changes in climate and flora. The right-hand column is devoted exclusively to events in the genealogy of the sequoia.

The earliest known species is represented by well-defined cones

which have been found in the Upper Jurassic of France. When we say that sequoias flourished in the Upper Jurassic we have a dim idea that they are a pretty old type and that, although compared to the most ancient known rocks the Jurassic rocks are mere infants, still the Jurassic age came to a close several million years ago. But we can form no more of a concept of the duration of several million years than

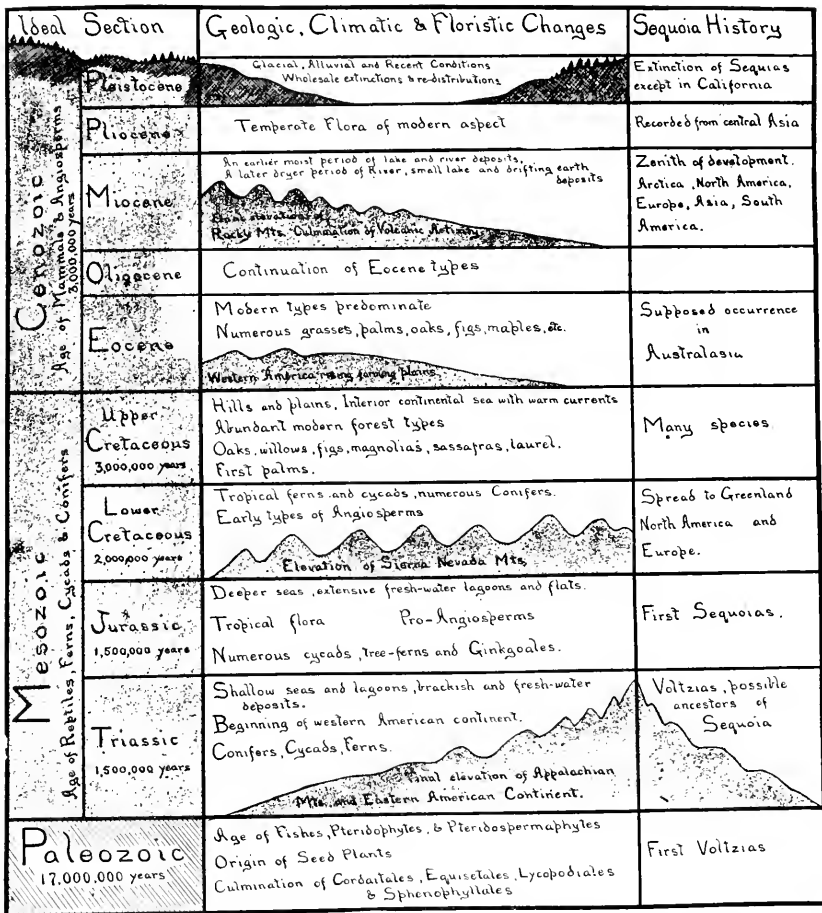


FIG. 1. DIAGRAM SHOWING GEOLOGICAL, CLIMATIC AND FLORISTIC CHANGES IMMEDIATELY PRECEDING AND DURING THE EVOLUTION OF THE SEQUOIA.

we do of astronomical distances, and it is only by glancing at the progress of life on the globe during all those years that we can get any sort of an idea of the remoteness of the period.

Fig. 4 is designed to show this progress of life in a general way, in the animal kingdom, which has been chosen rather than the vegetable kingdom because the changes in the former are more striking

and much more apparent to the casual observer. The plants have undergone a like evolution, which has been, however, more of structure than of external appearance. Could imagination transport us to Jurassic times and set us down near the mouth of the Hudson River,



FIG. 2. *Sequoia Reichenbachii*, A WIDESPREAD CRETACEOUS SPECIES, restored from numerous specimens from New Jersey clays.

we should find little that was familiar in either the fauna or the flora. The sediments which now exist as the red sandstones of the Connecticut valley and New Jersey had already been deposited. Volcanic activity

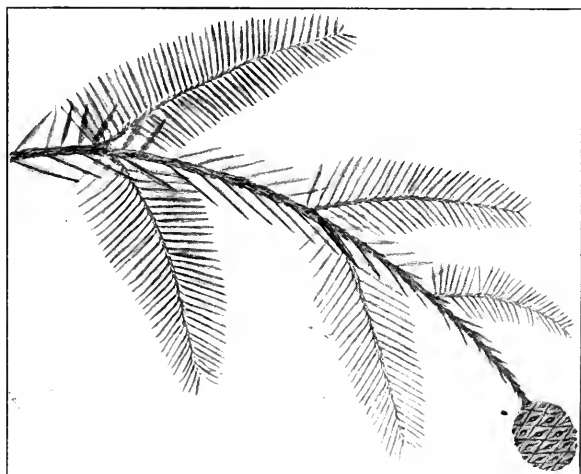


Fig. 3. *Sequoia Langsdorffii*, A WIDESPREAD, CHIEFLY TERTIARY SPECIES.

had been considerable and vast quantities of molten rock had been forced through the crust, forming, among others, the Orange Mountains of New Jersey and the noble line of Palisades along the Hudson.

However, it is quite probable that one would have been as little dis-

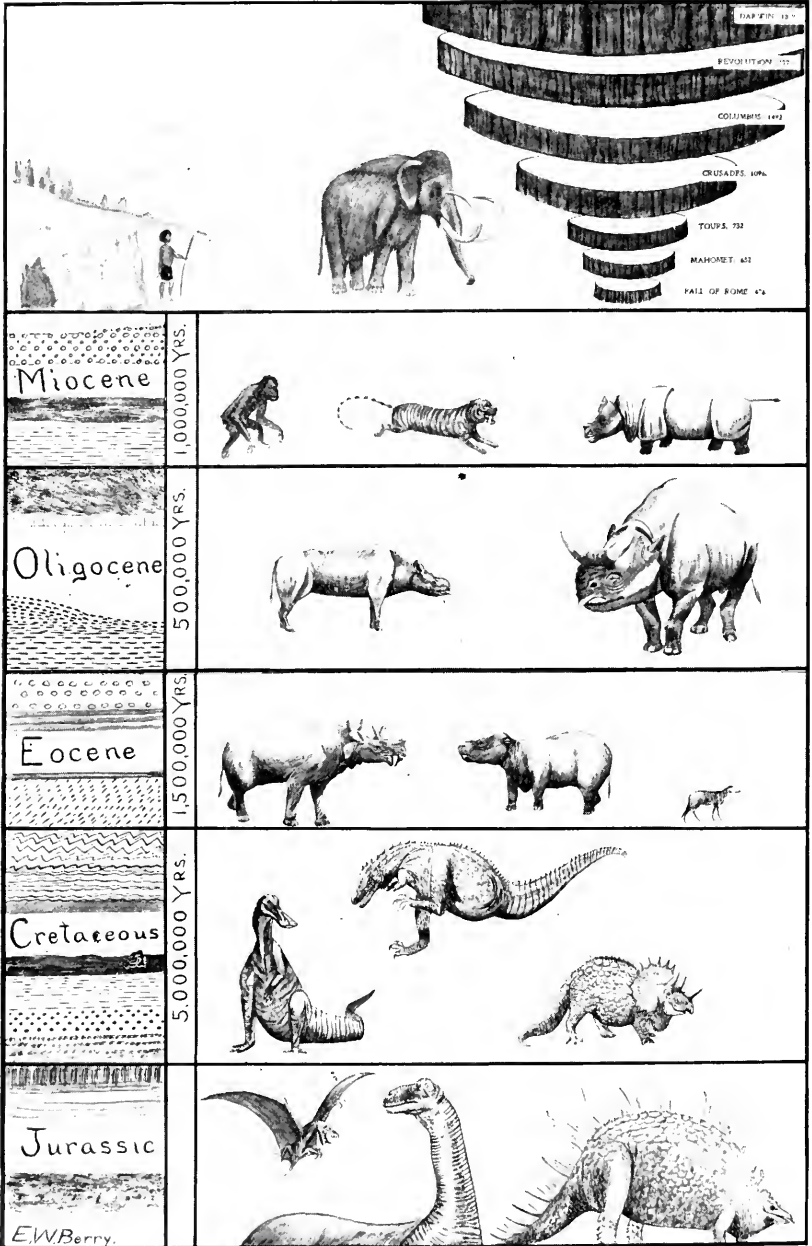


FIG. 4. SECTION SHOWING PROGRESS OF ANIMAL LIFE DURING WHICH SEQUOIAS HAVE FLOURISHED, UPPER SPACE SHOWS COMPARATIVE SECTIONS OF A TRUNK OF THE MODERN TREE.

These restorations which are after Chas. R. Knight's drawings are used with the kind permission of Professor Henry Fairfield Osborn of the American Museum of Natural History.

turbed by earthquakes eight million years ago as are the inhabitants of New Jersey at the present time by the sinking of their eastern coast. Events moved with inconceivable slowness then as now, though, of course, progress was quickened now and then. Our Jurassic sojourner would find everything strange. In the marshes flourished great ferns with undivided evergreen fronds (Marattiaceæ), and numerous representatives of our modern royal and cinnamon ferns (Osmundaceæ). Close by, ancient tree-ferns (Cyatheaceæ) vied with an amazing variety of forms known as cycads—curious plants of which the commonly cultivated sago palm is a familiar example. In the dryer spots flourished the numerous ancestors of the ginkgo, the maiden-hair tree, that curious relic of bygone days, which has been saved from extinction in modern times by the loving care of the priests about the temples of China and Japan.

The only representatives of those flowering plants which are dominant in the vegetation of the world to-day, the Angiosperms, were the little-known and curious (probably) semi-aquatic plants with netted veined leaves, which have been named pro-angiosperms. Ancient lung-fishes, gar pikes and crocodiles haunt the rivers; out at sea are swarms of sharks and ganoid fishes. Bat-like flying reptiles are the common denizens of the air, the primitive toothed birds with long reptilian tails being in the minority. Sea-inhabiting reptiles of gigantic size, long-necked plesiosaurs and dolphin-like ichthyosaurs, land-inhabiting dinosaurs (the name means terrible lizard), of immense size and bizarre form, are the dominant creatures, while the noble class of mammals with man at their summit is still but a promise and, so far as the fossils indicate, represented by only a few forms of mouse-like size. The continents had not yet assumed their modern dimensions. Such great mountain chains as the Alps, Himalayas and Rockies had not been elevated; and yet the sequoia flourished and its cones were not very different from those found in California at the present time.

The next succeeding geological period, the Cretaceous, continued to be the age of gigantic reptiles, some of which are shown in Fig. 4. The two left-hand monsters figured were between twenty and forty feet long, and were ancient Jerseyites, the spoonbill, a herbivorous, and the leaper, a carnivorous, species. Occasional bones and teeth of these and other related creatures are found in the marl beds that were deposited in the sea off the eastern coast of those days. The Mississippi valley was part of a great gulf that extended northward from the present Gulf of Mexico almost to the Arctic circle, and was a veritable summer sea, peopled with gigantic sea-lizards (mosasaurs), and with a host of other strange forms. Flying reptiles with a spread of fifteen to twenty feet circled overhead.

The vegetation, however, particularly in the Upper Cretaceous, begins to assume a more modern aspect and we find along with the ancient types of ferns (*Cladophlebis*, *Thyrsopteris*), broad-leaved conifers (*Nageiopsis*), and juniper-like evergreens (*Moriconia*), numerous leaves of oaks, willows, figs, magnolias, sassafras and laurel. The earliest known palms are found at this time. The Cretaceous clays which skirt Raritan Bay in New Jersey abound with these layers of leaves, as do also the Dakota sandstones of the middle west. The magnificent specimen of sequoia with the large cone and the needle-like curved leaves shown in Fig. 2 is from the clays near Cliffwood, N. J., where the twigs are among the most abundant fossils, looking like elegant lithographs against the background of dove-colored clay. This species had cones almost exactly like those of the living Californian tree and the foliage was also very similar. It was a very wide ranging form, and is considered to have been the source (in part at least) of the amber which is so common in the coastal plain Cretaceous at certain points.

Fig. 3 shows a flat-leaved form and attached cone of a species more like the modern redwood, in fact it was probably one of its ancestors, which first appeared during the Cretaceous and which became widely distributed, and continued through the Miocene. During the three to five million years of Cretaceous time the sequoias flourished and became widespread. They saw many changes going on all about them. Beneath their shade new races were springing up; the plants of a modern type which were to replace all others in the struggle for existence had obtained their start: animals gamboled about their trunks or climbed in their branches* that were destined to replace the unintelligent and clumsy reptiles, and by and by to give rise to the horses, dogs and cats of a later day, and finally to produce that animal which was to attain universal distribution, and to be the destructor of countless other species—man.

Remains of sequoias from the lower beds of the Cretaceous have been found in western Europe, in Spitzbergen, in Texas and in the eastern United States. In slightly more recent deposits we find them in Greenland, Canada, in the Black Hills and in Montana. By the middle of the Cretaceous we find over a dozen different species spread over the United States, with still others in Greenland and in central and western Europe. Their remains are often extremely common, whole branches bearing numerous cones, and innumerable twigs, often beautifully preserved, being common fossils. The warm humid climate of the period seems to have been very favorable for their development, and the elevation of the land, by which natural bridges, such as those

* The Cretaceous mammals are all small, about the size of squirrels, and were probably arboreal forest dwellers.

closing Bering Straits and the English Channel, enabled them to spread all over the northern hemisphere and even into the southern, for in the next age, the Eocene, we find their remains in far-off Australia and New Zealand,* while others occur in Alaska, stragglers from the migration into Asia.

The great frozen north of to-day had not yet been hinted at, a warm, if not subtropical, climate prevailed even in the far north, and Greenland was the garden spot that its name implies. On its western coast many plant-beds have been discovered, containing the remains of tree-ferns, cycads, incense cedars, figs, camphor trees, magnolias, eucalypts and other natives of warm climes. This northern region with numerous land connections to lower latitudes was probably the original home of our modern floras and faunas, which spread southward in successive waves of migration. We know that the Mid-Cretaceous witnessed the apparently sudden appearance of a host of new and higher plant types, and the basal Eocene witnessed a like sudden appearance of mammalian types. It is to the frozen north of to-day that we look, hopeful that it will shed light on ancestral forms that flourished there in the far distant past.

With the ushering in of the Eocene period the gigantic reptiles are entirely replaced by higher types; small mammals, some races of which soon attained great size, uncouth beasts long since passed away, besides the remote and generalized ancestors of some of our modern animals. It is in the rocks of this period that we find the dainty little four-toed ancestor of the horse. The Eocene, together with the next period, the Oligocene, represents a couple of million years, during which the sequoias were almost as abundant and widespread as are the pines in our existing flora. In Fig. 4 are shown some of the characteristic animals of these periods, and in Fig. 1 we get some idea of the geological and floral conditions. In the far west this was a time of plains, rivers and lakes, the verdant surroundings of the latter rivaling the Louisiana country of the present day.

Along with the sequoias were many hardwood trees—oaks and maples, hickory and ash; alligators pushed their way through the sedges; the cypress and palmetto grew in Montana, Colorado and Greenland. Stately palms furnished shade for primitive rhinoceroses, tapirs and camels. Monkeys swung from branch to branch and gathered the fruits, where to-day there is nothing but the barren wastes of the alkali 'bad-lands.'

The next period, the Miocene, witnessed the zenith of sequoia development. Contemporaneous with the tapirs, rhinoceroses, horses and

* The identification of these antipodean remains is not entirely beyond question.

saber-toothed tigers, the sequoias are found from Tasmania to Iceland and Spitzbergen, and from Ireland to Japan. Their remains are everywhere—in France, Italy, Greece, Bohemia, Greenland, America—they had even found their way down along the South American coast as far as Chili.

In the Yellowstone region whole forests have been changed to stone by the mineral waters, or buried in the showers of ashes from the active volcanoes in the vicinity. The remains of the trunks are still from six to ten feet in diameter, and the erect butts are often thirty feet or more in height, standing just as they grew, a veritable Aladdin's forest turned to stone. From a microscopic study of the wood we find that these Yellowstone trees are scarcely to be distinguished from the Californian redwood and it seems a reasonable inference that they represent its direct ancestor, particularly as other petrified woods from western Canada are likewise closely related to the redwood. The Miocene, like the Eocene and Oligocene periods, was characterized to a large extent by vast continental fresh-water deposits laid down chiefly by streams, small lakes and drifting sand. To the westward ran a low range of hills, the embryonic Rocky Mountains, where the ancient crystalline strata were slowly pushing their way upward through the overlying Mesozoic and Tertiary rocks. Around the water courses grew swamp maples and alders, gum trees and mulberries; figs still flourished in the latitude of Puget Sound; saber-toothed tigers hunted the hornless rhinoceroses; and the primitive mastodons with four tusks, two in each jaw, vied with the great horned rhinoceroses for possession of the soil.

The volcanic eruptions, which first became a prominent feature during the Cretaceous, culminated during the Miocene, as the immense number of extinct cones in the western half of North America give abundant evidence. The interval between the close of the Miocene and the modern sequoias is imperfectly known. Climates were becoming cooler and the sequoias were on the wane. But few fossils are found and it is presumed that the elevation of mountain ranges, shutting off the vernal breezes, and the consequent alterations in humidity, as well as the vast changes attendant upon the coming of the ice fields of the glacial period, were sufficient to all but extinguish the noble sequoia family.

At about the time the Neanderthal skull housed the brain of a cave dweller who fashioned the paleolithic flints, and who dwelt in the fear of the great hairy mammoth, the cave bear, the hyena and the woolly rhinoceros, or shortly thereafter, the sequoias reached their present habitation in California. Could they but hand down to us the record of history embraced in a generation or two, each lasting between two

and four thousand years, what a tale they might unfold. Tradition has it that Napoleon encouraged his soldiers before the battle of the pyramids with the picturesque phrase 'forty centuries look down upon you,' and yet the span of a single sequoia about equals what to the biblical chronologies of Napoleon seemed the limit of time. Many of the still vigorous and growing trees sprouted about the time that Christ was born at Bethlehem in Judea. Most of those still standing had commenced to grow at least before the fall of Rome. We can count the annual layers in the wood of those which have been cut down, and calculate with considerable accuracy their age and the varying rapidity of their growth. For instance, the huge section on exhibition at the American Museum of Natural History shows that the climate of California was very propitious about the time that Charlemagne was crowned by Pope Leo on Christmas day, A.D. 800, as is evinced by the rapid growth of the tree at that time shown by the comparatively thick layer it added to its girth.

It is not strictly correct to speak of these growth layers as 'annual.' They are primarily the result of the varying rapidity of growth of the cells; thus in trees of temperate climes there is a gradual slowing down of vital activity as the summer advances, followed by a prolonged resting period during the winter, and an accelerated resumption of activity in the spring. These varying functions are recorded in the size and nature of the cells formed. For example, in our oak or chestnut the spring wood consists largely of pitted ducts of large size, which are prominent and in marked contrast with the much smaller celled and more solid additions formed by the slower growth later in the season. In cone-bearing trees like the sequoia the differences are almost entirely of size, the transition being abrupt from the very fine wood-cells formed at the close of the season to the much larger cells of the vigorous vernal growth. In the tropics the varying rapidity of growth is not so marked, although here also there is usually a suspension of vital activity during the hot dry season and a vigorous growth during the humid season. This effectually records the alternation of seasons in the rings of growth. It follows that under certain conditions a tree might add more than one ring in a year, but for our purpose, and generally speaking, it is proper to designate these rings as annual. Year after year the sequoias have been adding layer after layer to their girth in ever widening circles. The thousands of tons of bark shed by each tree during its long career, the tens and hundreds of thousands of tons of sap that have coursed through their venerable trunks, and the innumerable progeny of a single tree in the older, more propitious days—a contemplation of these facts assists us in realizing the true proportions of these forest monarchs. Imagination, however, fails

in an attempt to picture the exquisite beauty of that virgin forest, standing age after age in all its unsullied glory—a veritable forest primeval.

Some of the Californian trees were still in their youth and others were approaching middle age when the various hordes of barbarians overran Europe. They had almost reached their full growth at the time of the Wars of the Roses and the discovery of America. They had reached their present height and girth and ripe old age before modern science had commenced its renaissance; in fact, every avenue of human endeavor—social, religious, industrial and intellectual—has shown its most marvelous progress during the time that it has taken the sequoias to add but a few feet to their already giant frames. In the topmost space of Fig. 4 the growth of an existing sequoia through the centuries is illustrated by an imaginary series of sections of the trunk, drawn to scale, showing the comparative diameter of the trunk at the time when the corresponding notable historical events occurred.

We can but wonder at the persistence of this type practically unchanged, for eon after eon, while all around were dissolution and evolution. Their early contemporaries are almost without exception cut off, and were we to go still further back to the probable ancestors of the sequoias, the Voltzias of the earlier ages, we could carry the genealogy back several million more years, almost to the coal period.

And yet the vicissitudes of time have not succeeded in wholly obliterating these ancient records preserved in the great book of history whose torn pages are the solid rock, and we are able to decipher a line here and a broken chapter there, gradually piecing together the main facts of the story, the reading of which becomes not only a labor of love, but a task of the most absorbing interest.

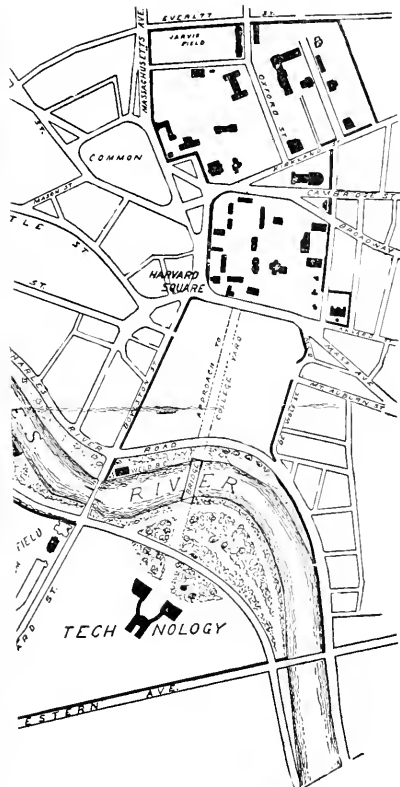
THE PROGRESS OF SCIENCE.

HARVARD UNIVERSITY AND THE
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY.

THE proposed alliance between the Massachusetts Institute of Technology and Harvard University is a matter of more than local interest. Among the questions involved are the relations of technological to liberal and other forms of professional education; the advantages of great size to a university; and the share in the control of educational institutions which should be assumed, respectively, by the trustees, faculty and alumni.

President Eliot has on previous occasions urged the union of the Massachusetts Institute of Technology with Harvard University, but it appears that the present plan was proposed by President Pritchett and the corporation of the institute, led thereto by the large bequest of Gordon McKay to Harvard University for work in applied science. The history of the movement is, in brief, as follows: On May 4, 1904, the corporation of the institute passed a motion requesting its executive committee to ascertain whether any arrangement could be made with Harvard University for a combination of effort in technical education which should substantially preserve the organization of the institute. On September 14, the corporation voted to secure the opinion of the faculty and alumni. On March 24 of the present year, an agreement was presented to the corporation, drawn up by President Henry S. Pritchett and Professor A. Lawrence Lowell, of Harvard University, on behalf of the institute, and by Dr. H. P. Walcott and Mr. Charles Francis Adams, on behalf of the university. This agreement provided for the re-

moval of the institute to the site shown on the accompanying sketch, where it would erect the buildings; the joint work in industrial science would be under the control of an executive committee appointed by the corporation of the institute and containing three members of the Harvard corporation; there would be at the disposal of this committee the income of the funds of the Lawrence Scientific School and three fifths of the income from the McKay



PROPOSED SITE OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND THE APPROACH TO THE BUILDINGS OF HARVARD UNIVERSITY.

bequest; the faculty would consist of the present faculty of the institute and of those professors of the university who now give instruction in industrial science; each of the institutions would retain control of its own funds, and the agreement could be terminated at any time by either party.

This agreement was submitted to the faculty of the institute, which, on May 5, by a vote of fifty-six to seven, adopted a report to the effect that in their opinion it was educationally unsound and prejudicial to the institute's development. The alumni who voted stood 458 in favor of the proposed agreement and 1,351 against it. In spite of this, and the further fact that the faculty of the Lawrence Scientific School was known to be opposed to the agreement, it was adopted by the corporation of the institute on June 9 by a vote of twenty-three to fifteen in a total membership of forty-seven. The agreement must now be submitted to the corporation and overseers of Harvard University, and if adopted by them will be put in force, unless the courts should decide adversely. The present site of the Massachusetts Institute of Technology can not be sold for business purposes without the approval of the courts, and the courts must also decide on the legality of using the income of the McKay bequest in the manner proposed. A committee of the alumni of the institute has been formed to test in the courts the validity of the agreement on behalf of those who have given or bequeathed funds to it.

Various arguments have been urged in favor of the merger and against it. It is said that the same community can not support two schools of applied science, to which it is replied that there is room in New England for two schools of different types, and that the competition would be beneficial rather than injurious. It is said that it is an advantage for a school of technology to be associated with the work of a uni-

versity in view of the broader culture given to the students, but it is replied that the earnest work of the school of applied science would be weakened by the dilettantism of the college. It is said that economy would result from the merger, but this is denied. It is said that larger gifts would be made to the combined school, but it is replied that the interest of the alumni and other friends of the institute would be alienated.

All these arguments have a certain plausibility. The case in favor of an alliance would certainly be strong if a new school, such as Mr. McKay at one time contemplated, were to be founded. But it is easy to understand the position of the faculty and alumni of the Massachusetts Institute of Technology, the strongest foundation of the kind in the country. They foresee that it would be placed at the mercy of Harvard University, and that the ultimate outcome would be a big school of applied science of Harvard University, rather than a continuation of the individuality and traditions of the Massachusetts Institute of Technology. It certainly appears that when the great majority of the faculty and alumni of the institute are of this opinion, and when the alliance is not wanted by the Lawrence Scientific School, the plan would be inexpedient, and for the corporations of the two institutions to force it would be unwarrantable. Most university professors will concur with the editorial article published in the last number of *The Technology Review*, the concluding sentences of which are "A partnership between Harvard and the institute to which substantially all the parties in interest consented might be practicable; but one like this, which is repugnant to most of those whose good will and enthusiastic efforts are essential, must inevitably result, if attempt is made to force it through, not only in the wrecking of the institute, but also in the controlling of education by

purely business standards. To use the methods of industrial trusts in conducting colleges and universities is to threaten the present efficiency and ultimately the life of all higher education." Thus, for perhaps the first time in the history of our educational system, the autocratic powers of presidents and trustees are directly challenged by the faculty. The outcome will exert a decided influence on the future character and control of our universities.

THE AMERICAN MEDICAL ASSOCIATION.

THE American Medical Association met at Portland, Ore., during the week beginning on July 10, under the presidency of Dr. Lewis S. McMurtry, of Louisville, Ky. There was a registration of 1,714 members, which is more than the average. The scientific sessions were good, and the business transacted was of more than usual importance. It appears that in this case a meeting held during an exposition has proved to be pleasant and successful.

The presidential address reviewed the history of the association which was organized in 1846. For many years it was chiefly a body for the presentation of papers, but it has recently assumed additional functions. Perhaps the most important step was the establishment of a journal some twenty years ago. *The Journal of the American Medical Association* has now become one of the strongest medical publications in the world. The publication expenses last year amounted to not less than \$181,000, but in turn the receipts of the association, largely through subscriptions and advertisements for the journal, amounted to \$244,709. At the Portland meeting, the association decided to compile a directory of the physicians of the United States, who are said to number about 120,000.

Four years ago the association

adopted a plan of organization which appears to be destined to unite the physicians of the country in a powerful body. The county medical societies are made the unit of organization, these are affiliated with the state organizations, which are in turn united in the national association. The legislative body of the national association is a house of delegates to which members are sent from the different states in proportion to the membership in the state societies. This body consists of 150 members, and has proved competent to transact the business of such a society. This form of organization appears to be both more efficient and more democratic than that of the National Educational Association, on which some comments were made here last month. It is, however, significant that both the physicians and the teachers of the country are developing compact organizations which have many of the characteristics of trades unions. They will exert an influence for the material welfare of the members of these professions, and may eventually become strong social and political agencies, which it may be hoped will ordinarily act for the welfare of the whole country.

The American Medical Association applied last year for a charter from congress, but this has not yet been granted. The question will come up again this winter. Here again the American Medical Association appears to be acting more wisely than the National Educational Association, the whole bill being

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That [Here follow the names of the incorporators] and their successors, and those who may be associated with them, are hereby made and constituted a body politic and corporate by the name American Medical Association with perpetual succession and power to take, for the purposes of its incorporation, by devise, bequest, grant, gift, purchase, or otherwise, and hold or convey, both real and personal property and transact business anywhere within the United States.

Sec. 2. That the object and purpose of such corporation shall be to promote the science and art of medicine and the public health throughout the United States.



DR. WM. J. MAYO, PRESIDENT OF THE AMERICAN MEDICAL ASSOCIATION.

Sec. 3. That such corporation shall have power to make by-laws, rules, and regulations, and choose officers for its government and the attainment of its purposes.

The council on medical education presented an important report. It was stated that the ideal standard to be held up should consist of

a. Preliminary education sufficient to enable the candidate to enter our recognized universities, the passing upon such qualifications by the state authorities

b. A five year medical course, the first year of which should be devoted to physics, chemistry and biology, and such arrangements should be made that this year could be taken either in a school of liberal arts or in the medical school. Of the four years in pure medical work, the first two should be spent in laboratories of anatomy, physiology, pathol-

ogy, pharmacology, etc., and the last two in close contact with patients in dispensaries and hospitals in the study of medicine, surgery, obstetrics and the specialties.

c. A sixth year as an interne in a hospital or dispensary should then complete the medical course.

The council holds, however, that a four-year approved course with the preparation above mentioned is all that can be expected at present. It believes that a preliminary college education is only desirable for a limited number of men.

The meeting of the association next year will be held at Boston under the presidency of Dr. Wm. J. Mayo, of

Rochester, Minn., who was unanimously elected. Dr. Mayo is one of the leading American surgeons and has the distinction of having declined all calls to large cities and institutions, preferring to remain in the small town where St. Mary's Hospital, of which he is one of the surgeons, was built for his father by the Franciscan sisters.

THE DEPARTMENT OF AGRICULTURE.

It is much to be regretted that there has been room for criticism of certain officers in the Department of Agriculture. It is also unfortunate that the work of the department may be injured by the lack of perspective and search for sensationalism with which the matter has been treated by the daily press. So far as is known only one officer of the department, and he not a scientific man, has been guilty of acts that warranted dismissal, but which scarcely justify prosecution in the courts. Two other officers of the department—scientific men of standing—have been charged with having connection with commercial concerns while retaining their positions under the government, but in both cases the connection was terminated some time ago. Whether the relation of these officers with the government was used to forward these business enterprises has not yet been made clear. In one case a patent for a discovery was taken out, and the patent given freely to the people of the United States. A company was, however, organized to supply the product. So far as the public knows, the man of science who made the discovery may have acted in an honorable manner. He might have resigned his position, taken out patents and become a millionaire. On the contrary, he gave his patent to the people, and may have taken part in the organization of the company for the public benefit. It appears that at one time he considered resigning from the government service and entering the

service of the company, which he certainly had a right to do, but that when he decided to remain in the Department of Agriculture, he gave up his connection with the company. Information has not been made public sufficient for any one to form a judgment as to the conduct of the two men of science referred to. It may have been entirely creditable to them, or it may indicate lack of a nice sense of honor.

An instructor in one of our leading universities made a discovery in the course of a scientific investigation, which he patented and sold for several hundred thousand dollars to a corporation. So far from objecting to this arrangement the trustees gave the scientific man in question leave of absence in order that he might arrange for the sale of his patent in Germany, and shortly afterwards promoted him to a full professorship. If such an instance were now made public in a government department, it would probably be distorted and criticized on all sides, but both the scientific man and the university acted correctly. It is somewhat dangerous for the man of science to keep his eyes on the patent office or to meddle with commercial undertakings, for he may thus be distracted from more important work, but it is still more dangerous to subject the scientific man to orders and discipline from an official superior.

For example, a newspaper as respectable as the *N. Y. Evening Post* seems to regard it as a scandal that a scientific man received payment for an article contributed to a magazine. It would be entirely disastrous to the scientific work done under the government if it were ruled that scientific men could publish only in the government reports. The only reason why these positions are attractive to men of ability is that they have adequate material for scientific work, and that, in addition to the utilitarian work that they do for the government, they are able to contribute to the advancement

of science. The salaries paid to chiefs of divisions are about \$3,000 a year, with almost no opportunity for advancement. The government finds it difficult to retain its ablest men of science, they being willing in most cases to accept university appointments. This added to civil service methods, desirable as they are in some regards, is in danger of giving rise to the survival of the unfit in the government service. There is some room for the complaint that men of science in the government service do not do work of as great distinction and originality as should be the case. Presumably this is due to too much supervision and red tape, rather than to too great freedom. The general spirit in the Department of Agriculture is very good, due largely to the wise administration of Secretary Wilson, and it is to be hoped that it may not be injured by an attempt to apply stricter discipline.

SCIENTIFIC ITEMS.

PROFESSOR ALEXANDER MELVILLE BELL, known for his contributions to phonetics, died on August 7, at the age of eighty-six years.

DR. E. RAY LANKESTER, director of the British Museum of Natural History, has been elected president of the British Association for the meeting to be held next year at York.—Dr. William H. Nichols, of New York, gave the presidential address before the Society

of Chemical Industry at its general meeting in London on July 10. Dr. Edward Divers, F.R.S., was elected president of the society for the ensuing year.—Dr. Samuel G. Dixon, president of the Academy of Natural Science of Philadelphia, has been appointed commissioner of health for the state of Pennsylvania.—Professor W. W. Mills has been appointed state geologist of Michigan.

A STATUE of Benjamin Franklin is to be erected at Paris at the end of the street that bears his name. Plans have been made for the celebration of the two hundredth anniversary of Franklin's birth, in Boston and New York as well as in Philadelphia.—A tablet was unveiled on July 14, by Signor G. Marconi, on the house in which Sir Humphry Davy once lived at Clifton, Bristol.—The American Medical Association has taken steps for the erection of a suitable memorial to Dr. N. S. Davis, who is regarded as the founder of the association.

THE official party of the British Association, including Professor G. H. Darwin, the president and the other officers, left Southampton by the mail steamer *Saxon* on July 29 for Cape Town, where they arrived on the sixteenth inst. The party included Professor Ernest W. Brown, of Haverford College; Professor Henry S. Carhart, of the University of Michigan; Professor W. M. Davis, of Harvard University, and Professor William B. Scott, of Princeton University.

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THE LAPSES OF CONSCIOUSNESS.*

BY PROFESSOR JOSEPH JASTROW,
UNIVERSITY OF WISCONSIN.

Introductory: The Formula of Conduct.

THE purpose of the present study is to set forth the range of certain common and normal types of thought and conduct that reach expression without the usual and attentive guidance of consciousness. Such subconscious direction of what we think and say and do plays a constant part in the ordinary, and occasionally in the extraordinary, operations of our mental machinery. So long as the operations are successful in purpose, there is little occasion for bringing to the light of our own awareness the process by which the result is accomplished. This is, indeed, the normal emphasis of nature, which places a premium upon the issue, but is relatively indifferent as to the means, giving its sanction of survival to such processes as effectively and economically lead to the desired end. It thus comes about that a variety of procedures may be developed for a common purpose. Owing to the similarity of human needs and endowment, there arise familiar types of mental habits, which become established without definite awareness of their nature or of the manner of their use. It is a peculiar type of straying of the process from the intended path that directs attention to it and makes one aware of a momentary lapse in the relation of issue and

* The substance of this article in a modified and abridged form serves as a chapter in a volume entitled 'The Subconscious,' now in the press of Houghton, Mifflin & Co., and shortly to be issued by them. The present article deals in the main with the presentation and classification of the evidence for the more common types of such subconscious action, and does not consider as carefully as the subject demands the synthetic interpretation of the data. This aspect of the problem is treated in another chapter of the volume. There is also included in the present article material presented in other chapters of the book.

purpose; such lapses not only disclose the nature of the ordinary well-adjusted relations, but offer an interesting means of determining what otherwise would be but vaguely recognized. As to the conditions favoring such lapses, they are so familiar as to make it sufficient to recall that they occur in moments of weakened or too dispersed attention. It is because the reins are too freely relaxed, or are relaxed at an inopportune moment, that our habits take the bit between the teeth, and, it may be, lead us where we had no intention of wandering. The state of mind in which this, as well as other types of subconscious action, occur, we call distraction; and when it becomes more pronounced, the type of the lapse may become both more variable and indicative of more complex deviations. 'Absent-mindedness' (for which the German has the more telling expression, 'Zerstretheit') offers the most typical and familiar attitude favorable to the display of these lapses of consciousness, trivial, amusing, but psychologically interesting. It is with the natural history of this familiar species and its varieties that we shall here be occupied.

To obtain a realistic survey of the kind of activities for which the subconscious gearings of our mental machinery are ordinarily held responsible, I instigated an inquiry among a group of persons* to whom I had access, asking them little more than to give such accounts of subconscious experiences as they could easily and rather distinctly recall. One need not claim for such a collection anything more than a fairly representative showing of the manner in which the subconscious disports itself in daily life and compels notice by the lack of harmony between intent and execution, or between memory and circumstantial evidence, or by intrusion of the dim and submerged operations into the ken of the conscious self. But as such, and with proper allowance for inaccuracy and prejudice in favor of the more picturesque incidents, their survey

* These responses (some two hundred in number selected as available from a group of about three hundred) were prepared by students of the University of Wisconsin, in the main in the form of a set theme, as part of the work in English composition, and others as specific contributions by students of psychology. There seems no reason to suppose that the instances differ essentially from those that could be collected in other circles; yet they naturally reflect something of the occupations of young men and young women devoted, though by no means exclusively, to scholastic pursuits. It would require a detailed and more systematically conducted inquiry to yield material capable of specific and minute discussion: but the general relations and types of frequency that alone are considered in the present *aperçu* are sufficiently 'documented' by this casual yet suggestive collection.

It should also be noted that the data did not specifically call for lapses of conscious attention, but suggested these and other types of instances as appropriate. It thus does appear that lapses actually furnish the largest quota of ordinary observations of subconscious activity. I have considered these as central, but have found it profitable to consider with them related types of 'cases.'

may serve as a natural and profitable approach to the general and theoretical interpretations, which form an important goal of the psychologist's efforts.

If one were to set forth the factors of an operation intelligently guided, that is, of a piece of human conduct, simple or complex, he would find that every distinctive phase thereof may, on occasion, be carried on with a markedly lowered, an unusually reduced, degree of the awareness which its performance normally demands. The contours of such a piece of conduct would show in silhouette, first, the perception of the situation by the message brought through eye or ear or other window of the soul; such message is offered to the appropriate powers of the mind for interpretation and for the elaboration, variably intricate, of the suitable response; and the bit of conduct is rounded by the fit and skilled execution of what it has been decided to do or say. What is here appropriate is that one may find any portion or the whole of these successive links in the chain of mental reactions sufficiently and intelligently directed by a subconscious type of adjustment. Though the factors properly form a unit, combining with like units into a series of expanding complexity of kind and number, yet each is naturally viewed as composed of its *receptive* or perceptive aspect, accompanied by a suitable *interpretation* through which the process acquires meaning: and again, of its *expressive* phase, which, as the issue of a preparatory elaboration, becomes not merely a muscular contraction, but a significant piece of conduct. For a different purpose it would become necessary also to consider quite separately and minutely what here must be treated *en masse*, the inner elaborative processes that bind perception and expression, and thus appraise the dignity of the intellectual response in terms of habit, training, insight, judgment or wisdom. For the present argument, whether we proceed by large general outlines, or by more detailed steps, we shall be able to illustrate that for each stage of the process a counterpart in subconscious terms may be found.

The Motor Lapse and its Sensory Clue.

The receptive (sensory) and the responsive (motor) phases of a bit of conduct are the ones most readily distinguished; and in regard to these, my data emphasize that the latter occupy the focus of the more common forms of subconscious activity: which means that, though the reduced awareness spreads itself over the whole procedure, it affects more prominently the motor response, the terminal, rather than the initial, phase of conduct; or, that once the nature of a situation is normally perceived, our motor habits step in to perform the appropriate (or unintended) response with submerged awareness, possibly amid distracted attention. A peculiarly apposite recognition of this rela-

tion is embodied in the popular game of philopœna. Here a premium is placed upon the guarding of one's subconscious tendency to allow the complacent habit of assent or difference to express itself, and specifically towards one individual, in the conventional 'yes' or 'no'; or in taking what is naturally or unobtrusively offered. It is surprising how quickly this charge upon the subconscious becomes lost amid the more vital interests of social intercourse, how readily the hand is entrapped into an acceptance of what is extended, or the tongue into an automatic 'yes' or 'no,' when the major attention becomes directed to the channels of our real concern. A situation lightly perceived, with still slighter reflection, awakens the natural response; and it is just this relation that my data indicate. Subconscious *doing* ensues somewhat more readily than subconscious *perceiving*; while the rôle of subconscious *elaboration* and interpretation can not be so easily appraised. Yet it must constantly be held in mind that subconscious doing involves and indeed becomes an index of subconscious perceiving, followed typically by some measure of interpretation. And it may be well to illustrate in detail this dependence of a motor action upon a sensory clue, mindful, in our choice of illustrations, of their bearing upon the lapses that form our main pursuit. In other words, we may deliberately charge our subconscious habits with actions that spring from no real sensation. For this attitude, particularly in its personal and social aspects, we have the apt term of affectation. One may affect a lisp, or a foreign pronunciation, or the broad *a*, or, with the changes of the fashions, an exaggerated hand-shake or manner of raising one's hat; and throughout the series there is constant danger of lapsing back into the natural form of expression. The affectation thus attempts to guide consciously what should be guided subconsciously; it attempts for some special effect to pass current as a natural habit, what really is the issue of a watchful guidance. The actor has professional occasion to cultivate such affectation; and it is sometimes amusing to detect the inexperienced actor reminding himself that he must no longer use his wounded arm, must continue to limp, or to reel, or to exhibit the manners of old age, or of the ruffian, or of the peasant. This artificial relation is interesting in that it presents in exact reverse the ordinary intrusions of the subconscious into the conscious field. The one formula expresses the fact that when the proper sensory clue is present we proceed to react to it without intent; and the other that having only a fictitious sensory clue we fail to act in spite of our resolution.*

* The more usual lapse of this temporary type occurs where the sensory clue is slight enough to pass readily in and out of notice; thus if one has slightly injured a finger, one is intermittently reminded by a sudden pain that it can not be used for the accustomed service; one steps upon a foot that is

The simplest type of subconscious motor response consists in carrying out a more or less suitable and habitual action, while remaining unaware of its accomplishment—a lapse, accordingly, not of performance, but of notification of the accomplished service to the conscious self. A. proceeds to wind his watch at a certain stage of his undressing to find it already wound through subconscious habit; B., already retired for the night, leaves his bed to lock the door and finds it securely fastened, and doubtless by his unobservant self; C., working at his desk on a warm summer's day, decides to remove his coat and finds he has already done so; D. looks about distractedly for a particular shirt and finds it on his own person under the one he had decided to discard; E., a clergyman, sends out the contribution plate a second time, much to the consternation of the congregation; F., a railway employee, changes the position of a switch, unaware that he has already reversed it, and wrecks a train: and so on with considerable variation of scene, plot and *dramatis personæ*. Let me note again that these instances involve a weakened sensory apperception, inasmuch as the second action is initiated because the first performance was so feebly attended to, so distractedly appreciated. Doubtless, more frequently than the complete dropping of the link out of consciousness is the doubt, the query, whether one really has wound the clock, or locked the door, or put out the lights, or posted the letters, or taken one's medicine, or even eaten one's lunch; and one proceeds to verify by actual examination or by some definite memory-clue that it has been done.*

I must give at least one instance of this memory-clue and its mode of working. A student, in this case a married student, had been entrusted to attend to some domestic commissions on his way to the university. Suddenly, in seeing the word 'business' in the course of his work, it flashed across his mind that he had forgotten the commissions; yet he was not sure. In trying to recall whether he had made the purchases or not, there clearly echoed in his mind the sound of the squeak of the door in leaving the shop. This sensory impression was his surest indication, and proved to be a reliable one, that he had entered the

not yet sufficiently recovered to bear one's weight; after operations to one's teeth, one unintentionally disobeys the dentist's injunction not to eat on that side for a day or two. A more complex instance of a lapse of this type is that of a young man who has just had an injection of belladonna put into his eyes, and who on his way home stops to buy a paper, chuses the one he wishes, and is quite unmindful of the fact that he will be unable to read it.

* The complementary memory failure occurs when one is quite certain that one of these habitual tasks *has* been done, and is confronted with conclusive evidence that it has *not*. It is the slight claim that the performance thereof has to our conscious attention that makes possible each kind of failure. It is not so much as lapses of memory, but as inattentive occupations that the instances are here apposite; and it is this aspect of them that makes proper their citation as motor lapses.

shop and performed his errand. The instance is apposite in both senses; first, the occurrence of the word 'business' arouses the dormant association with the earlier, somewhat submerged conduct; and secondly, the attempt to explore in this submerged region proceeds by the persistence of slight sensory impressions—faint afterglows—themselves quite uncertain, and not intrinsically connected with the central and important piece of conduct. As in retracing the more conscious links of memory, so also in the case of the subconscious ones, there is a tendency to reach the focus through some suggestive path from a dimly lighted margin.

Lapses of Confusion and Interchange.

Though this failure to make an impression upon the mental register offers the simplest formula of a subconscious lapse, it does not present the most common occurrence, presumably because it requires a somewhat marked degree of absorption or absent-mindedness. The most frequent type is that in which an action—usually partially inappropriate—is performed under the impression that it is a different, an intended and appropriate one. The first type is thus the suppression, obliteration, or omission of a strand in the network, the second a partial substitution. Here belong the many comedies of errors, trivial or embarrassing rather than momentous, in the lighter scenes of life's dramas. Cases of going off with a stranger's hat or cloak or umbrella or even his horse and carriage occur constantly, and furnish evidence that the absence of the signs by which we ordinarily recognize our own may itself go unheeded. The successful action of the process appears in the familiar feeling of suddenly missing something, at first not a definite something—cane, umbrella, parcel, book, shopping bag—which one has been carrying and has forgotten at some absorbed point of the day's commissions. It takes but a slight measure of distraction to submerge these superficial impressions so that they fail to perform the service usually expected of them. *Lapses that intrinsically have the same status appear in varied situations:* students occasionally go to the wrong class room; or find themselves on the way to the university on a Sunday; a college girl appears ready for a social evening in *toilette de bal* with a 'history' note-book in hand; an actress makes a hurried entrance upon the stage, having snatched a whisk-broom as a fan; a clerk, eating a hurried lunch and eager to start on his bicycle upon an important errand, finds himself carrying his chair out of doors, and making the initial movement to mount it as the iron steed. That here, as throughout the series, the degree of confusion depends upon the depth—momentary and temperamental—of the distraction may be taken for granted, and is definitely ascertainable in many cases; it is this dominant factor that, when written large, furnishes the clue to the more striking and the more

abnormal occurrences. It is, for instance, pertinent to note that a student who on leaving his class-room instantly observes that the hat and umbrella that hang upon his hook are not his, had not noticed this fact when he had taken these articles from his room-mate in the morning, and used them. The morning exchange occurs when the attention is not particularly directed to the recognizable personal marks of the articles; but in choosing one's own belongings from half a hundred others the identification process is more attentively demanded.

There is a characteristic and common variety of this substitution-lapse that consists in the interchange of parts of two activities, both of which are partially present to the mind. Sometimes the two activities are allied members of what may be regarded as a single occupation: sometimes the two are curiously unrelated, their connection being only that they are charged upon a common consciousness. Of the former I have quite an array of instances. There is the serving of the strawberry hulls while the berries are left in the pantry; the placing of the coffee-strainer on the tray while leaving the cup of coffee in the kitchen; the sprinkling of sugar on one's egg and dropping the salt in the coffee-cup; the placing of the washed dishes in the refrigerator and of the 'left-overs' of the meal in the pantry; the attempt to thread one's thimble; the intermittent dipping of the pen in the mucilage bottle and of the brush in the ink, while writing labels and pasting them on glasses; even the dropping of the watch into the boiling water, while consulting the egg to gauge the time; or, in the excitement of a fire, the throwing of a lamp out of the window while carefully carrying down the bedclothes. The more striking interchanges are naturally those of unrelated activities. The mind is charged with two tasks; and the round peg drops into the square hole. A young lady, upon receiving a letter while she is engaged in putting her hat away, tosses the perused sheets into the hat-box, and places the hat in the waste-paper basket. Under similar circumstances, with a book in one hand and some discarded papers in the other, the book is thrown into the fire or is rescued just as it is ready to leave the hand. A servant, instructed to fill the reservoir of the kitchen-stove with water and the grate with coal, drops the coal into the reservoir, but 'comes to' in the act of carrying water to the hot grate. Quite common is the throwing away of the article while retaining the wrapping, even when it happens to be a caramel, and the paper is put into the mouth. Unusual and yet natural is the instance of the young lady seated in the train and eating a banana, who, upon the approach of the conductor to collect the tickets, realizes that she has thrown her purse containing the ticket out of the window, while carefully placing the banana-peel in her hand-bag; or that of a young man, absorbed in a novel, conscious of the fading light, but too interested to stop to light the lamp, and also

conscious of a growing thirst, at length gets a match, then proceeds to the faucet and finds himself applying the match to the running water. Yet another interesting variation ensues when one or both of the two commissions requires verbal expression. Then we may encounter such confusions as that of the young lady asking a post-office clerk for 'individual salt-cellar,' or another demanding of a like official some 'gray matter.' The astonished clerk may have guessed in the first instance that the young lady had two commissions on her mind, one for the article demanded and another for stamps, and had uttered on the wrong occasion the request upon which her thoughts were bent; but he could hardly have surmised that the other was so occupied with an approaching examination in physiology that 'postal card' was intended when 'gray matter' was spoken. The last is paralleled by a third student who after a sleepless night asked his neighbor at the breakfast table for the 'sleep' when he wanted the 'cream.' There is a combined linguistic and psychological interest in these verbal lapses that entitles them to a more detailed consideration.*

Lapses of Persistence: Conflict of Habits.

I shall refer to two other types of subconscious activities in which the motor factors are prominent. One of these relates to the unintentional resumption of discarded habits after a rather long period of disuse. I have records of students trying to enter or actually entering rooms which they had occupied a term or several terms previously; and Professor James records that upon revisiting Paris after an absence of ten years, he found himself in the street in which he had attended school, and in a brown study reached quite unintentionally the door of the lodging several streets away in which in that earlier day he had resided. I have records from other sources of men recently married, returning to the parental home, momentarily oblivious of their newer responsibilities; of retired business men finding themselves in the train to the city quite without intent or definite purpose; and I have other incidents that require more detailed description. A young man had been employed as a conductor upon an interurban trolley line. He gave up this employment in March and in August found himself in the car on his old-time route. He entered the car tired and sleepy. Suddenly looking out of the window, he recognized, in no very wide awake condition, the point of the route at which it was customary to collect the fares; and a moment later he had begun to collect them and was 'ringing them up on the register,' when he realized the situation. Again, a young lady returns as a visitor to the boarding school of her youth, sits down at the seat which she had formerly occupied,

* Such consideration is given them in an appendix, entitled, 'The Lapses of Speech,' to form part of the volume announced.

and writes a letter. During the occupation she quite loses sense of time and condition, and having finished her writing, raises the desk to be confronted with the unfamiliar contents thereof. I have also from another source a tale—possibly mythical, but in regard to the individual concerned most plausible—of a mathematician who, bent upon the solution of an intricate problem while walking in the street, becomes aware of a black surface before him that suggests to his absorbed mind the familiar and convenient blackboard; he begins to chalk some formula upon it, when it moves off, for it is the back of a carriage that has been waiting for its occupant. In such wise do slumbering habits reassert themselves and take control of our actions when the attention is momentarily diverted; while the lapse is favored by the presence of a familiar external situation—one that arouses an easy, ‘at home’ kind of mood, one that may be responded to by the half-attention adequate to well-established bits of conduct.

A further indication of the readiness with which motor habits assert themselves in the absence of intentional initiative appears in instances in which such action persists and fails to recognize the new situation, or persists automatically by the mere inertia of a group of centers ‘set’ to a particular line of conduct. I have before me an anecdote that is quite as instructive, whether literally exact or not, relating that a tourist, reading the papers in a Berlin café, was repeatedly disturbed by men entering and tumbling violently over the door-sill. Seven times within an hour did the accident occur. His curiosity aroused, he made inquiries and found that these seven men were habitués of the place, gathering almost daily for a game of ‘skat’; and further, that the worn-out door-sill had just been replaced by a new one, in the unexpected height of which lay the cause of the series of mishaps. *Haec fabula docet* that we cross an unaccustomed threshold with sufficient and yet not apparent attention to our going to guide ourselves with tentative steps safely over any slight irregularity that may be encountered; but that for the several entrances and exits, literal as well as figurative, that enter into our daily walks, we have ready a decidedly more subconscious, inattentive response that may in the event of meeting new conditions set pitfalls in our path. Ordinarily such motor habits are exercised to meet situations the factors whereof are or may be—in the early stages of the acquisition doubtless were—realized in terms of visual and other sensory recognitions. To illustrate: the seven companions each originally learned to enter the café with a step appropriate to the worn-out door-sill, and did this by noticing visually the position of the sill, quite as I have learned with very slight attention to strike the several keys of my typewriter, to release the carriage, reverse the ribbon, engage the paper and advance it, by originally noting consciously and attentively how these mechanisms are set in operation.

And if I use an unfamiliar typewriter, I must assume a more attentive attitude to my manipulations, working out some of them deliberately anew; and I am quite likely to find myself intermittently attempting to perform on the new machine a manipulation that is proper only to the more familiar one. The relations are distinctly intensified when the coordination involved is more deep-seated, less consciously realized, more distinctively a function of the automatic centers. Activities guided primarily by the feelings accompanying muscular contractions, in contrast to those guided primarily by vision, furnish the most favorable instances of what is here involved. A very striking one is found in the attempt to ride a tricycle by one accustomed to the bicycle. The equilibration of the bicycle requires that one lean *with* the machine, to the right in turning to the right, to the left in turning to the left. This in itself is contrary to the normal walking habit of saving ourselves from falling by shifting to the opposite side, and had itself to be learned with some difficulty, because opposed to another ingrained tendency. Seated on a tricycle, the bicyclist unwittingly and in spite of himself maintains the bicycle-balancing habit, and is surprised to find the simple tricycle, which one without any experience with either can guide easily, quite beyond his control. The old habit persists and will not make way at once—though doubtless it would in time—for the new adjustment. What is distinctive of this experience is the strenuous persistence of the motor habit in spite of a considerable and conscious effort to check it—a relation that in turn is significant for the comprehension of unusual and pronounced lapses. Another example of such conflict of motor impulses may be arranged by attempting to write not by direct visual guidance of the pencil, but by following the tracing of the point (with the hand and pencil screened from direct sight) in a mirror or system of mirrors. The new and unusual visual guidance tells one to move the pencil in a given visible direction; but this direction of seen movement has always meant a certain kind of ‘felt’ movement; and when that type of ‘felt’ movement is set into action it proves to be, by the visual standard, completely and variously wrong. The struggle between trying to push the pencil in the direction one *sees* one ought to go, and also in the direction one *feels* one ought to move, may become so intense as to be quite agonizing; and the attempt must be abandoned as hopeless. Remove the mirrors and use the normal visual guidance, or close the eyes and use the normal muscular guidance, and the writing proceeds fluently, with but normal effort and attention. Oppose the two factors of the normal combined and harmonious synthesis, and confusion irresistible—a confusion, not of conscious intent, but of execution, of deep-seated automatic motor mechanisms—takes place. Likewise should it be noted that of all these modes of guidance are we normally but vaguely aware; so much is this the

case, that if called upon to describe how we guide our writing, many would be as much at a loss to reply as if questioned how we know which is the right hand; and while realizing that eye and hand both contribute to the writing reaction, would we be unable to apportion the manner of dependence that exists towards each of these sensation-groups.

Automatic Conduct: The Motor Dream.

I have introduced these considerations at this juncture in order that the rationale of the motor aspects of these lapses and confusions may be succinctly appreciated. We return to the more characteristically intellectual activities with prominent motor factors, to note the persistence of such occupations when the directive influences are removed. An important type of such removal occurs nightly in the condition of sleep. If regulated and complex groups of movements, organized pieces of conduct, may be performed without arousing consciousness or leaving a trace in the waking memory, then the thoroughness with which the motor habit may be aroused without arousing the awareness which its original acquisition required, becomes the more completely established; and though this is not in the strict sense a lapse, it does illustrate the nature of the tree and of the soil on and in which lapses grow. Though such occurrences demand a predisposed temperament or temporary condition of excitement, they occur quite frequently, and particularly in youth.* They appear as active dreams, of which sleep-walking (somnambulism) is but one type. The simplest type is that in which a lively dream passes over into action. A little girl who had spent several hours of a day in jumping into a sand pile, makes a similar leap in her sleep from the landing to the hall below, awaking with sobs and bruises and the explanation, 'I thought it was the sand pile.' A sleeping boy is aroused by the firm clutch of a hand upon his feet, and hears his younger brother call out, 'I've got you now.' These words proved to be the reaction to a dream of the younger lad that some one had stolen his stockings, that he had left his own bed to pursue the offender, and that in seizing his brother's feet he had just reached the *dénouement*, the arrest of the culprit. A high-school athlete, on the eve of a contest in which he had entered for the broad jump, awakes to find himself upright in bed, his knees under him, ready to jump; and is able to recall his dreaming of the contest, the trials of his competitors and the calling of his own number, to which he was respond-

* The number of instances of this character which my students record of themselves as children, or of their young sisters and brothers, suggests that early youth is the favorable period for active, somnambulistic, dramatic and somniloquent dreams. It is not that these habits are more automatic in youth, but that the intensity with which interest demands expression in action is then more pronounced.

ing when the waking consciousness took control. A young man is observed by his room-mate to leave his bed, grope about the room, step on a chair, and take down two pictures, disposing them under the bed, then returning to sleep ignorant of the whole procedure. Inquiry on the following morning revealed that he had dreamed of these pictures, toward which he felt a strong dislike, and had acted out the antagonism in his dream. Another boy, dreaming of swimming, dives out of bed, with unpleasant consequences. A fourteen-year old maiden, the star of the swimming class, was found at night by her mother, standing on the window in position for a dive to the ground below. A father, excited by an account of the kidnapping of a child, arises at night, goes to the cot of his little boy, places the child on the floor, tumbles the bedclothes over him, expresses satisfaction at having safely hidden the child from the pursuing kidnappers, and is with difficulty awakened and made to realize that he is responsible for the disordered room. The daughter of the house, placed in charge of the household in her mother's absence, prepares her father's late supper, and, though tired, persists in her labors, washing the dishes and laying the breakfast table. In the middle of the night her father is awakened by noise in the kitchen and finds his daughter rewashing the same dishes in her sleep. A young man, upon retiring, wanted some hot water, but was unable to find a match to light the gas-heater, and so went to sleep. He found himself at midnight, standing in the room with a lighted match in his hand. The details of the dream were gone; but it resulted in his finding a match in his sleep and in his proceeding to carry out the unfulfilled purpose.

These instances of dreams that reach the motor stage relate, in the main, to activities which were prominent in the waking consciousness at the moment of going to sleep, and the reverberation of which, as of the dominant theme in the mind's occupation, enacts itself in the hypnotic drama. Simple, habitual actions, and occasionally complex ones, are performed automatically without awakening consciousness, but apparently must, in a measure, be charged upon the sleeping self. A young man sleeping in a caboose lay down to rest with his clothes on, but awoke later, surprised and chilled, with much of his clothing removed, the normal undressing for the night's rest having been performed in a moment of lighter sleep, but without awakening. Again, a sleeper, partially disturbed by the entrance of his room-mate, falls asleep, but presently rises and pulls down the shade, a habitual action before retiring. Doors are locked and unlocked, alarm clocks are placed in their customary positions, lights extinguished, or other habits of the retiring hour are carried through in sleep. Cases of true somnambulism occur, including one in which dressing, walking to a pond, adjusting skates, and then skating were all properly guided in sleep;

including another that involved going to the kitchen, mixing the ingredients for a pie, and placing it in the lighted gas-range, the charred remains astonishing the nocturnal cook the next morning; or of still others recounting the prowling about at night in response to the sensations of hunger, or seeking coats and wraps because of sensations of cold. Subconscious doing in sleep as in waking reflects the motor versatility of our habits adjusted by training to the complex life in which we live and move.*

The Sensory Lapse.

The sensory side of the process demands equal recognition. It is well to repeat that all of these several types of subconscious action, the motor aspects of which have been singled out for analysis, do also involve a recognition of the situation, a sensitiveness to the suggestions of the environment, that both realizes—though it may be imperfectly or mistakenly—and responds thereto with submerged awareness. The first group of instances, in which actions are entered upon in oblivion of their accomplished performance, shows how readily sensations, that would ordinarily be registered, fail to make an impression; but this ‘absent-minded’ insensibility is still more neatly illustrated when an article is deliberately sought, and yet the sensations by which its presence would normally be recognized remain persistently ignored. This is indeed an accepted trait of the distract. My collection is replete

* I have not regarded it as necessary to include in this survey the familiar association of habits in the routine of complicated actions, by which the one step leads to the next, even though the occasion is an unintentional, inappropriate one. This type of lapse is extremely common and is apt to occur under but slight release of tension of the directing consciousness. It is also directly involved in several of the groups of unintentional motor actions just described. Its most typical form, however, is in ‘absently’ winding one’s watch when changing one’s waistcoat, or in continuing the undressing reaction to an unnecessary degree, simply because that act is more particularly associated with the complete undressing of the retiring hour; while as the feminine counterpart I am given the unintentional release of the hairpins when negligée is assumed; and in my collection, a frequent occurrence corresponding to this formula is the turning of the electric button, when entering the room, resulting at times in turning on the lights at daytime, or in an inadvertent turning off the light in passing the door, thus leaving the other occupants of the room in the dark.

† I pass by with slight mention instances of simple ‘anaesthesia,’ that is, the failure of sensations, through inattention, to enter the perceptive field. I do this because the relation involved, clearly important, is not likely to be overlooked. The inevitable contraction of the sensory field is familiar; and we have only to recall occasions when a question must be repeated, and we confess that we did not hear, at least with the mind’s ear, what was said. Such is merely the common and necessary, but here untimely, relaxation in the attention wave. Occasionally such insensibility does give rise to peculiar

with such lapses: looking for a handkerchief that is held in the hand, for a pipe that hangs in the mouth, for spectacles reposing on the forehead, for the umbrella grasped under the arm, for the pencil stuck behind the ear, for the package suspended from the hand—these are commonplace, usually of brief duration, but instructive, because of the attitude they present, the important query which they raise, in regard to how and why these sensations, usually sufficiently awarable, fail to qualify for consciousness. The moment of reentry into the conscious field is easier to detect than the manner thereof. The missing article that all along lay within the easy field of vision, seems suddenly to assume a familiarity that identifies it as the object of search; the vacant stare or bewildered reconnoitering is transformed into the intelligent look of recognition. The instances report little more than the fact that the handkerchief held in the hand, or the pipe in the mouth, or the umbrella under the arm, does suddenly yield the sensation of its presence. I have, however, one incident in which this realization was logically arrived at: the narrator was seeking his glasses which he had begun to use only a few months before; and, observing that he could clearly see the print before him, concluded that he must be wearing his glasses, which proved to be the fact. What is common to these cases is the peculiar and often unaccountable fluctuation in permeability of consciousness to definite types of stimuli. The failure or omission of perception—both when the mind is not particularly bent upon receiving the impression, and when such is the attitude—expands readily into an erroneous perception, a substitution; and naturally, similarity of observable characteristics favors such mistakes: and this, because of the general principle that minor fluctuations of attention occur more frequently than more pronounced ones, and of the further principle, that slight confusions, in which the confused objects present many common characteristics, require only a moderate relaxation of attentive oversight, while more serious lapses demand a more pronounced absent-mindedness. Hats and umbrellas and gloves and overshoes and overcoats are the more readily interchanged because of their generic uniformity. The more variable and distinctive feminine bonnet does not lend itself to such subconscious borrowing. The whisk-broom that is hastily seized for a fan presents some slight tangible resemblance, though we pass quite beyond such resemblance when the chair is handled as a bicycle. Quite pertinent to this relation is the confusion

situations which may be called negative lapses in that, though it would have been natural and profitable for the subject to awaken to the situation, he fails to do so. The best instance in my collection is that of a young man resigning himself unconcernedly to the manipulations of the barber, with the instruction to have his hair trimmed and his moustache shaved, who becomes aware only at the close of the operation, that through the barber's error he has had his head shaved and his moustache trimmed.

of a young lady upon whose table stand two similar boxes, one containing stamps and the other keys, and who 'absently' tries to affix a key to the letter which she has just sealed. Such disparate substitutions begin to require a different formula, one that recognizes two under-currents of thought and explains the confusion as the crossing-point of the two slightly or markedly divergent streams.

Subconscious Perception and Association.

The specific lapsing of the sensory factor in conformity to the psychologist's analysis would be revealed in the attitude of obeying, or tending to obey, an impulse with complete inability to account for its *provenance*, or with a vague haziness surrounding it, which eventually dissolves under a gradually rising attention. Awareness of impulse or action without awareness of the incentive thereto, sufficiently formulates the attitude, which is objectified in finding oneself handling something or other with the mental query, 'What was I wanting to do?' or, 'Why was I doing this?' The principle is important and finds application in pronounced and abnormal manifestations of consciousness, as well as in ordinary deviations. Illustrations thereof are somewhat elusive; the lapses are evanescent, momentary, but significant. A young man, busy with his studies, while his room-mate is away paying court to the one of his choice, is suddenly seized with the idea that it would be a good joke to disturb the courtship by telephoning to his chum that a telegram was awaiting him at his room. As he proceeds to the telephone, he is met by the landlady, who informs him that such a telegram had actually arrived. He is utterly astounded at the coincidence, but is forced to conclude that he had actually, but not consciously, received, two hours before, some vague, yet subconsciously effective indication of the arrival of a telegram for his chum. Two young ladies are lolling in a hammock on a hot summer's day. All energies, mental and otherwise, are relaxed. The mother of one of them asks the daughter to step into the library and get a certain book. The request seemingly goes unheeded; and the languid inactivity continues. Presently the daughter goes into the house, is heard fumbling among the papers and magazines on the study-table and reappears with the book, saying, 'Mother, I saw your book in the library and thought you might want it.' The surprise caused by the laughter that greeted her remark proved her ignorance of the request upon which she had acted.

Under fortunate circumstances a considerable variety of such subconscious perceptions may be detected; as a rule they escape observation, or are beset with vagueness and uncertainty. If we proceed beyond the outward recognition, to the elaboration that interprets the situation, to the associations which it arouses, we shall have another point

of view by which to gauge the intercourse between the conscious and subconscious movements of thought. A student has mislaid her notebook, and after a thorough search fails to find it. The next day as the telephone bell rings, she instantly remembers where the missing book lies; for on the previous day just as she was preparing to go to the university, notebook in hand, the telephone bell had rung, and in answering the call she inadvertently had left her book upon the telephone-stand. While riding a bicycle, I turned a street corner rather abruptly and in doing so I caught a glimpse of two ladies, and mentally recognized one of them as Mrs. S. Upon overtaking them, I discovered that the other one was Mrs. S. The first, less conscious recognition had been referred to the wrong sensory stimulus. Quite similarly, a young man engaged in some absorbing occupation is asked to go to the cellar and bring up some coal; presently he returns with an armful of wood. He had been sufficiently attentive to appreciate that fuel was wanted, but a precise recognition was lacking. A young lady was busy reading, taking notes with pencil in hand, and presently emerged from a spell of abstraction to recognize that she was holding, not a pencil, but a pair of tweezers. Retracing her occupation, she was able to recall that in reading she had been passing her fingers over her face—a common habit—had come in contact with a superfluous hair, had reached for the tweezers, and in resuming a more attentive attitude towards her reading, became aware of her lapse.

Absent-Mindedness: The Temperamental Factor.

Any further analysis of subconscious lapses, of their varieties and predisposing causes, requires a more intimate consideration of a factor to which repeated, and yet but casual, reference has been made—namely, the degree of abstraction that prevails, the remoteness of the action performed in the indirect field of attention from the focus thereof, or, it may be, the deviation in alertness of the faculties from their normal functioning. A certain intensity of concentration brings about a loss of orientation, a forgetfulness of self and surroundings; the regaining of which after such a moment of ‘rapture,’ ‘brown study,’ sleep or anaesthesia is variously interesting. Naturally the more bizarre and inconsequential lapses demand such decided fluctuations of self-adjustment as occur commonly only in those by temperament predisposed thereto. It is quite prominent how frequently those who contribute such instances admit that they are frequently detected in absent-minded loss of self. The slight or incipient form of the defective adjustment to which the state leads, every one can appreciate from the common experience of consulting one’s watch merely for one’s own information, and yet being wholly unable a moment later to tell what is the time. Students look up foreign words in the dictionary in some similar mental

preoccupation, and as they close the book, become aware that they do not know the equivalent which they had actually found and read. Just how extensive the loss of orientation becomes can not be determined by the nature of the error which it induces, but must be inferred more intimately from the temperament and introspective account of the subject thereof. The man who, suddenly fearful that he had forgotten his watch, hastily explores the outside of his pockets, fails to feel the object of his search, and a moment later consults his time-piece to see whether he has time to go back and get the forgotten watch, may be regarded as suffering from a decided lapse of orientation sufficient to becloud his rational habits. Yet the degree of objective confusion involved in the following narrative is no greater than in many others, though the context suggests a decided mental wandering. A young lady, after the wear and tear of an amateur play, was returning a helmet which she had borrowed as 'property,' and passing by a laundry, entered, wrote her name on the package, asked when it would be delivered, and was only 'brought to' by the astonishment on the clerk's face when a partial unwrapping revealed the nature of the article. The same comment may be made upon this instance as well: a young lady calling upon her friend to borrow a bicycle, found only her brother at home. The latter was pleased to be of service, brought out his sister's bicycle, inflated the tires, then took the trouser-guards from his own bicycle, offered them, along with the machine—and realized that explanation was hopeless. One also hardly needs the confession of the subject of the following lapses that she is constantly losing herself, particularly under mental excitement, or apprehension, such as examinations bring in their train. Knocking at her own door and waiting for an answer, rubbing one foot against the other and saying, 'Excuse me'; sitting in her room absorbed in work, and realizing the passing of muffled steps outside the door (such as made by rubber heels which she herself wears), she mentally comments, 'There goes ——,' meaning herself—such are the tales laid at her door, which in substance are acknowledged.* Here the condition approaches that of

* It may not be out of place to note again that the type of action here illustrated is just as apposite whether it leads to an inappropriate issue and thus figures as a lapse, or whether the subconscious mechanism correctly carries the action through to its normal result. The same degree of abstraction that is needed for these pronounced lapses is perfectly comparable with equally and even more pronounced activities correctly performed. I have the testimony of a lady of domestic habits and decided literary tendencies who frequently finds herself going through so prosaic an occupation as washing dishes in a vague sort of way, quite surprised to find that she is through, and about equally unable to retrace in memory the successive stages of her manual labor and of her far-away thoughts. Indeed there is abundant evidence that mental wandering occurs more frequently without leaving in its wake interesting or recordable trace of its influence upon the waves of thought, than it does thus aid the psychologist in the pursuit of his problems.

the transitional stages from sleep to wakefulness, in which partial adjustment to the real environment, partial domination of the dreamy unadjusted or inwardly absorbed consciousness is in control. In such a condition a night operator at a small railway station, who was rarely called between midnight and four o'clock and frequently slept during parts of these hours, though always awakening to the combination of clicks that formed his personal summons, dozed off at midnight, and was awakened an hour later by the appearance of a conductor of a special train that had arrived without awakening him. The latter at once asked him for his train orders. The signal was displayed preventing any train from passing the station without stopping for orders; on the desk at the operating key was an order in his own handwriting, which was verified and found to be correct. With only the feeblest recollection thereof, the drowsy or sleeping operator had interpreted and recorded accurately his telegraphic duties. It is doubtless more likely that in such a half-awake condition the wrong response would be made, such as that of an operator under similar conditions who, suddenly aroused, went to an automatic vending-machine and tried to call up the despatcher by manipulating it. The half-awake, half-oriented consciousness is typically not critical, is satisfied with partial resemblances, and is suggestible; it occupies the middle ground between the lapses arising from a temporarily sleeping orientation and the more serious disturbances sequent to more fundamental lesions of consciousness.

Revery and Dreaming as Lapsed Procedure.

We have now to observe that the apperceptive recognition takes place on the basis of the preparedness, the qualification to interpret, that is the expression of previous experience, dominant habits, customary modes of absorption; and that much of this preliminary setting or tuning of the mental instrument goes on subconsciously. We have found a rather effective formula for certain groups of lapses in positing that two trains of ideas cross, or intermingle, or get their respective components interchanged. Now, if one of these is the more attentive reaction to what is objectively presented, and the other what is less reflectively supplied from the subconscious preparatory mechanism, our formula could be extended to a further range of elaborative processes. A graduate of the University of Michigan, upon coming to Wisconsin, found himself for some time reading the posters announcing football and other events as referring to Michigan, the initial *W* being inattentively interpreted as an *M*, and the rest following from the inner expectation. Expectant attention, itself largely subconscious, enters to modify perception and to prepare the way for more and more startling illusions and misinterpretations. Similarly in regard to associations: A., hearing the

blowing of a whistle, suddenly thinks of the high school which he had attended and is able to trace the connection in that the school stood next to the engine-house that announced all fires by a similar whistle. B., while listening to a certain aria, finds himself visualizing a face that becomes definite and recognizable, and proves to be that of the friend who frequently played this air. C. awakens from a nap and, in the brief languor before rising from his couch, is able to arrest the association of the moment's waking reverie: his eyes rested upon the outlines of the window panes which presented a series of oblongs with the long side horizontal; he appreciated that the panes were really higher than broad, and that the effect was due to the crossing of the bars of the one sash with those of the other; reflected that the effect was pleasing, that he had seen it in old houses and in new ones built on old models; then visualized a window containing these broad panes; then thought how easily in ordering window panes of such shape, a carpenter might make a mistake and set them with the long side vertical instead of horizontal; speculated whether such an error would require the job to be done over again; then visualized a fireplace showing the color and design and setting, in a house which he had built fourteen years before, in which the faulty drawing of the architect had resulted in a badly proportioned opening, an irreparable mistake; then visualized the face of the culprit architect; and at this stage entered a wide-awake condition wondering why this face should be present, and was just able to resurrect by a reverse memory the aforesaid series of uncontrolled subconscious associations. D. emerges from a brown study, vaguely aware of a misty medley of flitting faces, is able to revitalize but one of them which, much to his surprise, proves to be his own reflection as he sees it in his glass while shaving; and is able to trace the appearance (a probable but not demonstrable source for others of the faces as well) to the series of illustrations scattered among the advertisements in a popular magazine which he had been perusing, one of them, on the open page before him, setting forth the excellence of a certain make of soap by picturing the foamy lather on the shaven cheek. And all of us meet with such unexpected sequences in trains of uncontrolled thought, of which we recall only the more striking and accountable. Towards the great majority of these we do not, and could not if we would, assume a successful introspective attitude; they are far too elusive to be caught in the resurrecting process that attempts to draw them from their submerged retreat. Depending, as such instances do, for their record upon favoring circumstances coupled with a somewhat skilled introspection, it is not surprising that my casual collection contains few of them. When, however, the elaborative processes are carried on, not in momentary lowering of attention, but in the vivid projection of a dream, we obtain a different though equally convincing

record of their prevalence and of their mode of operation. Such are instances in which the data are derived directly from the dreamer's environment, but the elaboration is supplied by the submerged mentality; the material is furnished, but the weaver operates the loom. The following is apposite: during the afternoon there had been a sham battle of the university battalion, and the narrator—a college girl—had watched with interest the passing of the regiments. During the night—about one o'clock—a telephone message arrived at the sorority-house announcing a death in the family of one of the members, A. The household was at once aroused and excited. There were more telephone messages, much walking in the halls, a message sent to the railroad station to hold the train if need be; and A. went off. Now the narrator was only partially aroused by all this commotion, had no distinct knowledge of A.'s departure, but had the memory of a vivid dream: "I dreamed that I was at the northwestern station in a large city and that companies of soldiers hurried to the train. I was very much excited, and it seemed to me that some one whom I knew well was about to leave. The engine whistled and started to move when some one called, 'Hold the train for two minutes; I must get home.'" Here is another lucid instance in which the apperceptive processes take the guise that dream-fancy gives them. From her seat in church the narrator noticed in one of the forward pews a young lady seemingly familiar, took note of her hat and dress, had no opportunity to ask any one who it was, and was vaguely worried during the day by attempts to identify the person. In the dream of the night there was an automobile race; motor-cars of all sorts whizzed by in rapid succession, each bearing the name of the owner. One with a buggy-top, had marked in red letters against the black body of the vehicle, 'Ethel R.' Miss R. was guiding it, and was wearing the hat and dress that she had worn in church; and so the recognition was complete. The association of the face with the automobile had been intruded subconsciously; and as there were few, if any other automobiles of this pattern in the town, the associative clue was naturally successful.

The Subconscious in Lapses and in Adjusted Conduct.

There are many other instances of identification processes and similar solutions of queries in dreams; indeed the successful completion of problems, linguistic, mathematical, mechanical, personal, constructive and imaginative, is far more common in my collection of subconscious activities than was anticipated. The intellectual labor thus accomplished is not frequently of a high order; but it adequately establishes the continuation in sleep, or at times the clarification of activities that were prominent, even absorbing, in the day's occupation. They thus conform to the formula of persistence of activity of a brain stimulated in a certain direction, with,

in addition, not merely a rehearsal of, but an advance upon, the foregoing stages. Those without much new progress or with only slight variations of the theme are clearly more frequent than those that browse in pastures new; and the simplest of these are hardly more than reverberations of neural excitement. After an ocean voyage many persons continue for days to react in their sleep to the sensation of the ship's motion, which enters variously into dream-composition. A young man, having been occupied during the day in hay-making, and another in rolling stones, each continues with the same operation in his dreams; a young lady having spent a weary day in making paper poppies sees rows of these in her dreams; and so on with familiar variations. The whereabouts of articles that have been mislaid and looked for strenuously, but in vain, is clearly revealed in a dream; anticipated examinations are rehearsed, and imaginary but pertinent questions set and answered; missing quotations are referred to their proper source; forgotten lines to complete a stanza are recalled; arguments to defend an actual position are passed in review; and in rarer cases such rational procedures find their way to utterance, the dreamer mumbling or speaking the words that express the onward movement of his thought; and in the rarest of cases the sleeper arises and records them. So various are these operations that it is safe to say that they include the entire range of psychological processes that enter into constructive thought; and likewise do they retain analogy to the intrinsic relations and modes of procedure that characterize them when performed with normal waking attention. Even these most rational achievements of the subconscious bear unmistakably the stamp of the normal habit of thought, and emphasize their conformity in spirit, along a variable divergence in form, to the characteristic traits of human psychology.

This collection of illustrations thus suggests upon what various occasions, with what different tempos, the mind freed of its normal guidance continues to trot with the accustomed gait, stopping, like the horse that draws the milk-cart, at the proper points of call without direction of the driver (who for the moment may be asleep); though, like the horse, content with the mere appearance of a service performed, unappreciative in part of its meaning, subject to lapses and inconsequential wanderings. But horse and driver are endowed with very different psychologies; and the relations that become established between them, however intimate and intelligent, reflect the limitations and divergence of needs and interests of the two. It is quite misleading to think of the subconscious as a veritable, independently organized 'psyche,' or as a subservient understudy, however partially apposite and wholly legitimate such comparisons may be as metaphorical aids. The conscious and the subconscious (if we may clothe these aspects of our mental life in substantive form) are two souls with but a single

thought, for the sufficient reason that they are but one soul; and the unity of their heart-beat is inherent in the organism that gives them life. It is because the silent partner of our mental administration is only the sole head thereof under other guise, in other mood, with other, possibly more playful, occupation, that his dominant habits, interests, endowment, experiences pervade their common business. It is again because the one contributes to the joint undertaking, all unheard and unseen, that those who have intercourse with this concern, as indeed the director thereof himself, have little occasion to come into direct contact with influences and data that do not appear upon the books. It has been our present purpose to set forth, and mainly through the minor departures in thought and behavior, how constantly the subconscious participation permeates the entire network of the mental business. It is indeed the peculiar virtue of the abnormal method that it illuminates the rule through the exceptions; and here finds in lapses illustrations of significant principles that prevail in the normal, well-adjusted conduct of affairs.

FAKE WEATHER FORECASTS.

BY F. J. WALZ, B.S.

DISTRICT FORECASTER U. S. WEATHER BUREAU, LOUISVILLE, KY.

THAT the dissemination of erroneous predictions and false prophecies of any kind is always injurious is very evident. In every community there are always many to believe and take fright at any prediction of disaster, however baseless such a prediction may be. Certain then it is that the publication of weather forecasts based on theories, often little better than superstitious conjecture, especially when these forecasts attempt a prediction of atmospheric phenomena of a dangerous and damaging character, such as severe storms, floods and droughts, is an injury to the public interest.

In our day and generation there are so-called long-range weather forecasters, who persist in their efforts to foist their predictions upon the public for personal gain. Too often they receive liberal compensation for their absurd predictions, thus preying upon the credulity of the public. It is mainly to help to counteract this growing tendency by explaining their methods and theories that this article has been prepared.

All times and all peoples have had their weather prophets. No factor among the forces of nature influences man's temporal well-being more than weather and climate, and hence the changes in weather conditions have been carefully studied from the earliest times, and attempts made to account for their causes, and thus be able to foresee them. The appearances which were found by experience to precede weather changes have been noted from time to time, and these have given rise to many weather proverbs, many of which are the result of close observations by those compelled to be on the alert, and hence are based in part upon true atmospheric conditions.

It was but natural that, in the lookout for weather signs, men should have studiously scanned the heavens, and have associated the celestial bodies with changes in the weather, often erroneously, as causation. Thus astronomy has been closely associated in the popular mind with meteorology. This has taken such deep root that even today a weather observer and prognosticator is to a large extent popularly associated with telescopes and the celestial sphere. This may account for the ease with which so many people can be gulled by weather predictions pretendedly based upon the influence of the planets. Meteor-

ology too was so long neglected, both in popular and liberal systems of educations. But this has changed, and now even throughout the public schools of this country the subject of meteorology has taken a firm place.

The moon was for a long time widely held, and deep in popular belief, as the great weather breeder and prognosticator. But in recent years the lunar idea of weather control has been largely discarded. This belief could hardly be considered more than a mere superstition, as it is impossible to see from an astronomical analysis how the varying positions of the lunar cusps could in any way be connected with the character of the weather.

The moon's appearance to us depends on the relative position of the moon and sun in regard to the observer's horizon. From new to full, the moon gradually increases from a crescent to a full circle, and back again from full to new. The positions of the crescent vary, as the moon (shining by the light of the sun which she reflects to us) is sometimes north of the sun's path and sometimes south of it. The variation is probably noticed most in the new moon which is seen when the sun is just below the horizon. A line joining the horns of a new moon is sometimes nearly vertical, and oftentimes nearly horizontal. These were supposed to foretell the weather, the first being called 'wet moon' and the second 'dry moon.'

Even if the several lunar phases did influence our atmosphere, the same phase should produce the same effect all around the world (as the earth revolves on its axis in twenty-four hours) for any given latitude circle. It is true that the ocean tides are for a large part the result of the moon's attraction, but this force, when applied to the earth's atmosphere, is wholly insufficient to produce any appreciable disturbance in the atmosphere. It is most probable that the moon belief grew up out of the naturally frequent coincidence between certain weather changes (and certain brands of weather) and selected moon phases. The moon enters a new phase, or quarter, every seventh day, and the weather (at least in the middle latitudes) changes on the average of one to two times in seven days; hence there must be a great many accidental coincidences. And if one counts the agreements and overlooks the disagreements, quite a theory could be announced. The lunar phase theory was not found to bear the test of accurate comparison of weather observations with the lunar phases, except in this very slight and imperfect manner, which is entirely insufficient to have any value in weather prediction. Nevertheless, the moon and her changing phases have been the basis of nearly all the weather forecasts found in the almanacs. And the almanac has probably received more wide distribution, and been more greatly cherished by the people of all countries, than any other publication, next to the Bible.

Nearly all countries have had their almanacs, but they were particularly popular in Germany and England. In America, probably, the almanac which has been more widely read and its weather forecasts more generally credited than any other, is the Hagerstown Almanac, which has been published regularly every year since 1794. Yet the weather predictions appearing in it were based entirely upon the time of day the moon entered into any one of her four quarters. For instance, if this happened between midnight and 2 A.M. it indicated fair weather in summer, and fair with hard frost in winter, unless the wind be south or southwest. While, on the other hand, if this change occurred between noon and 2 P.M., it indicated very rainy weather in summer, and rain or snow in winter. And so a table, claimed to be constructed on a due consideration of the attraction of the sun and moon in their several positions respecting the earth, was prepared for all the hours, and thus was weather forecasting simplified and made easy.

The full moon has usually been associated with clear, cold weather. This is probably because we notice the full moon so much more when the weather is clear, and also clear nights are cooler on account of more rapid radiation of the earth's heat than when blanketed with clouds. Also since the moon's path on the heavens is so near the ecliptic, and full moons are always 180 degrees from the sun, they are far north in winter, and thus longer above the horizon in the northern hemisphere than they are in summer, and thus we associate full moons with our long, cold, winter nights.

So much for the moon as a weather forecaster. Let us take a look into the planetary theories.

Along with astronomy, which had its beginning away back in history among the Chaldaeans, the Chinese and the Egyptians, there grew up the art of astrology. Egypt was a particularly rich field for this art. Astrologers not only professed to tell the future weather and the seasonal conditions from the relative positions of the planets, and the sun, moon and constellations in the heavens, but could foretell the results of all human endeavors and desires. They could read the future of the individual and the state. Astrological predictions, however, could not stand the light of education and modern scientific knowledge, and we could hardly say that in the twentieth century, in educated countries, they have any credence whatever. Yet the predictions of our day so-called long-range forecasters, based upon their planetary theories, have as little foundation in demonstrated facts as did those of the astrologers.

Among the most famous astrologers, outside of Egypt and the Orient, was one Dr. Thurmeisen, a man of truly great genius, who resided during the eighteenth century at the electoral court of Berlin.

He was the 'pooh-bah' of the court, occupying the positions of physician, chemist, printer, librarian, drawer of horoscopes, astronomer, etc. He compiled annually an almanac in which he indicated the principal weather events, including the temperature for each day, besides the general character of the seasons and the year. This almanac had enormous success for twenty years or more, and helped to amass a fortune for the author.

I have before me a little volume holding between its covers copies, for the years 1791-1800, inclusive, of an almanac published in London by one Francis Moore, physician. This almanac in its day had great sale and reputation. It gives predictions by months and also by quarters, based, as it says, 'upon observations of the influence of the Planets.' Besides the weather predictions, Dr. Moore seems to have read the horoscope, and prophesies about everything else in the universe. A few quotations taken at random might be interesting. "Summer Quarter, 1794. The Position of Saturn causeth Cold and dry Diseases proceeding from Melancholy, mixed with tough Phlegm, causing Obstruction and Indigestion in the Stomach, Heaviness in the Head, etc., the cure of which must be left to the care of learned and able Physicians; as for the Weather Consult the Calendar Part." Consulting the Calendar Part, I find the following predictions: For June, "Rain (more or less) may be expected about the 8th, 17th, 24th and 30th days of this month; the day before or the day after." The July and August predictions are similar to this, only a little variation in the dates. For January, 1794, we read the following forecast: "Rain or snow (more or less) may be expected about the 2nd, 10th, 16th and 28th of this month; the day before or the day after; that is, within the Triduum, or Compass of three days."

I also have before me a copy of 'Word and Works' for January, 1904, containing the weather forecasts of Rev. I. R. Hicks for that month. As these forecasts, as printed, take up more than two columns in that paper, I will not give them in full, but confine myself to exact quotations from the salient features:

"Forecast for January, 1904. We enter the new year in the midst of a Venus perturbation. This will insure some very great extremes of temperature, with violent storms and blizzards during the regular and re-actionary storm period. The first storm period is central on the 2nd, 3rd and 4th." (Central where, it does not say.) "During this period we have the moon in opposition, etc. A general reaction to warmer will set in to the west as we enter this period; the barometer will fall decidedly, and storms of winter wind and rain will turn to gales and blizzards as they advance eastward on and touching the 2nd, 3rd and 4th. Look for sudden reaction from moderate to extreme cold weather immediately behind the rain stages of storms at this and

other January periods. Electric storms, very high tides and seismic shakes are among the probable phenomena at this time. A regular Vulcan storm period covers the 6th to the 12th, being central with moon's last quarter on the 9th. This period lies near the center of the Venus period on the 12th. As we enter this period the weather will again moderate; winds will shift to southerly and easterly; the barometer will fall in western extremes, and general storms will organize and pass in regular order from west to east from about the 8th to the 12th. The first stages of these storms will most likely prove moderate and rainy, but as the high barometer pushes into the low areas from the northwest, look for high winter gales, blizzards of blockading snow and sleet and a severe, dangerous, cold wave. If the barometer is very low in the far south at this time, the cold wave will not stop short of the Gulf Coast. Watch your barometer as far south as Florida. If it is very low, keep your eye on any 'high' that may head that way from the northwest." In other words, the cold wave depends upon the relative distribution of air pressure, and it will be cold or warm, clear or rain or snow, according to the prevailing atmospheric conditions. And how are we to know these all-important prevailing atmospheric conditions without the reports of the U. S. Weather Bureau? How can you watch your barometer as far south as Florida, and keep your eye on any 'high' that may head that way from the northwest without these telegraphic reports? Neither Venus nor moon nor Vulcan has yet vouchsafed to send them by the wireless system.

I will not follow the month's forecast in detail further, but I challenge the reader to go through the whole two columns, and arrive at any conclusion in the predetermination of the weather for any day in any particular locality. Is it the same whether you are on the Pacific coast, in the Rocky Mountain region, the upper or lower Mississippi Valley or in the New England states?—the oracle and the prophet sayeth not.

Summarized, the prediction would read about as follows: Wind and rain turning to gales and blizzards the 2nd, 3rd and 4th (a day sooner or later); followed immediately by extremely cold weather (dates and regions not given); moderating weather, winds shifting to southerly and easterly, general storms organizing and passing in regular order from west to east, the 6th to the 12th; look for high winter gales, blizzards, blockading snow and sleet, and a severe, dangerous, cold wave (date and place uncertain); moderation of the cold and return of cloudiness and more rain and snow, the 14th, 15th and 16th; prolonged disturbed and threatening weather the 17th; rising temperature and winter storms, 18th to the 23rd; winter thunder and lightning the 19th; snow and blizzards, the 20th to the 23rd; cold relaxing, cloudiness gathering in the west and more rain and snow passing eastward,

the 25th, 26th and 27th; much colder from the west and north, lasting up to the 30th and 31st.

These predictions can hardly be said to be less absurd or to possess more value than those given in Dr. Moore's almanac for the month of January one hundred and ten years before. This statement is made without regard as to whether or not any of the storms passing across the United States during January, 1904, happened to agree in time in some part of the country with the storm periods mentioned in the 'Word and Works' forecast. During any month of January, from five to ten storm areas of from two to four or five days' duration pass across or over some part of the United States, and it would be strange indeed if some of these storms somewhere did not agree with the 'long-range' forecast periods.

Professor C. M. Woodward, of Washington University, St. Louis, Mo., has given a clear and most excellent review of the so-called planetary influence theory, in an article published in *Ware's Valley Monthly*, December, 1875. The article is entitled 'An Examination of Mr. Tice's Theory of the Planetary Equinoxes,' and was published very soon after the appearance of that wonder book, Tice's 'Elements of Meteorology.' Professor Woodward practically concluded that Mr. Tice 'built a house of straw upon the sand, and his theories fell under the first blow.' As Mr. Tice's disciples are still with us working upon the credulity of the people, and as Professor Woodward's article is probably not now generally available,* I will attempt briefly an explanation of this fantastic theory, drawing freely upon the work and words of Professor Woodward.

For the past seventy-five years or more the scientific world has been busy observing, collecting and tabulating all sorts of natural phenomena—astronomical, physical and meteorological—in the attempt to discover cycles, or regular recurring periods. Thus it was found that the sun spots show a period of 11.11 years between two successive times of maximum frequency; also that this period holds good for extra magnetic disturbances of storms. Further, that the times of maximum and minimum sun spot frequency fairly agrees with the times of maximum and minimum magnetic disturbance, and also that the years in which the sun spots were the most frequent, and the earth most electrically excited, were years as well in which hurricanes were the most terrible and most numerous in the East and West Indies. These striking coincidences set men to thinking, and the scientists—and some, unfortunately, not so scientific—to hunting for a possible cause.

* Since writing this article, Professor Woodward's paper in full has been published in Bulletin No. 35, U. S. Department of Agriculture, Weather Bureau, entitled 'Long-Range Weather Forecasts,' by E. B. Garriott, professor of meteorology. A copy of this bulletin can be obtained by addressing, Chief, U. S. Weather Bureau, Washington, D. C.—F. J. W.

It was noticed that the period of 11.86 years of the planet Jupiter to make the complete revolution in his orbit was so near an agreement with the sun spot period of 11.11 years that the coincidence suggested the possibility that Jupiter and the other planets might be the cause, or at least an influence, in the sun spots. However, nothing was satisfactorily demonstrated. "The planetary system represents so many periodic relations as to render it almost certain that any periodic changes in the sun's condition may be associated statistically with some period of planetary motion."

Now among those casting about for a *great cycle* was Mr. Tice. He had worked out to his own satisfaction that some meteorological phenomena were periodic, and concluded all were, and so set out to establish a *great meteorological cycle*, which would be the key for explaining all atmospheric phenomena. By an arrangement of meteorological tables, juggling with meteorological statistics, and smoothing out irregularities through resorting to averages, thus obliterating all individual phenomena, he arrived at an average period of 11.83 years. This he at once adopted as the wonder-working meteorological cycle. Naturally, of course, the near agreement of this with Jupiter's period of 11.86 years, and the sun spot period of 11.11 years, caught his attention. He jumps to the conclusion that Jupiter is the main cause of the sun spot period, the earth and the other planets helping. In this conclusion he entirely ignores the difference of .75 years, and that this difference is sufficient to change agreement into total disagreement in five or six periods. To fit its great cycle into this foundation he must have some starting point, and so he must know when, or in what part of his great orbit, Jupiter exercises the greatest influence in producing sun spots.

It has generally been believed that the weather about the equinoctial period, when the sun is in the plane of the equator, is very unsettled, and that there always occur the so-called equinoctial storms. That storms are more frequent, more violent, or occur with any more regularity at these seasons than any other is certainly not shown in established weather records. Still, there seemed enough truth in it for Mr. Tice, and so he assumes as undeniable (1) that the earth and atmosphere at the equinoxes *always* undergo an intense electric disturbance, and (2) that this disturbance extends to and affects the sun, and through the sun the other planets. He assumes these notwithstanding no maximum of sun spots is in evidence during the equinoctial months.

Reasoning from this unproved hypothesis, he comes to the conclusion through tables of statistics giving (1) the dates of maximum sun spot frequency; (2) dates of Jupiter's aphelion; and (3) and (4) *his own* dates of the major and minor equinoxes of Jupiter, that *Jupiter's equinoxes* are the immense influence. (These tables never proved any-

thing; or if anything, also its converse.) And so Jupiter's equinoxes (and if Jupiter's, the equinoxes of the other planets) are adopted 'as the main cause of the disturbances of the sun, and consequently the whole solar system.'

With this adoption of the equinoxes, it becomes necessary to know when these equinoxes actually occur. Now of all things concerning the planets—with the one exception of the earth—astronomers are able to tell us *least* about their equinoxes. This is because they have discovered no law pervading the obliquity of the axes of the various planets, and hence the inclination of the planes of their respective equators to their paths around the sun. This inclination produces seasons, as it brings the sun a part of the year above their equators and part of the year below. Hence, we know but very little about the seasons of the other planets. The inclination of the earth's equinoctial to the ecliptic is a constant, and so the several seasons should be constant if abnormalities were not the result of other causes.

One point, however, about which there seems to be no uncertainty is that no planet has fixed equinoctial points. The 'precession of the equinoxes of the earth' was settled back in the days of Sir Isaac Newton. At present the earth is in perihelion (the point of her orbit nearest the sun) very nearly at the time of her winter solstice. But the times of perihelion and aphelion come a few minutes earlier every year, so in the course of several thousand years the earth's perihelion will have gone backward in the year until it comes at the time of autumnal equinox, when the sun's distance from the earth will be the same in the winters and summers of both hemispheres. After another few thousand years the time of perihelion will come in the summer of the northern hemisphere. Then any difference of climate in the two hemispheres caused by the variation in the earth's distance from the sun will be the reverse of now. Not alone do all the planets revolve upon their axes, but the sun itself so revolves. His axis of revolution is not quite perpendicular to the ecliptic, with the result that the plane of his equator has an inclination of a few degrees to the plane of the earth's orbit—and also to the orbits of the other planets. In consequence of this slight angle the earth—and likewise each of the other planets—is exposed to the north pole of the sun during one half of its year and the south pole during the other half.

Now, according to Mr. Tice's theory, the influence exerted by the planets upon the sun, and retroactive, is entirely electrical, and hence not the force of universal gravitation. A safe assumption, as almost anything that we can not explain in any other way, may be laid to some form of electric energy with least chance of its being disproved. So electric energy and the equinoxes of the planets became the basis of the Tice electro-equinoctial theory. What foundation stones for his great

cycle arch! But the keystone, the illusory planet Vulcan (which will be discussed later) is even more mysterious.

The sun and each of the planets were regarded by him as immense magnets with north and south poles, and as the planets moved in their orbits they were exposed alternately to the north and south poles of the great sun magnet, and this alternating exposure aroused not only the planet to greater electrical activity, but influenced the sun himself, as evidenced in the sun spots. But even were this so, what has it to do with the planet's equinoxes? The amount of change to and from the poles of the sun depends, as shown above, solely on the inclination of the planet's orbit to the plane of the sun's equator, as, in the case of the earth, the inclination of the ecliptic to the sun's equator plane, and not of the ecliptic to the equinoctial.

Now it happens that (at this time) the earth is at its greatest distance south of the plane of the sun's equator, and hence most exposed to the sun's south pole, March 6; and the greatest distance north, and so most exposed to his north pole, September 5. These dates are so near the dates of the earth's equinoxes—March 22 and September 21—Mr. Tice assumes that they agree. And even though this difference, like the equinoxes themselves, is not a constant, further assumes a like coincidence to exist in the case of every planet. With this lame assumption he puts the source of the great electric energy of the sun upon the equinoxes of the planets, and reaches the conclusion that all atmospheric phenomena were produced by planetary equinoxes.

But with all these assumptions injected into his great meteorological cycle, it yet refuses to work properly. It was found that there were many phenomena occurring that would not fit into any of his assumed cycles, or that were contemporary with the causing planetary positions—that is, of the *known* planets. Thus it became necessary to find a new planet—one he could have his own way about, and so Vulcan—a planet so near the sun that only Mr. Tice, and two others, neither of whom was a trained astronomer, and using only ordinary telescopes, have ever been able to see it, and they only once each—is harnessed to the electric cycle wagon.

Lescarbault saw the supposed Vulcan March 26, 1859, Mr. Tice September 25 or 26, 1859, and Mr. Lummis in March, 1862. So this wonderful planet which plays such an important part in our welfare has been seen only these three times, and never since, although astronomical observers with the finest telescopes, and located all over the world, have been on the constant search for a planet interior to Mercury, and though during every total eclipse of the sun (when his intense light is for a moment shut out), it is the sole duty of some observer in every party to search for such a planet—yet the wily Vulcan eludes them all.

The main reason why Vulcan, or *some* uncertain planet, became so essential to the theory, was the fact that the planets in sight, though seemingly so well trained, far too frequently disagreed with the development and movement of cyclonic and anti-cyclonic areas over the field of systematic meteorological observations, and as these are the disturbances in the atmosphere which bring the variation in weather during the several seasons, something heroic was needed.

To his own satisfaction Mr. Tice established that Vulcan was a planet of gigantic size. He also assigns him a period of revolution around the sun of forty-six days, and sets the dates of his equinoxes—all essential to his planetary theory. Thus with a terrible Vulcan equinox every twenty-three days of from seven to eleven days' duration, and the aid of the equinoxes of a half dozen other planets, it is made possible to account for about everything under the sun. There is considerable uncertainty and confusion as to the energy of Vulcan's influence at his equinoxes; but as Professor Woodward concludes, "I infer it is immense when immense energy is exhibited and not noticeable when none is noticed—in fact, it depends upon the weather."

A good deal more might be said from a meteorological standpoint to controvert this theory, but I think I have given sufficient to show the absolute untrustworthiness of such a system in predetermining weather. Astronomers have no faith in the astronomical work, assumptions and deductions, and meteorologists certainly as little in the meteorological part. Neither part stood the test of critical investigation. It is believed that Mr. Tice was conscientious and honest in his investigation and theories, but that he was over-enthusiastic and ambitious, and could only see things as he wished to see them. Not so much can be said of some of his present-day disciples.

Some of our long-range weather forecasters base their predictions entirely upon tabulated weather statistics, with averages and departures, from which they believe they have discovered cycles and recurring weather changes and conditions. But their conclusions will not stand critical investigation, and their forecasts are of so general a nature as to be absolutely without value.

Nearly all the modern 'long-range' weather forecasters rely to a large extent upon the weather reports of established weather bureaus, and a mighty howl goes up whenever these reports are withheld from them.

I have reviewed most of the popular weather prognostication systems, but as yet have said nothing of the methods used by the U. S. Weather Bureau. To tell these would take many chapters, and would be a history of modern meteorology as revealed and built up during the past century. The Weather Bureau has taken, and ever stands ready to take, the best that scientific minds and training and scientific re-

search are able to produce. There is no secret or magic about the system of simultaneous observations, telegraphic reports, synoptic charts and weather maps of the U. S. Weather Bureau. The best scientific thought and the life work of some of the brightest scientific minds, together with long experience of the forecaster, are used in the discussion of these charts and observations in predetermining the weather elements for a day or two in advance. Many of the most eminent meteorologists, who have contributed so much in bringing our knowledge of the earth's atmosphere to where it is to-day—such as Maury, Ferrel, Abbe and Bigelow—were also astronomers, and it is not likely that they, in their research, should have overlooked the *terrific planetary influences*.

True, logical, scientific weather forecasts for a season, or a month even, in advance, is the aim and dream of the meteorologist and the inspiration of meteorological research all over the world. But in the light of all our present knowledge of original causation of variations and abnormalities in current weather and in the seasons, this meteorological 'millennium' is not yet, and there is work in plenty ahead for the earnest, capable investigator.

Will not the newspapers, the great enlighteners and disseminators of truth and knowledge in the present age, help these investigators by discouraging and discountenancing the publication of weather predictions founded upon such baseless theories as told in this paper?

The U. S. Weather Bureau is now erecting excellent observatories at Mt. Weather, located in northern Virginia on a spur of the Blue Ridge Mountains. These observatories are to be fully equipped with the latest and most approved instruments and apparatus for observation and research in meteorology and allied sciences. Here will be given opportunity for collection, correlation and study of simultaneous observations and measurements of meteorological and magnetic elements, changes in the activities of the sun's atmosphere, solar energy, radioactivity, atmospheric electricity, etc. Also exploration of the upper levels of the atmosphere will be made by means of balloons. As stated by Professor Willis L. Moore, chief of the U. S. Weather Bureau, "Research at Mt. Weather will be catholic in its broadness. There, we will look only for the truth, and shall not despise its source or the means of its conveyance."



VIEW OF THE WHITE DEER COLLEGE.

THE COLLEGE OF THE WHITE DEER GROTTO.*

BY CHARLES KEYSER EDMUNDS. Ph.D.

CANTON CHRISTIAN COLLEGE.

A NEWCOMER to China is sure to be surprised by two things at least, not to mention many others, viz., the grandeur of the scenery in certain sections and the unexpected excellence of the means of transportation on her chief waterways. Both of these were factors in the trip which the writer recently made to the famous Confucian stronghold, hoary with age, hid away among the hills of central China—the College of the White Deer Grotto.

In order to appreciate more fully the scenic surroundings and the secluded location of this most noted of Confucian schools, we shall notice the scenery encountered *en route* at a greater length than might on first thought seem suitable to our topic, for it is important to get the full setting of this cloister, within whose ivy grown walls there was in former days such deep searching into the doctrines of the 'Princely Man' and the 'Great Learning.'

Crossing the Woo Sung bar at the mouth of the Shanghai River at daybreak, our steamer, a modern screw craft of some 3,600 tons and 1,500 horse-power, turned her head up the mighty Yangtze, China's aorta of trade, and for four hundred and fifty miles we pushed against the swift current of that coffee-colored stream, passing *en route* the important ports of Chinkiang, near the mouth of the Grand Canal, Nanking, a former capital of the 'Celestial Empire' and still its most famous literary center, and Wuhu, an immense lumbering depot, to disembark at Kiukiang, the country's chief mart for 'china,' while the steamer passed on some hundred and fifty miles further to Hankow, the center of the great tea trade. The river steamers do not run up to piers or wharves, but at such ports as we have named they run alongside the dismantled and anchored hulks of former ocean-going vessels which lie offshore and are connected to the land by a sort of pontoon-

* There is a slight notice of this school and its refounder in Williams' 'Middle Kingdom,' and a fuller account is given in Mr. R. E. Lewis' 'Educational Conquest of the Far East' (New York, 1903), and in the 'East of Asia' (Shanghai, 1905), Vol. 3, No. 2, by Dr. Carl F. Kupfer. Although all these have been consulted and material freely drawn from them, the main source of the matter herewith presented was the trip which the writer made to the College in August, 1904, in company with a party of American friends, several of whom understood the Kiangsi dialect.

bridges. These hulks are 'fitted up' on the deck as residences for the local agents, while their hulls serve admirably as storage godowns. At



JUNK ON THE GRAND CANAL NEAR CHINKIANG LOADED WITH DRIED REED GRASS.



TEN LI BRIDGE PASSED BETWEEN KIUKIANG AND KULING.

the smaller ports the ship does not make a landing, but merely reduces her speed, and barges carrying freight and passengers (mostly the latter

at such ports) come out from shore and are made fast alongside—the transfer being made while under small headway. When the freight is sufficient at such ports the steamer casts anchor.

There are several lines of steamers plying the river and there is considerable competition, though the British rather have the lead on the others. There are two British lines and one Chinese line on whose steamers tickets are interchangeable, thus facilitating stop-overs, and between them they will shortly run a steamer each way each day on the six hundred mile run from Shanghai to Hankow. An enterprising Japanese firm and a German line are pushing for trade, and between these five regular lines and the many tramp merchantmen, the amount of freight moved easily makes the Yangtze the main trade-artery of the empire.

We approached Nanking in the small hours of the morn., and as I sat on deck watching the grayness of the early dawn give way to the upward slanting pinkish beams of the orb of day I beheld a glorious sight—the water at my feet, then the curving shore, beyond to the eastward the graceful towers and pagodas of the city, and in the distance the peaceful gray and bluish hills, along the sculptured heights of which the first gleams of a sun, that would soon be altogether dazzling, were silently but swiftly stealing. Out on the river three vague forms, like huge monsters of the sea crept into inland waters, loomed suggestively through the diminishing gloom, and as the first rays that marked the beginning of a central China scorcher stole over the eastern hills, the reveille call of bugles turned my eyes upon these monster shadows, and from out the disappearing mist there came three men of war under as many flags, British, German and Chinese; the last in snowy white flying the dragon flag, the others in darksome coats, as if prepared for war. Their bugle notes were answered, as by an echo, from the camps of Chinese provincial troops on shore.

When I first saw the Yangtze and traveled on its swiftly rushing surface it was the beginning of winter, and her waters were low and falling; but even then I was struck with the magnitude of this great waterway dividing the empire nearly in twain from east to west. On this trip it was summer and her bed was full, the rush and width of her muddy waters even more majestic. Piloting in midsummer is somewhat easier on account of the steady fullness of the water, but in the spring and autumn, during the rise and fall of the chocolate stream, the changes in the channels are many and various, so that piloting is no mean art. In sharp and yet pleasing contrast with the brown current, the banks and alluvial plains were green with tall reed grass, much used for fuel, which nearly everywhere attained a height of from seven to ten feet. On either side of the river away across the plains successive ranges of hills were overshadowed by huge masses of cumulus cloud

sharply outlined against a very blue sky. Sometimes the foothills stretched to the river's brink, and the occasional cliffs thus formed bore upon their tops graceful temples and pagodas, for in China the best places and sites are always given over to temples and pagodas, if not to graves.

As we left Wuhu, we passed many lumbering rafts, some immense ones with a draft of ten feet or more, carrying huts and food, live stock (mostly pigs and chickens), etc., for some thirty or fifty people, the families and assistants of the men who were bringing the lumber to market. They went with the current, of course, but they managed to keep clear of shallows, mud banks and rocks by the artful device of sending out a small crew in a heavy skiff with a large anchor, from which a hempen cable ran to the raft and was there made to wind up on a stout capstan revolved by some twenty pairs of hands. By sending this auxiliary anchor-boat to the proper point, both in direction and in distance, they could, by winding up the cable, drag the raft even athwart the very current of 'the yellow dragon,' the mighty Yangtze.

Though only thirty miles from Kiukiang to the White Deer Grotto, it is a good two days' journey on foot and by chair across plains and over hills of no mean height, for the route led us across the Lü Mountains by way of Kuling and the Nank'ang pass. Instead of arriving at noon, as it should, our steamer reached Kiukiang at midnight, at the end of a heavy rain; yet we decided to push right on across the plains and to do our climbing in the cool of the early morning. Accordingly, after much discussion with the coolies, who everywhere in China wrangle vociferously over the terms of any bargain, we managed to get four coolies for each chair, several torch bearers who carried long bamboo flare torches, and some three baggage coolies apiece, and our long procession stalked across the rice fields, or rather between them, for they were under water, across streams and along marshes, under a heavily clouded yet at times moon-lit sky. As we went ahead we found the chair coolies grumbling with the man who had bought the torches for not getting enough, and on persistent inquiry we found that the fellow had 'squeezed' half of the Mexican dollar we had given him for torches, and had bought only fifty cents' worth. Barring a few stumbles and one spill, however, we succeeded in arriving safely at the half-way house among the foothills at 4:30 A.M. After a short rest and a cold bite, we started on foot to climb the steep ascent to Kuling Valley. We went up slope after slope, one long stretch having some two thousand steps, getting, as the fuller light of day began to dawn, magnificent views of the plains across which we had come in the dark and of the Yangtze curving in a great S beyond. In some places the drop off the side of the path, which in many sections was paved with large granite blocks, was quite sheer and a fall would have plunged one

some two hundred feet into the rocky bed of the rushing stream, up whose course we were wending our way in search of a cool haven from the heat of the plains. As we journeyed, the sun rose, the cool of the morning gave way to the heat of the on-coming day, and we earned our ascent, if not our bread, by the sweat not only of our brow, but of back and thigh as well.

The toilsome ascent proved too much to allow the journey to be continued without a rest at Kuling, and we succumbed to the sleep-inducing effects of the mountain air of central China. Kuling is a long valley, with three side valleys, running about northwest and southeast,



VIEW SECURED ON ASCENDING KULING PASS.

and from the eastern slope, through the gap at the upper end and over the backs of the gigantic elephant-like hills that form the western slope, magnificent sunsets are to be seen. Here a concession has been granted so that foreign residents may have a retreat from the summer heat of the lower land, and some eight hundred people of various nationalities annually find refreshment in this valley. The bungalows are all simple, yet comfortable, one-story affairs, most of them of hewn stone taken from the adjacent hills which stand bare to view, the only attempt at covering being stubby foliage of no great beauty and of little height.

While resting here we made a half day's excursion along one spur of the Lü Shan, down to where several water-driven incense mills were

steadily pounding by the side of a small stream which came tumbling down by leaps and bounds over rocky places, and at several of these sudden descents small wooden over-shot water-wheels operated two long, heavy horizontal beams, making them see-saw up and down about a pivot where they pierced the wall of a squatty mat-shed, the half of which was a small closed chamber, within which the further ends of the beams carried great heavy stones, shaped like huge dull chisels, and these, working up and down on the stone floor of the closed room, pounded into a fine powder small chips of previously dried pine wood. The dry powder that results is the incense and is carried by coolies over the mountains to the towns and temples round about. This region was formerly the site of some four hundred monasteries and temples, and our route passed one sawed-off pinnacle which bore on its top the ruins of an old monastery while on a neighboring peak stood a delapidated pagoda, evidences of the wreck caused by the famous Tai Ping rebellion (1850-1864). On our way down to these mills we had several magnificent views from cliffs which dropped sheer off to the plains far, far below. With jagged rocky peaks to the right as we looked down, there ran precipitously between them and us a lovely silvery stream, all afoam from its conflict with the rocks and boulders. Away below stretched a row of small foothills clustered in groups of three and four, and around and beyond these a low level plain dotted with a thousand small lakes or ponds was intersected by dozens of streams and canals which at last combined to form a tributary of the Yangtze, a long graceful curve of which appeared in the distance as it rounded a promontory, bearing on its shores the town of Kiukiang. Above all this plain and surrounding the nearer mountain crests hung great masses of cumulus cloud tinted by the rays of the setting sun, the whole effect presenting a picture of such beauty and sublimity that the beholder could easily appreciate why native scholars have so often celebrated it in gladsome song.

We made an early morning start from Kuling, so as to reach the grotto by noon. On attaining the summit of Nank'ang Pass we saw spread before us the region between the southeastern slope of the Lü Mountains and the sacred Poyang Lake, and on a small promontory, straight before us, on the west shore of the lake, the city of Nank'ang, with its striking pagoda, was just discernible. Several steam launches, looking like mere toy boats, could be seen plying between the many lovely and populous islets enclosed by this most important of China's few lakes (90 miles by 20 miles). Descending the stone-paved trail that led us down these mountain precipices, we headed toward a point about seven miles north of the city. For some distance, after reaching the region of the lower hills, our path led us along the shady banks of a beautiful stream, in the limpid water of which we stopped awhile to

bathe, for it was impossible to resist the temptation to test the depth of such a series of great pot-holes as here invited to a plunge. Passing on, now among stunted pines, now across stretches of arid red sandstone and clay, over no real roads, but by winding paths between many small divisions of cultivated field, we came at last to a secluded valley at the junction of two rippling brooks, with 'five old peaks' standing like parapets on a rampart for the background, and the lake winding up a larger valley and spreading out beyond the undulating foothills.

Genius in China, as elsewhere, renders a place illustrious, and few spots are more celebrated than this lovely vale of the White Deer, where Chü Fu Tsz, the greatest commentator of Confucius, lived and taught in the twelfth century. It is still a place of pilgrimage to Chinese literati, for Chü's writings are prized by them next to their classics. Crossing the 'Fairy Bridge' over one of the rivulets, whose constant murmur lent enchantment to the otherwise quiet nook, we saw before us a high 'compound' wall, red in part and white in part. Passing the lesser gates, under gilded ideographs, we stood at last in the courtyard of a college older than any university of Europe, Salerno not excepted. This ancient seat of learning was *rebuilt* when the banners of the third crusade were advancing on Jerusalem, and its real beginning is hid behind the veil of past ages.

According to Chinese history, the grotto, which shows no signs of a natural origin, being dug out of a cliff and arched over with masonry, was the retreat of the illustrious poet Li P'u (or Li Tai-peh), who flourished during the T'ang dynasty, toward the latter part of the ninth century. P'u had a tame white deer which accompanied him in his walks abroad, and thus he became known as the 'white deer gentleman' and his dwelling as 'the white deer grotto.' A very crude stone image of a deer, placed there by Ho Tsing in the fourteenth century, now stands beneath this arch. When promoted to be sub-prefect at Kiangchou, now Kiukiang, P'u built a kiosk over his former sequestered abode, rendering the spot memorable from that day.

At a time when dynasty fast gave way to dynasty (five successive houses holding sway between 907-960) this sheltered corner was the retreat of worthy scholars from far and near, and here fields were bought, buildings erected, students gathered, and a school opened, from the famous halls of which were to come men able to help guide the affairs of state. Si Shan-tao, a master of the Nine Canonical Books, was taken from the Imperial Academy to become the president of this institution, styled the Government School of the Lü Mountains. In 906 it was raised to the grade of a university coordinate with the other three universities of the realm. The enrolment was then one hundred students.

The fortunes of this seat of learning suffered many reverses, fol-

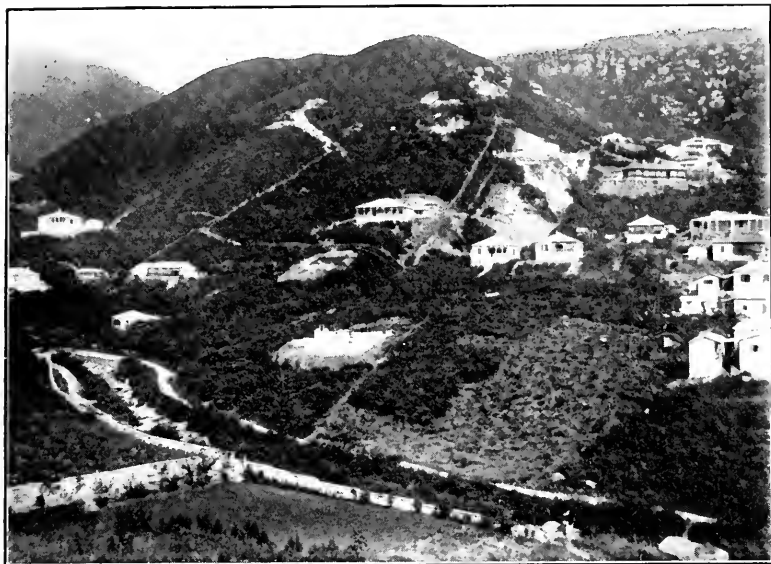


PANORAMA OF KULING VALLEY.

lowed by only partial recoveries, until 1174 (or 1179?), during the Sung dynasty, when Chü Fu Tsz (or Chü Hui-ngan, or Chü Hsi) became prefect of Nank'ang, and undertook to repair the buildings, then somewhat, as now, in ruin, and to restore prosperity to the institution, which held so high a place in the national annals, thus adding to its fame the luster of his own great name. He purchased additional lands for the support of the scholars, established a collegiate code, parts of which are inscribed on the backs of the doors, and frequently visited the college to instruct the students, many of whom rose to prominence.

The publication of the classics being at that time forbidden, general education had fallen to a low ebb, and all classes, officials and common folk alike, felt the consequent chagrin. Chü Fu Tsz in an audience with the emperor, as inspector of the State Department, made a plea for more liberal education, setting forth the great disparity between the numerous and prosperous Taoist and Buddhist temples (in the provincial capital more than one hundred, and in every prefecture several tens) and the sparse and poorly supported schools (only one in a prefecture and none in the small districts), and urging the bestowal of an Imperial Tablet (a stone bearing a classical inscription prepared by the Hanlin Academy), in order that the prestige of the Grotto University might be restored, honor paid to His Majesty's meritorious predecessors and the scholars of the realm favored. This he ventured to beg at the risk of his life, for the civil authorities regarded even this action with suspicion.

The request was granted, but the tablet did not assure perpetual



PANORAMA OF KULING VALLEY.

blessing. At the close of the next dynasty it was cast out into the brush during a commotion, and not till the sixth emperor of the Ming dynasty (cir. 1470) was it found and replaced. It is not recorded how long Chü Fu Tsz labored here, but legend claims that he spent the rest of his life as president of this institution and was buried in the shady grove near by.

The following is a rather free rendering of a part of this noted preceptor's collegiate code, written on the inner panels of the doors of the assembly hall:

The ancient worthies taught men to seek the principles of righteousness and to cultivate a moral conduct which would influence others. They did not wish men merely to exercise their memories in writing compositions to secure fame and profit. But the students of to-day (Chü Fu Tsz's time) do not follow the ancient worthies. Let all earnest students give heed, inquire and discriminate. If a man knows his duty and forces himself to do it, will he not finally know instinctively what is right without any rules of order? . . . The important subjects taught by the ancients I myself will investigate with all the students, and we will force ourselves to practise them. . . .

The unpretentious buildings, evidently designed for use and not for show, are comprised in eight paved but uncovered courts and afforded sufficient shelter for the four hundred students that are said to have gathered there in the palmy days when scholars prepared for the service of the state by writing verses to the stars. Three sides of each court are given up to living rooms for students, two in each,



THE GROTTO AND THE IMAGE OF THE DEER.

while the fourth or upper side gives space for teachers' quarters and class-rooms.

But in one court in place of the teachers' quarters there is a high pillard shrine-room, where behind red curtains sits the massive wooden statue of Chü Fu Tsz, an object of reverence as the intellectual father of the race of students cultured here. This room comes just in front of the grotto where the image of the white deer stands. An inscription in huge characters hangs above his throne and on either side are tablets to the memory of his distinguished disciples.

Passing into the adjacent court through a circular doorway we stand in the *sanctum sanctorum* of the college, in the very midst of its buildings, occupied by a temple with great double doors smeared with the ubiquitous Chinese red. Dark and damp, the main hall of this temple offers shelter to large images of Confucius, Mencius and fifteen of the famous disciples of the sage. This image of Confucius is rather contrary to custom, and is perhaps accounted for by the Buddhistic inclinations of Chü Fu Tsz. Besides this crude wooden image, there is also a portrait of the sage, one of the only three reputed to have been made. It is engraved life-size on a huge slab of dark slate, and is evidently the product of no mean skill.

In a small room in front of this Confucian temple is enshrined, curiously enough, a tutelar god. Formerly this room was supposed to bestow remarkable success in the examinations for high degrees upon all those who had studied in it, because of the literary god standing in a little pavilion across the brook, who holds in his hand a pencil which points directly to that room, and who guided the pen of the favored

occupant to heaven-bestowed success. In consequence of the favor thus vouchsafed to those who studied in this room, there was such a great rush each season to secure it that vigorous quarrelling and even murder ensued, so that it was relegated to an idol and since then no student has been allowed to study there.

Mr. R. E. Lewis, of Shanghai, in his 'Educational Conquest of the Far East,' recites the amusing experience of himself and three American companions when visiting the grotto a few years ago. The curiosity of the Chinese concerning all things foreign has often been noted before, but the actions of these students may still be recalled with interest:

We stood in Chü Hsi's venerable college, and presently one, two, three, hesitating, inquisitive men with long finger nails, approached, and stood awkwardly about. After a word of greeting we were shown the main eating room where high square tables, benches with no backs, rice bowls and chop-sticks were chiefly in evidence. Looking around for the New York man of the party, we saw him still in the outer court, beset by two importunate students. They had begun with his shoes, the laces and metal eye-holes being duly explained. They took in his stockings, which were black, in curious contradistinction to a Chinese gentleman's white hose. They fingered his white duck trousers and coat, anxious to know the cost. The chief Confucian inquisitor proceeded to ask and to prove how many sets of garments a foreigner wears on his arms. This coincided with the three coats which the Chinese expect to wear in weather somewhat colder. When they had reached the New Yorker's pith-hat, there was an outburst of ill-mannered laughter. This prince of Chinese investigators held the piece of head gear in his hand and commented on its lightness in comparison to its umbrella dimensions. He made this sally, 'What is your honorable hat made of?' The New Yorker being yet young in China could not recall the Chinese expression for 'pith,' and turned to another of the party

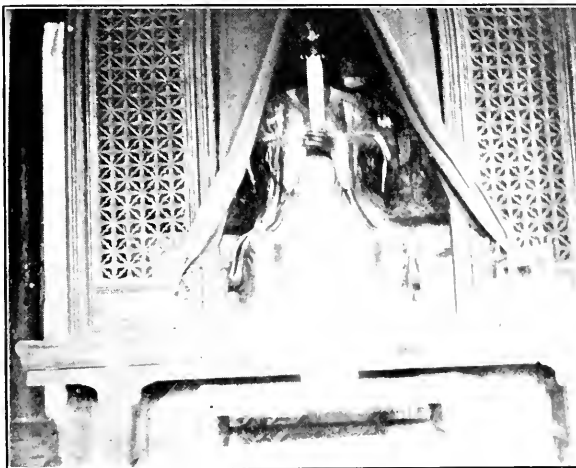


IMAGE OF CONFUCIUS.

to ask. Then came an ironical burst of glee—'This foreign teacher does not know what his own hat is made of.'

Still more significant is the treatment these visitors received from the master of the school, for it typifies in itself quite well the change in China's mental attitude in her contact with western thought, as pointed out in our first paper*—from initial arrogance and conceited ignorance to a lively appreciation of the value of the newer learning:

Before we left the college we found a teacher sitting at the head of one of the courts with a bandage about his head. He was not glad to see us, his



A VIEW OF THE COLLEGE HALLS.

malaria possibly accounted for his incivility, which, however, might have been aggravated by the fact that two of the company forgot to remove their spectacles on coming into his presence. However, his frigidity wore off, and when it came out that the foreigners could write (more or less) as well as talk his native language, the professor rose slowly and stood as he talked with us. Enquiring if we were students he seemed first abashed and then incredulous when he learned that all his interlocutors were second degree men. He looked as much as to say 'These foreign chaps must have bought their degrees, if they really have them'—not an unnatural thought for a Chinese.

At length when the professor was thawed out, to the point of civility at least, the Bostonian in the party produced from his impedimenta a large package of Chinese books. The professor, with a quizzical look on his face, received a beautifully illustrated life of Christ, and Dr. Faber's four volume Commentary

on the Classics, from a Christian standpoint. The learned man saw the beauty of the printing, and bowed his acknowledgments. Then ensued a scramble among the students for the remaining books. One fine-looking fellow secured a large volumed commentary on St. Mark and St. Luke, and three or four others chased him to his room in the attempt to get it from him.

We left the scholar and his students earnestly poring over the books, and went out of the compound. By the banks of a sparkling brook we spread our luncheon, and while talking over the experiences of the day, a messenger arrived from the professor. He was instructed to say that the books were much appreciated, that it was most kind of us to bring them; and might he ask that we bring another instalment, especially the Commentary on the Classics? We assured the messenger that in two weeks or so books could be secured from Shanghai and would gladly be sent.

Two years ago some ladies who accompanied a party of gentlemen from Kuling on a visit to the college were not allowed to enter the Confucian temple, and the gentlemen were required to remove their spectacles; but on our visit in August, 1904, not only were our glasses allowed to remain before our eyes, but the ladies of our party were granted ready entrance to this holy of holies. The real difficulty was rather that things were too free and easy and the long robed but rather youthful students too pert, even from a Chinese point of view. Evidence was not wanting of the shiftlessness resulting from Chü Fu Tsz's provision of free tuition and support of each student. Had it cost them more to gain this classical learning, they might have been more diligent in its acquisition and more earnest in making it bear fruit in helpful service to their fellows.

Without a competent head or organized faculty, without a governing board or scarcely a janitor, the students are a law unto themselves. They bring their own furniture and cooking utensils and build little hearths for private use, or perhaps in clubs. The dilapidated condition of many sections of the buildings no doubt results from a lack of other ready fuel. Some parts of the roof are crushed in and weeds flourish in several rooms. Many of the memorial tablets have fallen down, and altogether the place has become nothing more than a sleepy and degenerate cloister, where about twenty students, free from the disturbances of home life and the new spirit of change spreading over the land, can better prosecute their antiquated studies. As typically representative of China's ancient educational system, the College of the White Deer Grotto has upon it the mildew of decline, while in many places throughout the empire schools of the newer learning under foreign and native auspices are preparing the alert of China's youth to lead in the strong and masterful civilization which she is destined to attain.

UNCONSCIOUS ASSUMPTIONS IN ECONOMICS.*

BY REV. W. CUNNINGHAM, D.D., D.S.C.

AMONG the members of any such gathering as a meeting of the Economic Section of the British Association there are likely to be some who come to give information and some who come to get it. In the latter class may, I am sure, be included all those *habitués* of the section who have seized the opportunity which the visit of the association affords, with the view of learning something about the present condition and prospects of the enormous territory which we hope to be able to traverse. It may not be so to the same extent in all sections. Those who come from the great chemical and physical laboratories of Europe may have much to say as to the result of experimental investigation, which they can carry on under more favorable conditions than are at present generally available to students in South Africa. But in economics there is no room for experimental inquiries consciously undertaken in the interest of the advancement of science. The issues are too serious; the conditions on which they depend can not be arranged for the convenience of the inquirer. Economics is a science of observation, not of experiment; and we are fortunate to find ourselves in specially favorable circumstances for noting and appreciating the results of investigations which have been made by skilled observers on the spot.

While we gratefully acknowledge the pains that have been taken here in preparing papers for this section, we may yet feel that the task we are setting ourselves as visitors is not an easy one. There are few harder things in this world than to preserve a genuinely receptive frame of mind, and hold the judgment in suspense when we are brought face to face with the unexpected. There are so many assumptions we all make, and so many canons of criticism we have habitually accepted, that are not easily laid aside, even temporarily. 'The worst use of theory,' as a great Cambridge professor has warned us, 'is to make men insensible to fact,† and the danger may be most real when we are not aware of the influence exercised by some hypothesis which we habitually make.

I. The popular discussion of economic problems teems with unconscious hypotheses, which tend to obscure the facts of the case. Mill

* Address by the president to the Economic Science and Statistics Section of the British Association for the Advancement of Science, South Africa, 1905.

† Lord Acton, *English Historical Review*, I., p. 40.

described political economy as a science which, assuming the facts of human nature and of the physical world, considers the laws of the production and distribution of wealth. But what are the facts of human nature which we may legitimately assume? At first sight we are inclined to take for granted that human nature is much the same all the world over. The late Professor Jevons gave clear expression to this view. "The laws of political economy," he says, "treat of the relations between human wants and the available material objects and human labor by which they may be satisfied. These laws are so simple in their foundation that they could apply, more or less completely, to all human beings of whom we have any knowledge." He adds: "I should not despair of tracing the action of the postulates of political economy among some of the more intelligent classes of animals."* It has seemed as if in the march of progress modern industrial conditions must inevitably be introduced in backward countries, and that they would everywhere result in molding individual aims and character on the same lines. Each individual is to some extent affected by his environment; and it has been supposed that the keen competition and struggle for existence, which in one form or another dominates economic life in all parts of the globe, would make for the survival in all areas of men of the type with which we are familiar in business circles at home. In England there is on the whole a condition of free exchange, where each individual puts in his quota of service to the community and bargains for payment. His success in the management of land is rewarded by an increase of rent; his enterprise in investing his capital, by larger profits; his diligence and skill as a workman, by the wages he draws. The man who is self-disciplined enough to follow routine work habitually for the sake of reward, and whose ambitions lie in the direction of better paid and more responsible service, is the normal man of such a society. But it must be remembered that modern civilization is also producing another class; whatever the force of social environment may be, it does not, as a matter of fact, form each unit of the rising generation on the same type. There are men who do not fit readily into our modern system; they dislike the monotony and stationary life which steady industry imposes, though they may be able to work well and hard when the fit takes them. The tramp of the American continent is as much the product of existing industrial conditions as the ambitious leader of an organized body of skilled artisans. The 'ins and outs' of Great Britain have characteristics which may be described as nomadic.† Economists recognize that the fluidity of labor is one of the assumptions that can be fairly made in regard to modern society.‡

* W. S. Jevons, 'Principles of Economics,' p. 196.

† J. C. Pringle in *Economic Review*, XV., p. 60.

‡ W. Bagehot, 'Economic Studies,' p. 21.

The conditions under which labor is fluid give opportunity for the growth of a half-employed and migratory class, who are, as a class, a tax upon the well-being of society. It is the greatest of all problems in the old world to see how the educative influence of society can be brought to bear so that it shall rear as much as possible the sort of man who is 'capable of standing on his own feet and of contracting when and how to render services to those who are willing to offer services he wants in return.' The question, What is to be done with those who can not and will not thrive on this system? is constantly presenting itself in new forms. For our present purpose it may suffice to recognize that this question exists, and that even when the conditions of race and history and social surroundings are similar they do not produce one type of individual only. Under these circumstances we can no longer take for granted that human aims and activities are becoming closely similar in all parts of the globe, even for economic purposes. The individual estimate of the utility and disutility of labor at any given moment may often be very different from that which the economist would assume to be the natural conclusion. It is obviously absurd to suppose of vast numbers of our fellow-creatures that they are in the habit of acting in accordance with what appears to be common sense to the average traveling Englishman, but they need not necessarily be fools on that account.

II. What is true of unconscious assumptions in regard to individuals personally also holds good for the mechanism of society; we can not assume that it works everywhere in the same way. The classical economists were inclined to limit their investigations to the areas and regions where free competition has been dominant, and thereby to exclude from consideration all those important problems which arise from the contact of individuals of two races, with different economic habits and ideals, upon the same soil. But even if the ages and areas of free competition could be cut off from the rest of the world, and we fixed our attention exclusively on this single plane, we should not find simplicity and uniformity throughout the whole region. The habits of business practise and labor organization differ in different lands; the banking system in Scotland is by no means the same as that in England, and a form of currency which finds favor in one is illegal in the other. There is also a want of complete conformity between the eastern and the western states in this matter; we can not argue directly from the one to the other. When this is true about the medium of exchange, it is obvious that the differences between one highly advanced community and another in regard to the terms on which labor is carried on, or the method in which land is managed, will be even more striking.

The great difference in the working of the mechanism of society, as we know it in England and as we find it in other lands, was the chief

impression which was left on my mind on the occasions when I have had the opportunity of traveling far afield. A quarter of a century ago it was my good fortune to spend a few months in India, and to get some insight into the extraordinary contrasts between Britain and her great dependency. At that time many of the changes which had revolutionized English industry and internal traffic were beginning to make themselves felt throughout India. Railway communication was being opened up in all directions, and cotton spinning was carried on at mills in Bombay and in Hyderabad in the Deccan. The results of the age of mechanical invention had begun to invade the changeless civilization of the east. Still the persistence of the old order was also noticeable. The village community, as an exclusive group, with the headman who supervised all transactions with the outer world, forced itself upon my attention when I attempted to hire a pony to visit the cave at Karli. I passed a granary in Kathiawar where the officials of a native state were measuring out the crop and collecting the revenue in kind. The highly developed gild system at Ahmedabad was the very image of much that I had read of regulated industry in medieval towns. On every side it seemed as if the survivals of the past had been preserved in the east, so as to make the story of bygone ages in the west alive before my eyes. On the other hand, the transition from the old to the new, which had gone on steadily in England for centuries, seemed to be ready to sweep over Hindustan like a flood that would disintegrate existing institutions, while it showed little constructive power. And when I heard discussions on the incidence of taxation, the pressure of the salt tax, or the impossibility of imposing an income tax, I at least realized that the conditions were strangely unlike those of which a chancellor of the exchequer would have to take account in England. The mechanism of society is entirely different; the expedients which would make for convenience and equality and inexpensiveness in England would not necessarily be feasible in India at all.

Five years ago I had occasion to reside for some months in the United States, and once again I came away with a strong impression that the mechanism of society was very unlike that with which I am familiar in England—the differences were more subtle, but not less real, than those between English and Indian economic life. Throughout the states there are few vestiges of past history; the alleged relics of Norse invasion have disappeared under the solvent of critical investigation; and though frontier life has been till lately an abiding factor in American civilization, comparatively little influence has been exercised by the native races on the economy of America to-day. The English stock, with grafts of many kinds, has had a clear space in which to grow. In India the conflict of the past and the present seemed to be the dominating condition, but in America there had been

room for the development of a new country pure and simple, unhampered by the traditions and customs of bygone days, except in so far as their wisdom was confirmed in present experience. Hence, on the other side of the Atlantic the practical economic problems as to the development of a large and wide territory are presented in their simplest form. It is there that we can note most clearly the lines on which modern industry and commerce develop with the full employment of modern appliances and the minimum of control from traditional habits and institutions.

There is one economic conception which is deeply ingrained in English habits, and which seems to me to have no corresponding hold in America—that of the markets. Its former importance as the center of trade in many towns is sufficiently vouched for by the space that it occupies, and its legal history takes us back to the very beginning of urban life in England. In medieval opinion a sale in open market, where buyers and sellers met together publicly, had all the guarantees of an honest transaction; it was important both as evidence of the sale and as an indication that the bargain was above board and fair, since there was one price for all alike. Private transactions which did not come into the market—forestalling and such like—were viewed with suspicion; they were supposed to be methods by which some wily person drove an extortionate bargain or gained at the expense of others. And, in modern times, organized markets, where there are facilities for public information, are common, not only in every locality, but in a great variety of trades. Commercial transactions in the United States seem to have sprung up and developed on rather different lines; markets are frequented in the country towns of Lower Canada, but there is little sign of them in the cities of the states. It almost seems as if commercial practise there were based on the habit of ‘having a deal’ privately, and took its character from transactions outside a market rather than from the higgling which occurs where many buyers and sellers meet. There can, at least, be little doubt that the methods of bargaining which are current in the states have been favorable to the building up of great organizations—both the industrial organizations which control all parts of some industrial process, and the trusts which monopolize some line of business. The lack of public markets, either for produce or for goods, at various stages of the process of manufacture, has apparently rendered it easier to form great monopolies in America than it would have been in Great Britain. Indeed, it may almost be said that the struggle for existence among business rivals takes a different form in the two countries. As Professor Jenks points out, the whole terminology which is habitually employed to analyze the movements of prices in England is inapplicable to the United States. ‘The normal price of economists has been based upon cost of

production under a system of competition among small capitalists.' But in such an industry as sugar-refining, in the United States, this condition does not hold good. 'There is no normal level of competitive price based on the cost of production.*' The whole industrial organization takes other forms, and the mechanism of competition does not work in the fashion which English economists would assume. We have need to be doubly on our guard, since unconscious assumptions may not only affect our powers of observation, but may also be present to color the language we use in describing unfamiliar phenomena.

III. It is not easy to overrate the services which the classical economists rendered in their day to the progress of economic science, owing to the clearness of the conceptions they applied to the limited field they studied, and to the accuracy they endeavored to introduce in regard to the use of familiar languages. It was their misfortune, rather than their fault, that their manner of treating individual human nature and the mechanism of society has given some excuse for the popular misuse of their teaching. In the public mind, principles which had been legitimately put forward as convenient hypotheses for the investigation of a particular sphere have been transmuted into axioms of universal applicability. But when we turn to other subjects of economic inquiry, the limitations, and consequent defects, of the classical school become more apparent. The idea of the growth of society was not easily brought within the limits of a system which makes so much use of terminology borrowed from physics. Some of the precursors of economic science in England had treated national life as organic, and had relied on biological conceptions. Hobbes had devoted a chapter of the 'Leviathan' to the nutrition and procreation of States; † and Sir William Petty, who had held the chair of anatomy in the University of Oxford, entitled an important statistical work 'The Political Anatomy of Ireland.' But another and less fruitful habit of thought existed side by side; the mercantilists, in discussing the benefits of commerce, wrote much of the balance of trade; and the physical analogies they introduced—especially the notion of equilibrium—exerted a dominating influence over the form which the science took in the hands of the classical economists. These last were so much absorbed in the discussion of the mechanism of exchange and the mechanism of society that they failed even to recognize that it is essentially organic. As has been well said, "the classical economists belonged to the pre-Darwinian age. We differ from them in our whole view of life and of the ends of life—in our whole mental method as well as in our possession of the practical experience of the last sixty years." ‡ It is only in recent

* J. W. Jenks, 'The Trust Problem,' p. 141.

† Pt. II., Ch. XXIV., Camb. Univ. Press edition, p. 175.

‡ C. L. Garvin, 'Principles of Constructive Economics,' in 'Compatriots' Club Lectures,' I., p. 2.

years, when we have passed beyond the arbitrary limits they accepted and imposed, that it has been possible to enter on new fields of research. Carl Bücher* has brought out the importance of the relations which subsist between economics and anthropology, and Thorold Rogers proved himself a vigorous pioneer in the interpretation of history. In this fashion the whole range of the phenomena of economic life, in its earlier as well as in its later forms, is being brought within the sphere of scientific treatment as exhibiting various stages of growth. The men of the classical period of economics, who devoted themselves to the study of new countries, were not in a position to deal with the subject properly, and their writings seem singularly lacking in grasp. Times have changed since their day, both politically and economically. Lord Brougham wrote at a date when responsible government was undreamed of; he pleaded for the benevolent treatment of dependencies, and his language is wholly inapplicable to the great self-governing nations, which have been formed partly under English influence and partly through English neglect. But none the less is his writing, and that of some other enthusiasts for the development of the colonies, of abiding value as a monumental warning against a sort of pseudo-philosophic habit of mind. There is an underlying assumption that the one type of colony he had in mind was the only one worth taking into account; he was really thinking of a particular case, but he allowed himself to write of it in general terms, and thus to give an air of philosophical detachment to his remarks.† In the year 1803 there were many circumstances that gave prominence to questions connected with the West Indies; the agitation in regard to the slave trade was one, the trade rivalry between the French and Spanish and English islands was another. Brougham was thinking of the West Indies; all that he said of the dependence of these little islands on the mother country for defence, of the necessity of the colonists relying on English help to repel prospective invasions and annexation by France or Spain, was true enough; it might well lie at the basis of the economic relations between the planters and the government in England, but it has no bearing on the actual conditions of the great continental countries which are still called colonies, and which are at least under no anxiety as to their ability to repulse a foreign invader.

The greatest of all Brougham's contemporaries who wrote on the art of colonization was not exempt from a similar defect; he professed to write in general terms. Few names are more deserving of honor

* 'Arbeit und Rhythmus.' His 'Industrial Evolution' has been translated by Dr. S. M. Wickett, and I desire to acknowledge my indebtedness to the volume.

† Lord Brougham, 'The Colonial Policy of European Nations' (1803), I., 108.

than that of Edward Gibbon Wakefield, and there is something very extraordinary in the contrast between the strong practical sense which distinguished him as a man of action, and the doctrinaire spirit which pervades his writings. He fell into the error which characterized the classical school when they dealt with practical problems, and generalized from the special conditions of his own day.* There was, to Wakefield's mind, one, and one only, method of successful colonization; all others were to be condemned in so far as they departed from the true system which he had devised. Wakefield, too, was the victim of unconscious assumptions; the type of colony he had in mind was a white man's country, in which raw produce might be obtained for export. He showed under what conditions Australia, Tasmania and New Zealand might be most successfully developed;† but his scheme is certainly unsuited to tropical regions, and it need not necessarily be preferable to the alternative of developing a community on the lines of subsistence farming. On this point at least we can make a very definite comparison: Virginia, Carolina and Georgia have all been colonies which raised such commodities as tobacco and rice and cotton for export; they started more rapidly than the New England colonies, where the settlers were engaged in subsistence farming; but as we look at these states at the present time, we can hardly say that the type of community to which Wakefield devoted exclusive attention is that which has given rise to the most healthy and vigorous economic life.

Even Adam Smith, in writing of the growth of societies, fell into a similar error; he passed out of the region of actual life, where he showed himself such a master, and attempted to discourse in a pseudo-philosophical strain on the manner in which countries ought to have developed, but never had. He allowed himself to elaborate an account of a supposed natural progress of opulence, which might have occurred in an isolated state. There is scope for a pretty play of fancy and much elegant writing in such a theme, but no attempt was made to show that isolated states ever do develop, so long as they remain isolated. Much may be said for the view that the chief stimulus to development is supplied by contact with communities on a different plane of economic conditions. In the history of England there are long periods of apparent stagnation and decline, and occasional epochs of rapid advance; but, whether in the days of the Danes or the Norman kings, of the Edwards or the Georges, the opening up of new trading relations has been the impetus to internal development. Economic experts are not even yet acquainted with philosophical principles as to the manner in which communities ought to develop, and therefore we are not justi-

* Cunningham, 'Growth of English Industry and Commerce in Modern Times,' p. 740.

† E. G. Wakefield, 'Art of Colonization.'

fied in pretending to train up a young country in the economic way it should go.

IV. Every undeveloped country presents a network of fresh problems, each of which must be studied separately; but they must also be considered as interrelated and viewed in their mutual dependence. There is a mass of experience in the past which may be drawn upon as a help; we may appropriate it, and save ourselves the expense of buying fresh experience in a costly fashion; but in order to reap the fruit of human experience in the past we must be prepared to take a great deal of trouble; it is not lying about for any one to pick up at haphazard. The teachings of history as to the rise of great nations from small beginnings, or as to the causes which have led to premature decay, do not lie on the surface. Since the days when Lord Burleigh recognized that the mineral wealth of the Spanish conquests in the new world did not really add to the strength of the monarchy at home, there has been a tendency to disparage extractive industries. "Moile not too much underground," said Lord Bacon, "for the hope of mines is very uncertain, and useth to make the planters idle in other things";* and Adam Smith does not at all dissociate himself from this view.† It appears to have been thought that mining for the precious metals, however attractive it might be for a time, could never be a secure foundation for the building up of stable society. But, after all, it would be wise to discriminate a little before we adopt this conclusion, and to examine the condition of different parts of Spanish America separately.‡ The richest mines of all, those of Peru, were situated on the arid slopes of the Andes, where cultivation was impossible, and there were insuperable obstacles to the planting of well-ordered and prosperous communities; but very different results were achieved in Mexico. These workings occurred on a plateau where cultivation and settlement were possible, and the wealth which was obtained by mining reacted on the prosperity both of agriculture and manufactures. Extractive industry served to give a stimulus to that varied life, partly urban and partly rural, which is necessary for a community that hopes to take a real and independent place in the civilized activities of the world. It is foolish to jump to the conclusion either that mining gives a feverish and unhealthy stimulus, or that the Spanish system of regulation was incurably bad; we ought to distinguish carefully, and to try to learn from Spanish experience, both in South and in Central America, what are the conditions under which mining for the precious metals can be pursued so as to be not merely of temporary, but of permanent advantage to the welfare of the community.

* 'Essay on Plantations.'

† 'Wealth of Nations' (Nicholson's Edition), pp. 71, 73.

‡ Merivale, 'Colonization and Colonies' (1861), pp. 25, 27.

In fact, we must remember that the experience on which we rely in regard to economic growth has been obtained, not by experiment in a laboratory, but by observation in the world itself. The investigator in a laboratory can note all the conditions under which an experiment is conducted; he can be certain that under the same conditions the same result can be secured over and over again. But in the world of political and economic activities we never find the same conditions repeating themselves; the fundamental inquiry must always be, How far were the conditions of some growing community in the past similar to those of some growing community to-day? How far are they on all fours, so that we can argue from one to another directly? Sometimes we may get a very close analogy, and instructive comparisons may be possible; but even when the conditions are very different, when there is hardly any close parallel, we may still get a suggestion as to a mode of development that might prove fruitful or as to a danger which it may be well to bear in mind.

There is pleasure in completing, so far as the limits of time and energy allow, an empirical economic investigation; but to those who have any vigor of mind at all there is a keener delight in seeing new fields of possible inquiry opened up. It is very enjoyable to renew acquaintance with an old difficulty in a fresh form, or to find that some question which seemed to be settled is forcing itself clamorously on our attention for reconsideration; and hence we have, as economists, set out for our too hurried visit here with eager anticipation. The conditions of South Africa seem to be very different from those of any other part of the world, and therefore every particular economic problem presents itself in an unfamiliar aspect. There has not been such a clear field for the working out of new ideas as was presented in the great West, or even in Australasia; and all questions as to the opening up of the country and the economic aims and aspirations of the settler are necessarily more complex. There may not be the sharply defined conflict between the old and the new which renders British India such a fascinating field for study, but the African problems are not simplified on that account. It is, rather, true to say that there is additional complication with regard to all industrial activity in a land where the natives have not been schooled to regular habits of work by the discipline of a high traditional civilization. As passing tourists we can obviously make little progress in understanding how these practical difficulties are to be solved, but at least we hope to learn to know better how the questions ought to be stated. We shall have our reward if we carry back with us as a cherished possession a not wholly unintelligent interest in the great economic problems which must be worked out in South Africa.

THE DISTRIBUTION OF THE DAILY TIME OF CORNELL STUDENTS.

BY DR. GUY MONTROSE WHIPPLE,

ASSISTANT PROFESSOR OF THE SCIENCE AND ART OF EDUCATION, CORNELL UNIVERSITY.

IN the course of an address before the freshmen of Cornell University in the fall of 1903, President Schurman emphasized the necessity of a systematic distribution of the daily time of college students and urged each student to prepare and to follow as closely as possible a daily time-schedule. He recommended the following general apportionment of hours: for work, eleven; for sleep, eight; for amusement, one; for meals and athletics, two hours each. It should be added in explanation that the period assigned to 'work' was intended to include not only time given directly to the work of the student in class-room, laboratory and study, but also to work in various fraternal, religious and collegiate societies, to work for self-support, or even to other work wholly independent of the university.

Without this explanation, which did not appear in the original newspaper reports, the assignment of eleven hours daily to work naturally seemed extreme, and it was not surprising that other educators, when interviewed upon the subject, reduced this amount. Thus, President Eliot, of Harvard, advocated nine hours for work, three for meals, two each for amusement and athletics and eight for sleep. Still others, as Professor Burton, dean of the Massachusetts Institute of Technology, thought eight hours sufficient for work.

In view of these differences of opinion, the writer conceived the notion of trying to ascertain how the students at Cornell University actually did distribute their daily time.

On account of the wide range of courses offered, Cornell is an unusually good field for such an investigation, as the students in the various colleges: mechanical and civil engineering, law, medicine, veterinary medicine, agriculture, and arts and sciences, may be fitly compared with those of technical schools like the Institute of Technology, with those of various law, medical and agricultural schools, and with those of any of the colleges offering the A.B. degree for a 'liberal culture' course, while the several hundred women students, mainly in arts, may be compared with women at colleges like Vassar, Smith and Wellesley. It was, accordingly, the purpose of the investigation not only to ascertain the average time-schedule followed by Cornell students as a whole, but, also, for purposes of comparison, that followed by each of the various groups just mentioned.

METHOD.

To obtain the desired information, a copy of the following report-blank was mailed or otherwise distributed to all Cornell students in Ithaca, *i. e.*, to approximately 2,700 students.*

Some of the daily papers have recently been discussing the recommendations which President Schurman, President Eliot and others have given to university students in regard to the allotment of time to work, athletics, meals, sleep, etc.

The Department of Education desires to ascertain the actual distribution of time by the average Cornell student during a typical week. To bring this about your hearty and faithful cooperation is needed. We want bona-fide, unbiased reports of the distribution of your time during the week *December 7 to 12, inclusive*. Kindly fill in the subjoined blank *daily* during that period. Do not try to vary your usual routine in order to make a 'pretty' report. Your name will not be open to inspection, nor seen by any person other than the compiler.

INSTRUCTIONS.

1. Put general reading, letter writing, etc., under amusement.
2. Put drill, gymnasium, athletics, walking, etc., under physical exercise.
3. Express fractions of an hour as a decimal part of an hour, and take care that each day sums up 24 hours.
4. Divide days at midnight in reckoning sleep.
5. Note under 'remarks' anything that will further contribute to the understanding of your returns. Especially in case you think the report does not fairly illustrate your normal habits, state what occupation has been over or under emphasized.
6. Leave the report at the registrar's office through the doorslide, or mail to Dr. G. M. Whipple, Dept. of Education, not later than Monday, December 14.

Name

Course

Class

HOURS SPENT DECEMBER 7-12, 1903.

	M.	T.	W.	Th.	F.	S.	Total.
Lectures							
Laboratories.....							
Shop or field.....							
Outside study.....							
Amusement.....							
Physical exercise							
Meals							
Sleep.....							
Unclassified.....							

Remarks:

* Members of the section of the Cornell Medical College at New York City, about 278 in number, are therefore, not represented in the returns from the College of Medicine, but only the first two years of the medical course.

THE RESULTS. CRITICAL.

Limitations and Sources of Error.—Before examining the results in detail, it is well to consider the limitations under which they were secured and the sources of error to which they may be thought liable.

Number.—It may be thought that the results lose something of their meaning because only about one blank in three (940* out of 2,700) was returned, but this was considered a very satisfactory showing, because, in the nature of the case, the filling out and return of the blank were not obligatory. Notwithstanding the definite assurances to the contrary contained in the announcement, many students feared that their records would, in some way, be open to the inspection of officials of the university, and therefore balked at making records of their doings in ‘black and white,’ while more still were either too busy or too lazy and too little interested to make out reports.

It is a familiar principle, though worth mention in this connection, that the habits of relatively homogeneous groups, such as all those under discussion, may be inferred with considerable certainty from data secured from a relatively small percentage of the members of the groups, provided the representation is typical. The more homogeneous the group, the smaller the data essential for safe induction.

That our data are typical is attested by two apparently paradoxical facts: (1) When the results are compiled on the basis of classes and courses, it is found that the averages for a given group are closely similar to those of other groups working under similar conditions, *e. g.*, the freshmen and the sophomores in the College of Medicine give 19.72 and 19.30 hours per week, respectively, to outside study, 10.30 and 10.37 hours per week, respectively, to amusement, while the freshmen and sophomores in arts give 14.10 and 14.94 hours, respectively, to amusement. (2) In every group we note the presence of some extreme cases which vary widely from the average of the group. Thus, 41 male freshmen average 30.04 hours per week in outside study, yet one freshman records 57.00, and still another but nine hours. In a similar manner, we find that every group contains both the studious and those little given to study, both those who over-indulge in athletics and those who scarcely take physical exercise at all, both leisurely and over-hasty eaters, etc., etc. In short, the reports are representative.†

* Of this number 45 were rejected, most of them as being incomplete—lacking a day, or a statement of course or class, etc. About 35 per cent. of the undergraduate, 20 per cent. of the graduate, students sent in reports.

† If any allowance is to be made, possibly we should discount somewhat the average time found for university work in general and outside study in particular, and increase that for amusement or exercise, on the ground that the class of students who are less studiously inclined would be less likely than

Week Chosen.—It is, of course, difficult to select a week for purposes like the present which shall be entirely typical and free from circumstances which tend to produce distortion in one direction or another. The week December 7–12 was sufficiently removed from the influence of the usual written tests, examinations and generally unsettled conditions of the week just preceding the Christmas recess, and might be regarded as a typical winter week, save that the unusually good skating increased the time of many students for physical exercise. Probably, however, the average for physical exercise is no greater than that expended during warmer weather when tennis, rowing, baseball, walking and other forms of sport and recreation combine to entice the student from his work, so that physical exercise may be considered, after all, as not far from normal in amount.

On the other hand, the amount of field work in civil engineering and agriculture is necessarily somewhat low during any winter week. A few students in chemistry reported university work slightly less than normal owing to a change from qualitative to quantitative analysis, while a few other students in various courses reported an excess of university work due to preparation for tests or preliminary examinations in one or two studies. But such disturbances are slight and tend to counterbalance one another.

Omission of Sunday.—The investigation may possibly be considered incomplete because it embraces but six days of the week.* Two reasons contributed to this. In the first place our object was merely to obtain the average daily time distribution of college students, and the daily routine of college work is maintained during the six week days only. Secondly, if Sunday were to be included, additional categories would have been necessary, and a separate tabulation of the week-day totals and of the Sunday items—all of which would entail labor quite out of proportion to the results achieved.

Moreover, it is not difficult to see, in the light of remarks appended by numerous students, that Sunday would have an influence significant for us in one respect alone, viz., the time credited to outside study. It is unfortunate that no attempt was made to obtain quantitative estimate of this time. We might, perhaps, add some two hours to the weekly average for outside study (and university work).†

others to fill out and return *bona-fide* statements of their negligence in these matters.

* We are, for instance, in receipt of a lengthy letter from a student condemning the investigation on that score.

† But it is, of course, impossible to make any quantitative allowance for this increment in computing the average day from our returns, save by obtaining a full record for Sunday and averaging for seven days, which was inadvisable for the reasons already cited. We can feel, at any rate, that this increment more than removes the discount for lack of representation from the unstudious.

Items Chosen.—As already explained, the original intent was to obtain statistics in regard to the five items cited in the president's address, *viz.*, work, meals, amusement, athletics and sleep. It seemed desirable, however, to obtain some further indication of the distribution of the time included under work. Hence the subdivisions—lectures (including recitations), laboratories, shop and field, and outside study—which are summarized in the tables as 'University work' by the figures in parentheses following that item. The term 'physical exercise' was chosen as being more comprehensive than 'athletics,' and the 'unclassified' category was added for obvious reasons.

After the blanks had been distributed, but before they had been filled out, the writer's attention was called to the desirability of obtaining a record of the time devoted to work for self-support. Notice was accordingly given in the college papers that students who spent time in this way should record the amount as a separate item. Many observed this request; others, who did not, added explanatory remarks to their reports so that the writer was able to compute the time correctly and subtract it from the time assigned by them to physical exercise, unclassified or meals* as the case might be. On the supposition that some self-supporting students failed either to itemize this time or otherwise to indicate it, we may assume that the percentage of self-supporting students and the percentage of time allotted to self-support may be slightly too low.

Finally, in the light of our experience, we may mention three improvements that might have been made in the list of items.

In the first place, 'shop and field' did not prove of sufficient importance to justify the separate item, being only pertinent to students in engineering, agriculture and architecture (draughting), and the amount of field work in civil engineering and agriculture being at a minimum in the winter. All phases of university work other than class-room work might be conveniently indicated collectively under some such term as 'practicums.'

Secondly, many, especially freshmen in arts, hesitated to include recitations with lectures—a difficulty which had to be remedied by the writer in tabulation, but which might have been avoided by specific instruction.

Thirdly, a number of important student activities are not easily placed under the present rubrics, and thus fell into the unclassified category. We refer to such things as musical club rehearsals, Y. M. C. A. meetings, work for the college papers, in class politics, upon fraternity business—time spent for various university organizations. Such activity is not strictly university work, but neither is it amusement, nor physical exercise. An item should have been introduced to include this significant phase of student life.

* In the case of those who waited upon table.

Fidelity of the Reports.—There is no way to know whether the reports are truthful and reliable statements of the students' activities save by the internal evidence of the reports themselves. Judged in this way and in the light of the general interest manifested in the matter at the time, the writer feels confident that a high degree of reliability can be attached to the 895 reports which were admitted to tabulation.

Accuracy of the Reports.—About one third of the reports contained inaccuracies, chiefly errors in the addition of the totals, or, less often, errors in the number of hours recorded *per diem*—25 being a favorite amount! These errors obviously rendered it impossible to tabulate the reports with any accuracy, so that every one of the 895 reports had to be added anew—an operation requiring some 75 hours of solid work for two persons.* Obvious errors were corrected on the spot; many reports were returned to students for revision, but, in a few cases, where this was not feasible, minor errors were corrected by the writer in accordance with his own judgment.

Averages and Variations.—For economy's sake the mean variations have been omitted from the tables which follow, for, although they afford a concise index of the uniformity of the individual instances summarized in the average value, their computation would consume more time than they are worth. In place of the mean variation we have recorded the two extremes of individual variation for each group, as 'high' and 'low,' respectively, while the index of uniformity which would have been supplied by the mean variation is afforded by a comparison of the average values for the same item in different groups and classes. Thus the high uniformity of the time registered for sleep is shown by comparing the final average for sleep, 7.90 hours daily, with the same average in the table by classes (8.00, 7.96, 7.77, 7.83) or in the table of courses (8.00, 7.86, 8.22, 7.75, 7.90, 7.91, 7.62, 7.76, 7.95, 7.74, 8.02). Or, again, the relative uniformity of the results for the various groups and classes can be shown fairly well by computing what might be called the 'mean group-variation,' both in terms of absolute hours and in percentage of the final average. Thus, when we compare the averages found for sleep for freshmen arts, sophomore arts, junior arts, senior arts, first year law, etc., through the 39 primary groups, with the final average for all students taken collectively, we find (Table 5) a mean variation for these group averages of slightly less than three per cent., while that for meals is eight per cent., and so on.

THE RESULTS. STATISTICAL.

Explanation of the Tables.—With these apologies and explanations we are ready to examine the results themselves.

* My thanks are due to my wife for her assistance in this laborious undertaking, and in the subsequent task of tabulation.

The reports were first classified into 39 sets, each set representing a single class within a single college, the electrical engineering being considered separately from the mechanical engineering students, and the sexes being treated separately within the College of Arts and Sciences. A miscellaneous group was introduced to comprehend the few graduate and special students who represented activities too heterogeneous to form a typical set.

In this series of tables there was indicated the average and the highest and the lowest weekly record of each class in each college. Only a single specimen (Table 1) is here printed—that of the civil engineering freshmen. The figures in parenthesis after ‘meals’ denote the number of students who gave six hours or less, *i. e.*, an hour a day or less, to their meals, while similar figures after ‘support’ denote the number of students therein represented.

‘University work’ is the sum of the first four items.

TABLE 1.
Specimen of the first series. C. E. Freshmen. 43 cases.

Topic.	Average.	High.	Low.
Lectures.....	11.55	23.00	7.00
Laboratories.....	8.28	26.00	2.50
Shop and field.....	4.96	22.00	0.00
Outside study.....	26.27	44.50	10.00
(University work).....	(51.06)	.....	.....
Amusement.....	12.55	29.00	0.00
Physical exercise.....	11.93	25.00	3.50
Meals.....	(12) 8.55	16.25	2.92
Sleep.....	48.11	57.50	34.00
Unclassified.....	6.71	21.50	0.00
Support.....	(12) 5.09	35.00	0.00

The chief interest of the investigation attaches, however, to the second series of tables, which are derived from the first series by division by six (to reduce to a single day basis) and by combination in various ways. We thus are able to secure (1) a comparison of classes, (2) a comparison of courses, (3) a comparison of the sexes, and, finally, (4) the daily time of that hypothetical being, the *average* Cornell student.* Save in the last, the extremes of variation have been omitted in these derived tables.

The division into ‘courses’ corresponds, naturally, to the division of the university into colleges, *viz.*, arts and sciences, law, medicine, veterinary medicine, agriculture, architecture, civil engineering and mechanical engineering.

The College of Medicine in Ithaca has two classes (1st and 2d year); the Colleges of Law and Veterinary Medicine have each three classes, which are here treated as first year, junior and senior; all the other colleges have four years.

* Hypothetical because, of course, the time would never correspond in actuality with that of any single student.

In comparing the classes, the women are included with the men, though their number is specified; in comparing the courses, they are separated from the men in the arts and sciences group only.

The percentage of enrolled students actually represented is indicated in every instance. It ranges from 19 per cent. to 43 per cent.

Comparison of the Classes.—As will be seen from Table 2 it is difficult, if not impracticable, to assert any general differences in the distribution of the daily time of freshmen, sophomores, juniors and seniors. The only generalization that is suggested is that freshmen and seniors give less time to university work than do sophomores and juniors. This statement is borne out by the table, and by inspection of the tables of the first series it may be discovered that the least work is done by freshmen or seniors in eight of nine courses; conversely, most work is done by sophomores or juniors in six of nine courses. The shorter time of freshmen is evidently due to the fact that prescribed work in certain professional courses calls for less laboratory and field work in the first, than in succeeding years. Thus the courses in which the hours of the freshmen class are shortest are law, veterinary medicine, civil, mechanical and electrical engineering.

TABLE 2.
Totals by classes, all courses.* Average Day.

Year.	Freshmen.	Sophomores.	Juniors.	Seniors.	Specials and Grads.
Total number.....	253	201	204	185	36
Number women.....	21	18	12	25	8
Per cent. represented	24	37	43	43	—
Lectures	1.95	2.25	2.19	2.50	1.71
Laboratories.....	1.38	1.81	1.62	1.79	2.90
Shop and field	1.02	1.40	1.06	0.36	0.28
Outside study.....	4.34	3.69	4.42	4.38	4.01
(University work)...	(8.69)	(9.15)	(9.29)	(9.03)	(8.90)
Amusement.....	2.17	2.34	2.26	2.28	1.89
Physical exercise.....	1.96	1.69	1.59	1.63	1.29
Meals	1.49	1.36	1.34	1.41	1.44
Sleep.....	8.00	7.96	7.77	7.83	8.02
Unclassified.....	1.21	1.25	1.42	1.52	1.76
Support	0.48	0.25	0.33	0.30	0.70

Comparison of the Courses.—As shown in Table 3, the several colleges of the university may be arranged in the following order in terms of the average number of hours given in university work: medicine, veterinary medicine, mechanical and civil engineering, architecture, law, agriculture, arts. †

* Includes all but 16 specials in agriculture (14 men and 2 women).

† The special group is excluded in this discussion, being too heterogeneous to be classed as a graduate group. Its place would be between architecture and law.

Electrical and mechanical engineering, if computed separately, are found

TABLE 3.
Totals by courses, all classes. Average Day.

Course.	Arts, Men.	Arts, Women.	Law.	Medicine.	Vet. Med.	Agriculture.	Architecture.	Civ. Eng.	Mech. Eng.	Special Group (Largely Graduates).
Total number.....	178	69	46	29	29	47	19	120	322	36
Number: women....	0	69	2	3	0	3	1	0	0	8
Percent. represented	40	25	19	35	34	35	30	39	34	—
Lectures.....	2.46	2.52	2.52	1.27	1.85	1.67	1.42	2.35	2.10	1.71
Laboratories.....	1.24	0.88	0.04	6.27	4.44	2.46	0.05	1.50	1.61	2.90
Shop and field.....	0.09	0.00	0.00	0.00	0.02	0.38	6.17	0.87	1.79	0.28
Outside study.....	4.36	4.63	5.75	3.25	4.06	3.70	1.67	4.62	3.94	4.01
(University work)...	(8.15)	(8.03)	(8.31)	(10.79)	(10.37)	(8.21)	(9.31)	(9.34)	(9.44)	(8.90)
Amusement.....	2.61	2.21	2.50	1.72	1.70	2.14	2.12	2.17	2.18	1.89
Physical exercise....	1.86	1.43	1.85	1.44	1.43	1.67	1.64	1.79	1.76	1.29
Meals.....	1.43	1.55	1.53	1.43	1.46	1.41	1.48	1.37	1.35	1.44
Sleep.....	8.00	7.86	8.22	7.75	7.90	7.91	7.62	7.76	7.88	8.02
Unclassified.....	1.48	2.78	1.07	0.69	0.63	1.43	1.28	1.03	1.22	1.76
Support.....	0.47	0.14	0.52	0.18	0.51	1.23	0.55	0.54	0.17	0.70
Number support.....	33	3	9	3	7	15	3	24	21	9
Per cent. support.....	19.1	4.3	19.5	10.3	24.1	31.9	15.9	20.0	6.5	25.0

It will readily be seen that the high averages of 10.79 and 10.37 hours accredited to medicine* and veterinary medicine, respectively, are due to the large amount of laboratory work required by these courses. Medicine has, in fact, the smallest number of lecture hours and the smallest time given to outside study. In a similar way the one hour excess of architecture and the courses in engineering over law and arts is easily traced to the large amount of time expended in draughting, shop, laboratory and field work of various kinds.

These figures raise the interesting question as to whether we can assert that the students in professional courses work harder as well as longer than those in arts. It seems to me manifestly impossible to get behind the figures and answer the question positively by assigning any qualitative value to time spent in 'practicums' as *versus* lectures. At any rate, it would be unfair to manipulate the figures in accordance with the correlation generally observed in this and other universities that two and a half hours laboratory, or three hours shop or draughting, work are equivalent for university credit to one hour of lecture or recitation. If this relation is based upon the assumption that the lecture-course student spends from one and a half to two to be almost identical. Since the work required is identical during the first two years and closely comparable in the last two, we have an additional confirmation of the value that may be placed upon the results as truly representative.

* It must be borne in mind here that we are comparing a two-year with three- and four-year courses, though there is every reason to suppose that the same *tempo* is observed in the two years of the medical course taken at New York City.

hours in outside study as a preparation for each hour of lecture or recitation work, the relation is evidently unfair, because the laboratory student, in most cases, is obliged to put preparation or outside study time in some form or other upon the work which he has been doing in the practicum. And this will be seen to be true even though, as our figures indicate, the average lecture course student spends *more* than one and a half hours outside study for each hour of lectures. Thus, if we take the women in arts, who have a small amount of laboratory work, we find 2.52 hours lectures accompanied by 4.63 hours outside study, or, if we take students in law, whose laboratory hours are practically *nil*, 2.52 hours lectures are accompanied by 5.75 hours outside study. If we may assume, then, between lectures and outside study, a general relation of one to two, we should expect students in medicine to accompany 1.27 hours lectures with 2.54 hours outside study, whereas their actual time as reported is 3.25 hours. Similarly, veterinary medicine reports 4.06, instead of 3.70 calculated, hours of outside study. Either these students have lectures which are more difficult to prepare for than are those of other students, or their laboratory work demands time outside the laboratory. The latter is presumably the case. It seems, therefore, fairly evident that in so far as our reports are truly representative, students in the two medical colleges work both longer and harder than students in other courses in the university.

It is very doubtful whether we can make such an assertion in the case of the students in the various branches of engineering. In the first place, such a discrepancy as that just discussed is not observable. The ratio of outside study to lectures is very close to the two-to-one ratio shown in arts and law. Hence we may suppose that shop and field work require very little outside study and that the laboratory work has been more equably adjusted than in the medical courses. In the second place, field work in engineering, and probably shop work, too, demand less persistent attentive work than laboratory and lecture work in general. The various forms of surveying, for instance, consume much time, but it is seldom that all the members of a surveying section are actively and continuously employed. We shall, therefore, be inclined to think that most engineering students expend more time, but not necessarily more energy, than students in law or arts. Yet the actual discrepancy in the time of these three groups of courses—arts and law, the engineering courses and the medical courses—is considerable; students in the last named courses working *two hours*, and students in architecture and engineering, *one hour*, more *per diem* than students in arts, law or agriculture.*

* Very possibly the time given in agriculture would be higher in the warmer months of the year.

The one or two hours time gained by the arts student over his mate in the other courses is expended largely, as might be expected, in amusement, physical exercises and unclassified pursuits, as the hours for meals and sleep are fairly constant, though law and arts do exceed other courses slightly even in this respect. It is perhaps not without significance that students in the two medical colleges have the least amount of time that can not be classified, whereas, of all the courses, arts and law give the longest time to amusement, the longest time to physical exercise, the longest time to sleep, and arts the longest time to miscellaneous activities.

On the other hand, the average student in agriculture, who has a relatively short period of university work—less, in fact, than law—devotes the time thus gained very largely to work for self-support, giving from 0.68 to 1.18 hours more time daily to this sort of work than the students of other courses.

Comparison of the Sexes.—Of special interest is the comparison of the daily time of the sexes in a coeducational institution.

In examining Table 4 we must remember that a large majority of the women (69/86) and but relatively few of the men (178/809) are arts students. Hence it is not surprising that the men exceed in the

TABLE 4.
Totals by sexes, all students. Average Day.

Number. Per Cent. Represented.	Men.	Women.
	809 34	86 24
Lectures.....	2.16	2.34
Laboratories.....	1.73	1.29
Shop and field.....	1.03	0.06
Outside study	4.17	4.39
(University work)	(9.09)	(8.08)
Amusement.....	2.25	2.17
Physical exercise.....	1.75	1.42
Meals.....	(215) 1.39	(5) 1.55
Sleep.....	7.90	7.86
Unclassified	1.21	2.72
Support	(121) 0.41	(5) 0.20

time spent in laboratory, shop and field work, the excess here more than counteracting the slightly greater time spent by women in lectures and 'outside study,'* so that the average man spends an hour a day more at university work than the average woman.

Now, to make the comparison entirely fair, let us contrast the men in arts with the women in arts (where they are mainly to be found). We discover, however (Table 3), that the conditions are practically the same even here, though the differences are less exaggerated. Men

* But if we assume, as seems highly probable, that more men than women study on Sunday, we may suppose that the total time per week given to outside study is as great, if not greater, for men than for women.

exceed women in time spent in laboratories; women exceed men in time spent in lectures and outside study (with the reservation as to Sunday study just noted). Even so, the men in the College of Arts and Sciences, who give less time to university work than the men of any other college, give more time than the women of the college. In other words, the women at Cornell give the least time of any group to university work. Those who fear lest women are overdoing in their attempt to work with men in a coeducational institution may find some comfort in these figures.

With regard to the remaining items, we find that, whether we compare the women in arts with the men in arts or the women with the men in the university at large, women spend less time than men in amusement, in physical exercise, in sleep and in self support, but spend more time at meals and over an hour a day more in the miscellaneous activities recorded as unclassified.

Our general result, then, is that women give less time than men to university work, to amusement, to physical exercise, to sleep and to self-support; they give more time to meals and unclassified pursuits.

The Final Average.—In Table 5 will be found the final average-day of all students taken collectively. For the purpose of discussing the relative uniformity of the figures for the various items this average is supplemented by two further groups of figures. The last two columns indicate the extreme individual variations found in the entire student body (reduced to a 24-hour basis). The second and third columns express what we have ventured to term the 'mean group variation.' This was computed by comparing the *average* of each of the 39 groups comprised in the first series of tables with the final average of the present table. Thus the averages for the four classes in arts, the three classes in law, etc., vary from the final average by a mean of three quarters of an hour in absolute time (second column), which is equivalent approximately to a variation of 21 per cent. (third column).

Let us first consider the relation of the final average to the amounts recommended by the authorities mentioned in our introduction, and then take up the various items for further consideration in the light of the variations and extremes.

By a curious chance, the period of university work for the average Cornell student is exactly nine hours, or precisely the time advocated by President Eliot. Even if we add the time given to self-support (0.39) the time given to work (in the wider use of the term) is not materially modified. Only if all the unclassified time is assumed to be of the general nature of work—an assumption entirely unwarranted—can we obtain anything like the eleven hours advocated by President Schurman.

TABLE 5.
Final totals, all students. 895 cases (33 per cent.).

Topic.	Average.	Mean Group Variation.		Extreme Individual Variation.	
		Absolute.	Rel.(Per Cent.).	Highest.	Lowest.
Lectures	2.17	0.45	21	4.00	0.00
Laboratories.....	1.70	1.14	67	9.50	0.00
Shop and field.....	0.94	1.31	139	10.33	0.00
Outside study.....	4.19	0.82	20	12.67	0.00
(Univ. work).....	(9.00)	(0.88)	(10)	—	—
Amusement.....	2.23	0.25	12	6.87	0.00
Physical exercise	1.72	0.31	18	5.50	0.00
Meals.....	1.40	0.11	8	3.50	0.47
Sleep.....	7.90	0.21	3	10.00	5.50
Unclassified	1.36	0.44	32	7.43	0.00
Support	0.39	0.31	81	7.33	0.00

It is evident that eleven hours is much more than the time given to work by the average student, and in my opinion, much higher than can be expected. For, judging from what I know of the conditions in other universities, especially in the east, I believe that Cornell students devote more serious and longer attention to their studies than the students of most institutions of learning, and I should certainly be surprised if further investigations of this sort should reveal institutions of a comparable type whose students average more than nine hours daily in university work.

Comparing our results still further with the hours recommended, it will be seen that the eight hour period uniformly thought desirable for *sleep* is very closely approximated.

The time given by the average student to *amusement*, however, is about a quarter of an hour longer than that suggested by President Eliot and an hour and a quarter longer than that suggested by President Schurman. This may be due in part to the fact that our term 'amusement' includes letter writing and general reading not directly connected with university work—both items that might possibly be regarded as 'work' in President Schurman's use of the term. On the other hand, the discrepancy is not uniformly present, for we may note, by reference to Table 3, that less than two hours of amusement is indicated for students in the medical colleges and for the group of graduate and special students.

In contrast to amusement, the time given by the average student to all forms of *physical exercise*, including military drill, walking, skating, gymnasium, out-door games and athletics is less than that recommended. This is true of every course, of every class and of both sexes.

Precisely the same thing may be said of *meals*, the period being uniformly less than that assigned—about half an hour less than the figures of President Schurman and an hour and a half less than those of President Eliot. We shall return to this point in a moment.

Let us next turn to the variations and extremes as related to the final average. The variations here expressed are necessarily somewhat high and should not be confounded with mean variations of individual cases, because they represent merely the variations of averages of groups, each one of which stands for a particular set of conditions and thus tends to exaggerate some one or more items at the expense of the rest. Under these conditions we should expect just what the table shows—that the hours for sleep and meals, which are little affected by course or class, are the most constant, the variation being but 3 per cent. for sleep and 8 per cent. for meals. In the case of university work, we may note that there is considerable variation in the distribution of the type of work, *e. g.*, 67 per cent. for laboratories, 139 per cent. for shop and field, but that the final outcome is fairly constant, being slightly under 10 per cent. variation.

When we glance at the individual extremes many of the figures are surprising. Thus, while we know that many students give no time to laboratory or shop work or to self-support, we should scarcely anticipate that there are students who give no time (at least for this week) to outside study, and others who have no lectures or recitations. It is equally unexpected to find that some students give more time by an hour or more a day to a single phase of work, like laboratory or shop work, than the average student gives to all phases of university work combined. The highest *lecture* time is that, of course, of a student who is attending as an auditor several courses in which he is not registered. With regard to *amusement*, the chief interest lies in the fact that four students, two in medicine, a freshman in civil engineering and a junior in electrical engineering—report no time for amusement, while periods aggregating only an hour a week, *i. e.*, about ten minutes a day, are reported by several others. Similarly, we find six students who gave no time at all to any form of physical exercise, notwithstanding the temptations of fine skating.

But it is with regard to *meals* that the extremes are most interesting. We have already noted that the average time is considerably below the time allotted. One student, a freshman in engineering, reports three and a half hours daily for meals; a sophomore in civil engineering reports 3.22 hours, and four students report three hours each. In other words, only *six* (less than seven tenths of one per cent.) give the time to meals recommended by President Eliot. But it is equally true that but few students give even the two hours recommended by President Schurman. Indeed, no group or class of students, women excluded, average even an hour and a half daily for meals, while the women students average but 1.55 hours.

This is the feature of the president's speech which, next to his advocacy of eleven hours for work, appears to have aroused the most

comment on the part of the student body. Thus, a freshman in agriculture adds to his report: "It may not be out of place to remark that, if President Schurman went to a Huestis Street boarding-house, he would not require two hours for meals."

So, as a matter of interest, a record was made of all the individual students who give six hours or less weekly to meals. As summarized in Table 4, 215 men and 5 women, or *24.6 per cent. of the students who answered our inquiry, give but 20 minutes or less to each meal.* When it is remembered that most of the students eat in boarding-houses where more or less time is lost by the slowness of the service, some idea is afforded of the unwarrantable haste with which students eat.*

Furthermore, numerous students report 45 minutes, others 40, 35 or 30 minutes; last of all, a junior in architecture gives *26 minutes daily* to his meals. Certainly we should welcome any influence which could make the student's dining-table more attractive as a place for leisurely eating and beneficial conversation.†

The time given to *sleep* is very uniform, with the variations wider below than above; the longest sleepers are two young men, a senior in law and a junior in mechanical engineering, who demand ten hours daily, while one student reports but six hours; two, five and two thirds hours; and one, a freshman in agriculture, only five and a half hours, daily.‡

The *unclassified* time is regularly higher in women's than in men's reports, while the extreme of 7.43 hours daily not otherwise accounted

* Doubtless many of these 220 students prepare their own breakfast, and make a very simple fare of fruit, cereals and milk. If ten minutes sufficed for this, they might spend 25 minutes each upon the two remaining meals at some boarding-house.

† The trouble may lie in part in the fact that the atmosphere of the typical college boarding-house is one of haste: the table service, and even some share of the preparation of food and the resetting of tables and washing of dishes, falls to student waiters who must hurry their fellows to save time enough for their own meals. And, at Cornell, this haste is augmented by the prevalence of 'eight o'clocks,' and by the restriction of the noon interval, in many cases, to the single hour between one and two, and, still further, by the fact that nearly all the students board off the campus and must take practically a mile walk for their lunch. Some confirmation of this opinion may be seen in the higher average for meal hours of the women who board in commons on the campus.

But the trouble lies even more, in my opinion, in the fact that the average student has never been 'educated' to a proper recognition of the possibilities of the dinner-table as a place for general conversation, for the exchange of views, for the leisurely discussion of college news and of the events of the day in the world outside. The 'talk while you eat' habit should replace the 'bolt and run' habit.

‡ This young man rises every morning at four o'clock, and works seven hours every day for his support.

for is found in the report of a young lady in sophomore arts. Very many men, on the other hand, especially those in the medical and engineering courses, were able to account for all their time under the rubrics we employed.

As already explained, the time assigned to *self-support* may be somewhat understated, because of the lack of the item in the original blank. We know, however, that at least 121 men and 5 women, or 14 per cent. of the students here figured, work for their support. In the extreme case, a special student in agriculture, seven hours and twenty minutes daily are devoted to earning a livelihood, while a freshman in the same course, as previously cited, devotes seven hours similarly.

In Table 3 we have incorporated figures to show the absolute and relative distribution of the cases of work for self-support. It appears that not only is it the average student in agriculture that devotes the most time to support, but also that a greater percentage of such students (about one in three) are so engaged. The lowest percentage, 2.9, is that of mechanical engineering (apart from electrical engineering), which is even lower than that of the women in arts. Or, if we combine mechanical and electrical engineering, we observe that only 6.5 per cent. of Sibley College students work for their livelihood, as against 19.1 per cent. in arts, 19.5 per cent. in law, 20 per cent. in civil engineering, and 17.2 per cent. in the two medical colleges (by combination). This relation seems significant enough to demand attention. In the opinion of a Sibley College professor, it is to be explained on the ground that a larger proportion of Sibley than of other students are the sons of wealthy or well-to-do parents. If the explanation be correct, it is of interest as showing the increasing tendency of those who are identified with large business interests to give their sons a 'professional' rather than a 'liberal culture' training.

SUMMARY.

On the basis of returns from about one third of the student-body, and subject to the limitations which have been discussed at length above, the following propositions may be laid down in regard to the daily distribution of the time of Cornell students:

1. Freshmen and seniors give slightly less time to university work than do sophomores and juniors.

2. The average length of time given to university work is greatest in the colleges of medicine, and progressively less in those of engineering, architecture, law, agriculture and arts—the extremes varying from 10.79 to 8.03 hours daily. Though these differences are largely due to the varying amounts of laboratory, shop and field work required, the courses in medicine still seem to demand not only longer, but also harder work than others.

3. Students in arts and law exceed those in the other colleges in amusement, physical exercise and sleep. Students in agriculture exceed those in other colleges in the number devoting time to self-support, and in the amount of time thus spent.

4. Both in the university at large and within the College of Arts and Sciences, men give more time to university work than do women, whose time is the lowest of any group. Furthermore, women devote less time than men to amusement, physical exercise, sleep and self-support, but more time to meals and over an hour a day more to the miscellaneous activities recorded as unclassified.

5. Taking the university at large, the average student devotes just nine hours daily to university work, which are distributed as follows: lectures and recitations, 2.17; laboratories, 1.70; shop and field work, 0.94; outside study, 4.19. The average student sleeps 7.90 hours, devotes 2.23 hours to amusement, 1.72 to physical exercise, 1.40 to meals, 0.39 to self-support, and 1.36 hours to unclassified activities. Of these amounts, that given to university work is less than that recommended by President Schurman, precisely that recommended by President Eliot, and more than that recommended by Dean Burton; that given to sleep closely approximates the eight hours generally cited; while that given to amusement is longer, and that given to physical exercise and to meals, particularly the latter, is shorter than that recommended by any of the educators quoted.

6. Some 14 per cent. of the students give some time to occupations that assist them financially.

In conclusion, the writer suggests that similar investigations, undertaken with the modifications and precautions which this study has shown to be advisable, would afford an interesting basis for the comparison of student activities in various institutions of learning.*

* Since this article was prepared for publication, a similar study has been reported from Harvard University, but it has not been possible to incorporate a comparison of results here. According to newspaper comments, the average time given to university work was much less than that found at Cornell.

GREEK IDEAS OF VULCANISM.

BY DR. CHARLES R. EASTMAN,

HARVARD UNIVERSITY.

‘GREEK philosophy was born,’ as has been aptly remarked, ‘on that day when some thinker tried to find a rational explanation of the universe.’ Tradition awards the honor of this initiative to Thales of Miletus, who lived in the beginning of the sixth century, B.C. Meager and unsatisfactory as is our knowledge of this early pioneer, his place is none the less honored and secure in the history of natural philosophy. According to common report he was well versed in the astronomical lore of the Chaldeans, predicted eclipses, investigated meteorological phenomena, sought to explain the causes of earthquakes, and attained to the truly sublime height of conceiving that all existing things had a common origin, and that water was the primordial matter of the universe.

In the teachings of Thales and his followers we discover not only germs of suggestion destined to become extremely fruitful in biological science, but also the first serious attempts at geological speculation during classical antiquity. Previous to the sixth century B.C., neither the Hellenic, Egyptian nor Oriental mind seems to have advanced beyond intellectual childhood in proposing to itself a rational explanation of nature. The ancient feeling for nature amongst the Greeks, as revealed in literature, was decidedly prosaic and practical; only by slow degrees did they come to the idea of nature as a single power or being, more or less personified, and possessing the attributes of beauty and conscious intelligence. With the earlier deistic interpretation of nature, with the numerous legends and ‘observation myths’ of antiquity, and with the invocation of supernatural agencies by way of explaining vulcanism, we are not now especially concerned. Merely be it noted in passing that the localization of geological myths, such as that of the Chimæra, the Deucalion deluge, the fall of Hephæstus upon Lemnos together with his various subterranean forges, and also significant place-names like Rhégium, Tempe, Piræus, Kaimeni, Katakekaumene (‘Burnt Country’), etc., frequently attests the occurrence of geological events which were afterwards forgotten.*

Volcanoes themselves did not at first engage the attention of Ionian philosophers, for reasons easily understood. In the first place, the eruptions known to have taken place in the Greek Archipelago occurred

* It has been suggested with much plausibility that all the traditions of certain islands in the Mediterranean having at some time or other shifted their positions, and at length become stationary, originated in the great change produced in their form by earthquakes and submarine eruptions, of which there

either at the very dawn of Hellenic culture, or during its wane. Secondly, the mainland on either side of the Ægean being free from volcanic action, knowledge of this form of energy was dependent upon the reports of travelers who had visited Etna or Argæus; and our sole reason for supposing that either of these centers was in eruption during the early historical period is based upon their persistent association with Typhon myths. As for the first tremendous convulsion which overwhelmed Thera (Santorin), this happened so long anterior to documentary history that not the least vestige of a tradition has survived. The next fiery outbreak did not occur until about two hundred years before our era, and that of Methona only about a century earlier. Hence, until considerably after the time of Aristotle, the opportunity for studying active volcanoes, either near at hand or in distant regions, was extremely limited.

On the other hand, secondary manifestations of vulcanism were everywhere abundant. The extraordinary prevalence and violence of earthquakes throughout the ancient world, their effect upon the popular mind, and the extent to which even historical events were influenced by them, are facts too well known to require comment. Frequent references in literature to mud volcanoes, solfataras, fumaroles, sulphur springs and allied phenomena reveal a lively curiosity in these matters, and a growing tendency to associate them with volcanic action. Attention early became attracted to the numerous jets of mephitic vapor in western Phrygia, their fancied connection with the infernal regions giving rise to such names as *Charonia* and *Plutonia*. The Plutonium of Hierapolis was particularly famous, and so too were the hot springs in various parts of Greece, as at Thermopylæ, and in the north of Eubœa. All these occurrences were associated in the olden time with Heracles in his character of fire-god; and owing to constant succession of earthquake shocks in the Peloponnese, that district became the focus of the worship of Poseidon, the 'earth-shaker.' Gradually a mythological interpretation of these phenomena gave place to a philosophical, crude at first, but elaborated little by little, until finally ideas were developed which have become the heritage of modern science.

It will repay us to trace the development of some of these ideas, though in view of the thoroughness with which this has already been done by Sudhaus in his scientific commentaries on 'Ætna' (Leipzig, 1898), we need not attempt here more than a cursory retrospect. After Thales, who regarded earthquakes as universal disturbances produced

have been many modern examples in the new islands raised in the time of history. When the series of convulsions ended, the island was said to become fixed. Cf. Lyell, 'Principles of Geology,' Vol. I., Chapter 1, and Emerson's vice-presidential address on 'Geological Myths,' *Proc. Amer. Assoc. Adv. Sci.*, 1897. Abundant references to the literature will be found in the first part of Max Mayer's 'Die Giganten und Titanen in der antiken Sage und Kunst' (Berlin, 1887).

by movements of the underlying support of the earth's crust, the next to expound their origin was Anaximander, always supposing that the disciple of Thales has not been confused with some later writer in the following passage from Ammianus (xvii. 7, 12) :

Anaximander says that the earth when burnt up by excessive heat and drought, and also after excessive rains, opens larger fissures than usual, which the upper air penetrates with great force and in excessive quantities, and the earth, shaken by the furious blasts which enter those fissures, is disturbed to its very foundations; for which reason these fearful events occur either during periods of dryness, or else after unusually severe rainstorms. And for this reason the ancient poets and theologians gave Neptune the name of Earth-shaker, since he presided over the moist element.

Neither Anaximander, Archelaus nor Xanthus is mentioned by Aristotle in connection with earthquakes or volcanoes, although their opinions have been preserved by other writers. Briefly, the two leading theories before Aristotle's time to account for seismic movements were these: The first, which is attributed to Anaximenes, referred them to fractures in the earth's crust which were produced by its passing through a process of drying, after having been previously saturated with moisture. The other was that of Anaxagoras, who believed that they were caused by the fiery elements of the ether, as well as by confined masses of water, which had penetrated into the interior of the earth, and were struggling to escape thence. In a modified form of the same theory, Democritus and Archelaus attached special significance to confined air as a cause of earthquakes, and this agency was still further insisted upon by Aristotle.

It will be noted that both of these theories contain potential germs of suggestion. That of Anaximenes, according to which the crust caves in, owing to the splitting of underlying rocks after periods of extreme dryness, foreshadows the modern contraction hypothesis. Excluding, as this view does, the idea of any connection between seismic and volcanic disturbances, the later theory of Anaxagoras directly favors it; and in the hands of the great Stagyrite this connection became the leading feature in the discussion of the question. According to Aristotle, both forms of subterranean disturbances were due to the action of winds (or gases, as we should probably say) which were confined beneath the earth's surface and were endeavoring to find a vent. The element of fire which appears in volcanic eruptions was explained at the result of vapors becoming rarefied and thereupon igniting. Imperfect as this theory may seem, it subsequently met with general acceptance and after slumbering for many centuries, was revived by Cecco d'Ascoli, contemporary of Dante, when Italy again caught the reflection of Greek learning. Posidonius, Strabo, Ovid, Pliny, and the unknown author of 'Ætna' whom some have sought to identify with Lucilius junior, all were influenced by Aristotle's view. Ovid, for instance, in his description of the upheaval of the promontory of

Methana* in the Argolis peninsula, which happened about the year 282 B.C., likens the process to the inflation of a bladder: "The earth," he says, "became distended by the force of impregnated vapor like a bladder filled with air, or like the skin of a goat." A like influence is betrayed also in the beautiful poem of Lucretius, where the following explanation is offered (VI., 639-702): "Ætna emits its flames in this way: caverns of rock run under it, full of wind which heats first itself and then the rocks with which it comes in contact, and then bursts out with flame, ashes, smoke and huge stones. Again, caverns reach from the sea to the mountain; through these pass from the sea both water and wind mixed; this wind and water force up flame and rocks and clouds of sand."

By more careful observation of these occurrences it was further established that volcanoes served as a vent in consequence of which the frequency and violence of earthquake shocks were diminished. Thus, Strabo remarks that the destructive shocks to which the island of Eubœa was subject, ceased when an eruption took place in the plain of Lelanto, near the city of Chalcis.† Again, he explains the cessation in Southern Italy of any such convulsions as were supposed to have separated Sicily from the mainland by the formation in that region of cones of eruption, like those of the Lipari Islands.‡ Elsewhere he uses the term of 'breathing holes' in reference to such cones. That he had a clear understanding of this feature is evident from the following passage:

But now these mouths being opened, through which the fire is drawn up, and the ardent masses and water poured out, they say that the land in the neighborhood of the Straits of Sicily rarely suffers from the effects of earthquakes; but formerly all the passages to the surface being blocked up, the fire which was smouldering beneath the earth, together with the vapor, occasioned terrible earthquakes, and the regions being disturbed by the force of the pent-up winds, sometimes gave way, and being rent, received the sea, which flowed in from either side; and thus were formed both this strait and the sea which surrounds the other islands in the neighborhood.

Notwithstanding our indebtedness to Strabo for many interesting details concerning Etna and other volcanic districts, to say nothing of his luminous remarks on the elevation and subsidence of land-masses, he does not seem to have advanced any original explanations of physical phenomena, but merely to have re-echoed those of his predecessors, foremost of whom were Aristotle and Posidonius. Indeed, it is no exaggeration to say that nearly all of Strabo's physiographic ideas were inspired directly by these marvelously keen investigators.* The in-

* *Mctam.*, XV., 296-306. Pliny ('Nat. Hist.,' II., 192) also gives his adherence to the same view.

† Strabo, VI., 1, 6.

‡ *Ibid.*, I., 3, 16.

* Compare, for instance, the estimates given by M. Dubois, in his 'Examen de la Géographie de Strabon' (Paris, 1891), and S. Sudhaus, in his interesting essay on 'Ætna' (Leipzig, 1901).

fluence of Posidonius, certainly one of the most intelligent travelers of antiquity, upon writers in all departments of science is particularly marked. Strabo has preserved for us his observations in connection with Etna eruptions, with the elevation of volcanic islands, with earthquakes which happened in Phœnicia, and with a great variety of phenomena, sometimes in considerable detail, and in terms which agree closely with those of modern experience. The following graphic description of the formation of a new volcanic orifice amongst the Lipari Islands may suffice for an example:

Posidonius says, that at a time so recent as to be almost within his recollection, about the summer solstice and at break of day, between Hiera and Euonymus, the sea was observed to rise suddenly to an extraordinary height, and to abide some time raised in a compact mass and then to subside. Some ventured to approach that part in their ships; they observed the fish dead and carried by the current, but being distressed by the heat and foul smell, were compelled to turn back. One of the boats which had approached nearest lost some of her crew, and was scarcely able to reach Lipari with the rest, the men being stricken like epileptic persons, at one time fainting and giddy, and at another returning to their senses. Several days afterwards a mud or clay was observed rising in the sea, and at many points the flames issued, with exhalations and smoke; after a time the scum congealed and assumed the appearance of millstone.*

Accounts of the upheaval and disappearance of volcanic islands in the Mediterranean are by no means rare in classic literature, probably the best known example being that already alluded to in connection with Thera in the year 197 B.C. On this occasion, a number of reports tell us, flames rose from the water for four days between Thera and the neighboring Therasia, so that the whole sea boiled and blazed; and little by little an island was ejected, being lifted as it were by mechanical force, and composed of volcanic rock extending over an area of twelve stadia in circumference. It is now generally admitted that the Santorin group is the basal wreck of a very large and ancient volcanic mountain, the eruptive history of which is comparatively well known. Prior to the sharp outbreak which occurred in 1866, memorable in geological annals, it was supposed that the eruption of 197 B.C. was the earliest which can be associated with the period of its human occupancy. Shortly after the last outbreak, however, relics of an ancient civilization were discovered in the islands of Thera and Therasia, buried beneath a layer of pumice-stone and other volcanic débris. As to the period of culture indicated by these remains, archeologists are agreed in referring them to the Proto-Mycenæan, which is supposed to antedate our present era by at least 2,000 years.

Eloquent testimony exists in classic literature that men were profoundly impressed even in earliest times by the class of phenomena typified by Thera and the mythical Atlantis. From the rise and dis-

* Strabo, VI., 2, 11. Compare also the similar accounts given by Pliny ('Nat. Hist.,' II., 19) and Aristotle ('Meteor.,' II., 8, 19).

appearance of islands, sometimes in connection with vulcanism, sometimes as the result of other causes, thinkers were led to conceive the possibility of large land-masses, or even continents, undergoing elevation and subsidence. Areas were known which the sea had invaded, and other tracts were pointed out where submergence was plainly indicated. Thus Xenophanes, in the sixth century B.C., and after him Xanthus, Eratosthenes, Herodotus and others, not only entertained the idea of continental subsidence, but interpreted fossil remains of marine animals as evidence of former submergence. When we come to Aristotle, Posidonius and Strabo, we find that their opinions concerning oscillations of the sea-level and other progressive changes of the earth's surface are worthy of modern geologists. This phase of the subject has been so ably treated by Lyell in his 'Principles of Geology,' by Lasaulx, in his 'Geology of the Greeks and Romans,' and more recent writers, that it must be more or less familiar to all. That which is important to remember, however, is that local manifestations of vulcanism, dispersed over a wide region, and isolated examples of inconstancy of the sea-level, should have been viewed from the uniformitarian standpoint at a period so far antedating our own, should have been reduced to a general system, and should have led to the framing of hypotheses to account for them which have a singularly modern aspect. One can not but marvel that some of the most difficult problems in geology were solved by rational methods, and in the main accurately, by those ardent questioners of nature who often seem to have grasped intuitively that which has cost the rest of the world centuries of patient effort to rediscover.

The limits assigned to the present article do not permit us to examine Roman contributions to the study of vulcanism, interesting as such an inquiry would be. Nor have we attempted in this sketch to enumerate all of the lesser luminaries of Greek science who assisted, either by accumulation of facts, or by cleverness in putting them together, toward a fuller understanding of important principles of geology. Archelaus, Diogenes of Apollonia, Metrodorus of Chios, author of a famous 'Treatise on Nature,' Empedocles, whom a characteristic but probably apochryphal narrative reputes to have perished in Etna's crater,—these and various others have been passed over in silence. Enough has been said, however, to indicate the general trend of investigation and some of its fruitful conclusions. This brief sketch will have succeeded in its purpose if any shall become interested to pursue the subject independently in its details. Such retrospect has not only a broadening value, but is well-nigh incumbent upon all who would escape the fate against which Goethe so energetically warns us:

Wer nicht von dreitausend Jahren
Sich weiss Rechenschaft zu geben,
Bleibt im Dunkeln, unerfahren,
Mag von Tag zu Tage leben.

WESTERN EXPLORATIONS FOR FOSSIL VERTEBRATES.

BY DR. HENRY FAIRFIELD OSBORN,

GEOLOGIST AND PALEONTOLOGIST, U. S. GEOLOGICAL SURVEY.

OWING to the establishment of new natural history museums in different parts of the United States, western exploration for the past history of the reptilian and mammalian life of North America is becoming more active and energetic every year. Formerly (between 1869 and 1877) the only explorations of this character were conducted by Professor Cope, of Philadelphia, one of the ablest zoologists and anatomists this country has produced, and by the still more widely known Professor Marsh, of Yale College. The fossils came in so rapidly that, while rousing keen scientific interest, they could not be placed on exhibition for the benefit of the public. In 1877 Princeton College began its series of western trips under Professor Scott and the present writer. Then Kansas University, under the able leadership of Professor S. W. Williston, went actively into the field, chiefly in the old Cretaceous sea bottom of western Kansas.

In 1890 the American Museum of Natural History of New York paved the way for a new order of things, by initiating a series of explorations on a large scale into different regions of the west, and placing the fossils on public exhibition as rapidly as possible.

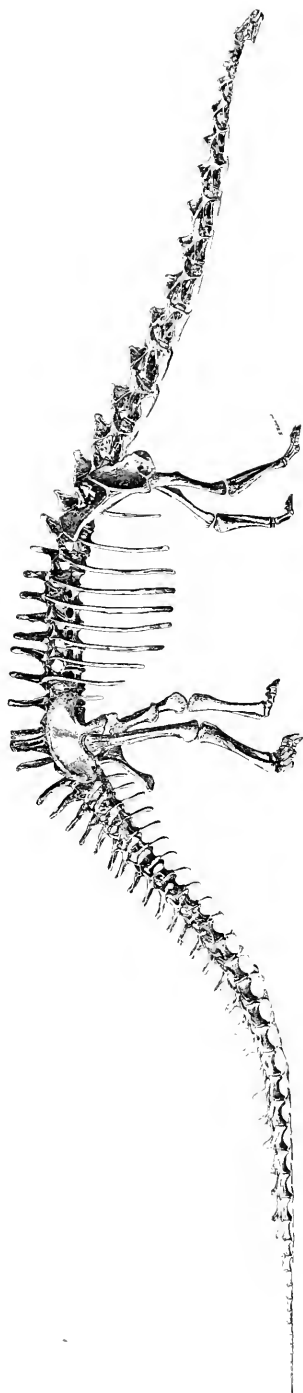
The next comer was the Carnegie Museum of Pittsburgh, which, under the active direction of Dr. Holland, secured as a leader Dr. J. L. Wortman, who had proved his unusual abilities in this line, first by his wonderful discoveries in the Big Horn Mountains in northern Wyoming and elsewhere in the service of Professor Cope, and later in the service of the American Museum of Natural History. The work of the Carnegie Museum, however, soon passed into the hands of Mr. J. B. Hatcher, another explorer of the highest ability, who had previously gained a world-wide reputation by his exploration of the fossil beds of Patagonia in the interests of Princeton. The death of Mr. Hatcher during the summer of 1904 was a very great blow to American paleontology. Under Wortman, Hatcher and Peterson the collections at the Carnegie Museum have grown apace, and the museum now has an almost unique collection of the gigantic amphibious dinosaurs, reptiles from fifty to eighty feet in length, which inhabited the shore lines of the nascent Rocky Mountains in the Jurassic period. When the new portion of this great museum is completed and sufficient space is provided, it is proposed to mount some of these great animals com-

plete. In the meantime Mr. Carnegie has ordered a cast of one of the finest specimens (*Diplodocus carnegiei*) to be presented to the British Natural History Museum in London, where this cast is now mounted. Not content with these monster reptiles, the Carnegie Museum has sent out other expeditions, for fossil horses, camels, titanotheres, and other quadrupeds and carnivores which formerly inhabited the now desert regions of South Dakota and Wyoming.



THE LATE JOHN BELL HATCHER.

A year or so after, the Carnegie Museum and the Field Columbian Museum of Chicago instituted a series of annual expeditions, chiefly for the great amphibious dinosaurs found in Wyoming and Colorado. Under Dr. E. S. Riggs some remarkable discoveries have been made, most notable of which is a nearly complete skeleton of *Brontosaurus* in a fine state of preservation. In central Colorado were found the arm bone, or humerus, and thigh bone, or femur, of another reptile of the same group of still more gigantic size. In most of these dinosaurs the femur is decidedly longer than the humerus: but in this beast, although the femur is actually 6 feet 8 inches in length, the humerus is fully as long. Dr. Riggs has accordingly named this animal *Brachiosaurus*, in reference to the great size of the brachium, or arm.

RESTORATION OF THE *Diplotocus carnegii*, BY J. B. HATCHER.

There is naturally a strong feeling in the far west that some of these remarkable fossils should be kept nearer home and not continually be the subject of eastern enterprise. Accordingly, the University of Wyoming, situated at Laramie, under the active leadership of the late Professor Wilbur C. Knight, for many years sent out expeditions, chiefly into various parts of the great state of Wyoming. These also were highly successful in securing remains of the amphibious dinosaurs, also of the great long-necked marine reptiles of the order Plesiosauria. To one specimen of the latter type, distinguished by a swimming paddle 7 feet 4 inches in length, Professor Knight gave the name of *Megalneusaurus rex*. Unfortunately we have to record the death of this ardent naturalist and indefatigable explorer, who made up in energy and personal hard work what the university lacked in financial resources.

We have to add also the University of California to the ranks of exploring institutions. Professor James Perrin Smith and Professor J. C. Merriam explored in 1895 and 1901, 1902, 1903 the bottom of an ancient inlet of the sea, of triassic age, in which are deposited the remains of very peculiar types of ichthyosaurs. These have been described by Professor Merriam, who has appropriately given them the name *Shastosaurus*, in reference to the proximity of the beds in which they occur to Mt. Shasta. These reptiles are in general distinguished from the plesiosaurs by the dolphin-like form of the body and the shark-

like tail, smooth, scaleless skin, very effective, dolphin-like paddles, and long, pointed snout. Dr. Merriam at first regarded *Shastosaurus* as a segregated or isolated type which developed from some more primitive ichthyosaur stock in this ancient bay of the Pacific; but his more thorough study and the additional materials collected during 1903 have revealed a very interesting fact, namely, that these animals are closely related to a species discovered long before by an English paleontologist, Professor Hulke, and named by him *Ichthyosaurus polaris*. The demonstration of the identity of this Pacific and extreme north Atlantic form speaks for the continuity of the Pacific and Atlantic oceans in triassic times, and is a fact of interest to geographers as well as to zoologists.

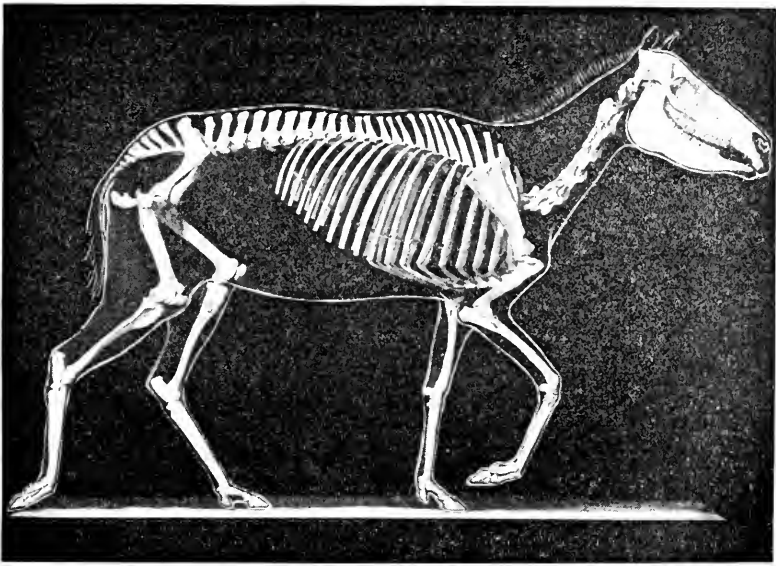
Dr. F. B. Loomis, of Amherst, who also spent two seasons with American Museum parties, has begun what we may hope will prove to be a series of annual expeditions in behalf of Amherst College. He took his students in 1903 into western Dakota to the 'Titanotheres' and 'Oreodon' beds, and secured what is reported to be a very fine collection. In 1904 he conducted an exploration into the Wind River Eocene of northern Wyoming, discovering a special deposit of Lower and Middle Eocene fossils in this rather barren horizon. At Amherst College is the remarkable collection made by the elder Professor Hitchcock of fossil footprints found along the Connecticut River, which were at first attributed to birds, but are now known to have been made by dinosaurs. Professor Lull, of the Massachusetts College of Agriculture, has been restudying these tracks and has drawn from them some remarkable conclusions as to the mode of life of these ancient denizens of Connecticut, which have been published in the form of a memoir by the Boston Society of Natural History. Professor Lull has also been attached to the American Museum expeditions as a successful field worker.

The American Museum of Natural History has by no means been inactive during the years 1903 and 1904, having sent out no less than four expeditions, which together have secured two large freight carloads of fossils.

The first of the expeditions in 1903, under Mr. J. W. Gidley, was especially searching for the fossil ancestry of the horse in western Nebraska and on the Rosebud and Indian Agency in South Dakota, where a permit was secured. Here the bed of an ancient washout or local flood was discovered containing the remains of a variety of three-toed horses of Upper Miocene age belonging to several species of the genera *Protohippus* and *Neohipparion*. No complete skeleton was discovered, but these horses supplement the series found in previous years, and demonstrate one fact of great interest, namely, the coexistence in western America of at least three entirely distinct kinds of

three-toed horses, including (1) those with excessively light, almost deer-like limbs; (2) others with shorter, more robust limbs, less specialized and leading apparently into the true modern horse; (3) others again, forest living forms, with spreading side toes, perhaps designed to prevent the animals from sinking into the soft ground of the swampy regions which they may have inhabited. Here also was found the complete skeleton of the camel, *Camelus occidentalis*, of mastodons, and of several other new types of animals, especially the wolves and foxes of the period.

Another American Museum expedition worked its way into the waterless desert in western South Dakota, where, in the bed of an



COMPLETE MOUNTED SKELETON OF THE *Neohipparion whitneyi*. A THREE TOED HORSE OF THE UPPER MIOCENE EPOCH. In the American Museum of Natural History.

ancient inlet of the sea, perhaps ten million years ago, were deposited the skeletons of two well-known varieties of sea reptiles, mosasaurs and plesiosaurs. These were found encased like mummies in a soft rock imbedded in larger concretions which stood up like mushrooms in what the westerners called a 'blow-out.' Numerous skeletons were found in a beautiful state of preservation, and formed the chief feature of this expedition. Just as Mr. Barnum Brown, the head of this party, was on his way east, a telegraphic order directed him into northwestern Arkansas to a comparatively recent deposit, perhaps 200,000 years of age, made just prior to the glacial period. It recorded chiefly the small western preglacial fauna, the field mice, shrews, minks, badgers, rabbits, ancestors of familiar living western types, mingled, however, with re-



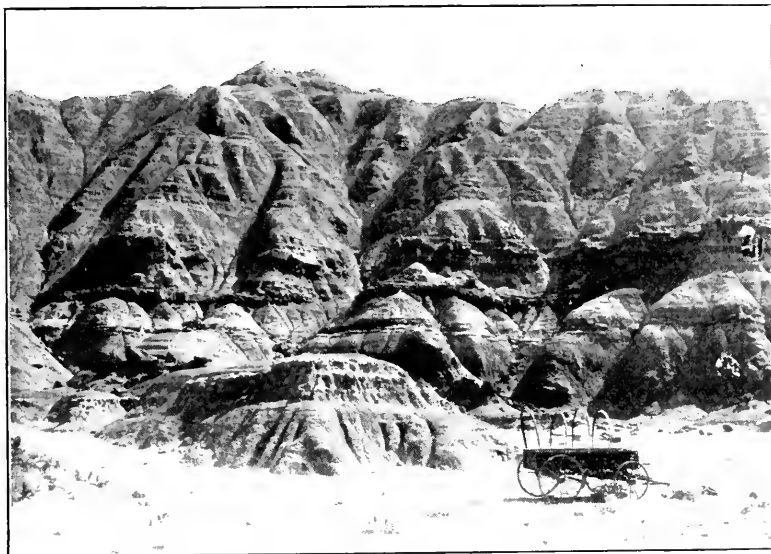
FOSSIL BONES OF THE GREAT *Brachiosaurus altithorax*, BEFORE REMOVAL FROM THE ROCK
AFTER E. S. RIGGS

mainly of camels, horses and of the great saber-toothed tiger. This was a great fissure deposit, into which enormous numbers of these small animals had been washed, so the collection was numerically very large. It is an interesting but not surprising fact that this small fauna survived the subsequent glacial period, whereas the horses, sloths, camels and saber-toothed tigers were all exterminated.



THE BONE CABIN QUARRY, SOUTH CENTRAL WYOMING. Fossilized bones of many different kinds of the great amphibious dinosaurs, of the plated dinosaurs (Stegosaurs), of the large carnivorous dinosaurs and of the small carnivorous dinosaurs are found mingled together in this quarry.

A third American Museum party was in the heart of the Laramie plains of Wyoming, where in 1898 the ruins of a sheep herder's cabin composed entirely of dinosaur bones led to the discovery of an extraordinarily rich deposit of the great amphibious dinosaurs and other reptiles of the Upper Jurassic age, which is roughly estimated as 6,000,000 years distant. The museum has been working in this same quarry six years, and each year has taken out a very large freight car-load, yet the deposit is still far from being exhausted.



STRATIFIED DEPOSITS IN THE BRIDGER BASIN, SOUTHWESTERN WYOMING.

A fourth expedition was in southwest Wyoming, just north of the Uintah Mountains, nor far from the once famous Fort Bridger, a now deserted army post. This middle eocene flood plain or lake basin dates back about 2,500,000 years in its fauna, which embraces small ancestors of the horses, about the size of a whippet hound, a great variety of monkeys, hundreds of small quadrupeds remotely related to the tapirs, including one especially large type. Also of the great *Uintatherium* or Uinta beast, a very archaic type of quadruped, the discovery of which between 1870 and 1873 aroused widespread interest in this country. The museum party was very fortunate also in this region and brought back remains of about five hundred individuals. In this collection were one hundred and twenty-one turtles, chiefly found by Dr. O. P. Hay, both river and land forms, some ancient, some surprisingly modern in type, including species which are now only represented in South America.

During the summer of 1904 three expeditions went out from the

American Museum, the first in charge of Messrs. Matthew and Granger into southwestern Wyoming, making special search for additional remains of the great horned *Uintatherium*. They were rewarded by the discovery of two skeletons and a fine lower jaw. One of these skeletons was in such a position that it appeared to have been mired in what was at the time a soft, tenacious clay, but is now an olive shale. They also discovered two fine skulls of the primitive running rhinoceros, *Hyrachyus*, the skull and part of the skeleton of *Hyopsodus*, which has long figured as a lemur, but is now thought to be an insectivore; three skulls of the primitive tapir, *Isectolophus*; six skulls and portions of the skeleton of *Palaeosyops*, and two skulls of carnivores. In spite of diligent search no additional remains were secured of the fossil horse of the Bridger. The most important general feature of this work, however, is the fact that the Bridger formation can now be definitely divided up into a series of great geological steps, A, B, C, D, each characterized by a distinct assemblage of animals or by distinct and different stages of evolution. The second American Museum party, under Mr. Brown, well known for his successful explorations in Patagonia and Montana, went out with the special object of securing a complete skeleton of some of the great plesiosaurs of the cretaceous. Continuing his work of 1902 and 1903, Mr. Brown made special search in the Pierre shales, securing near Edgemont, South Dakota, the greater part of the skeleton of a Plesiosaur, including skull, jaws, complete neck about fifteen feet long, one complete paddle, part of the pectoral girdle and some dorsal vertebræ. In the same locality another plesiosaur and several long snouted marine crocodiles were found.

In the museums which have been enriched by last season's explorations the work of preparation for exhibition and scientific description is progressing. It is, unfortunately, an extremely slow and difficult matter to prepare a fossil, however carefully collected, for exhibition. It takes two years or more to work out the collections of a single season; the result is that most of our museums are collecting materials more rapidly than they can be worked up: hundreds, and in some cases thousands, of boxes are stored away. With larger endowments or with special gifts these treasures could be more rapidly brought to light.

The popular interest in the ancient history of North America as shown in the rise and fall of the successive dynasties of animal life is rapidly increasing; the daily journals give a large amount of space to fresh discoveries—usually with a considerable amount of exaggeration. The animals in themselves are so wonderful, and the mere presence of representatives of South America, Africa, Asia and western Europe, in the Rocky Mountain region, appeals so strongly to the imagination, that the bare scientific facts are of sufficient interest without exaggeration.

THE PROGRESS OF SCIENCE.

DR. WILLIAM OSLER.

IN the acceptance by Dr. William Osler of the regius professorship of medicine in the University of Oxford, the Johns Hopkins University loses its professor of medicine, the Johns Hopkins Hospital its physician-in-chief, and the medical profession in America a leader untiringly devoted to its service.

Dr. Osler is one of several talented brothers, sons of an episcopal clergyman in Canada. His life has thus far been a series of successes, long enough and valuable enough to give him a permanent and distinguished place in the annals of American medical history. He is still a relatively young man, younger even than his fifty-six years would indicate, and it may with confidence be predicted that important additions to his records of service will follow upon his residence in England.

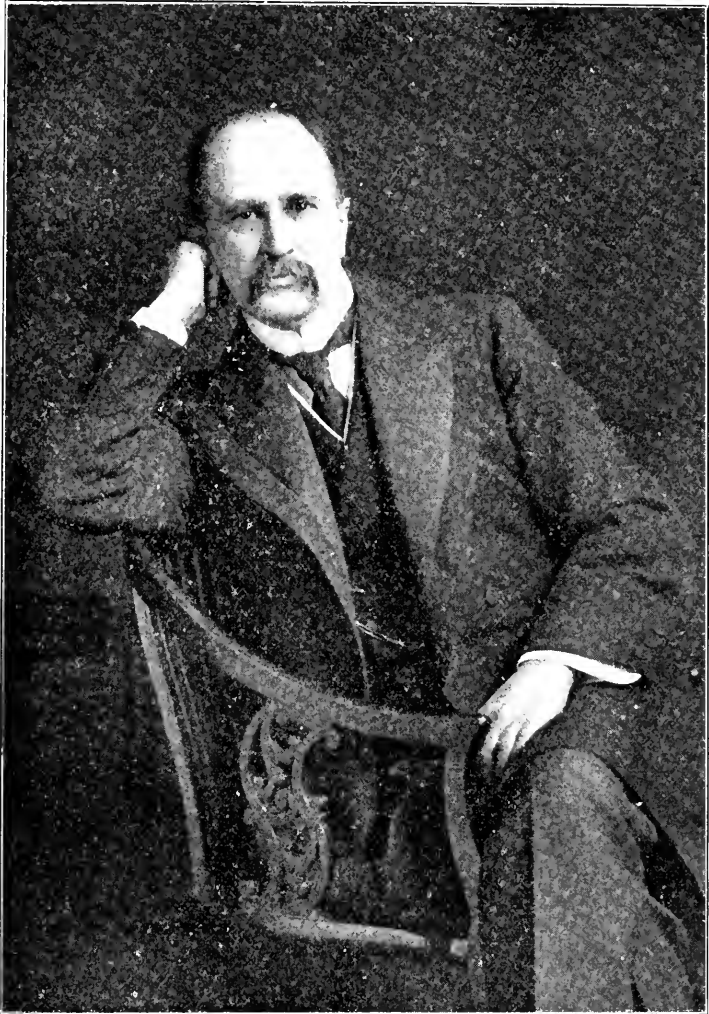
In Montreal, as a young physician, he taught physiology, pathology and clinical medicine for ten years after graduation, at the end of which period he accepted a professorship of clinical medicine in the University of Pennsylvania. Five years later he was appointed to the Johns Hopkins positions, in which, during the past sixteen years, his most important work has been done. The results of his Baltimore activities testify to the sagacity of the men who selected him to meet the unique opportunities which the hospital and university there offered.

The services Dr. Osler has rendered, though difficult to estimate accurately at this nearness, has certainly been varied. It includes that of an investigator, of a medical teacher, of a practitioner, and last, by no means least, of an ethical preacher.

As an investigator, his earlier studies

dealt with the histology of the blood, and his name is well known in the bibliography of the nucleated red corpuscles and the blood-platelets. Later on, his researches consisted chiefly in the combination of accurate clinical observation with careful post-mortem examinations. Among his best known publications are those dealing with acute ulcerative endocarditis, the cerebral palsies of children, chorea and allied disorders, typhoid fever, tuberculous pleurisy, abdominal tumors and chronic cyanosis. Though in the Johns Hopkins period his many teaching and executive duties, together with a rapidly increasing consultation practise, did not leave him much consecutive time for original work, he was ever stimulating the young men about him to undertake such work and encouraging them by sympathy and affording opportunity.

As a teacher of medicine Dr. Osler achieved extraordinary success. He knew how to excite enthusiasm in those who followed him through the wards or listened to him in the amphitheater or the dispensary. He is one of the few teachers of internal medicine who have competed successfully with the surgeon and the gynecologist in holding the attention and inspiring the interest and ambition of the medical student and young medical graduate. In the hospital he adopted the English-Scotch system of clinical clerkship in the wards, and improved upon it. He did away with didactic lectures and made his students, even before graduation, learn medicine by studying themselves the patients directly, using books and teachers only as guides and aids. The importance of thorough objective routine examination was urged; the laboratory and the current litera-



DR. WILLIAM OSLER.

ture were constantly called upon to throw light upon unusual phenomena. His idea that responsibility is essential for serious study and for real development has borne fruit in the students upon whom it has been his custom to place as much as could safely be carried. More widespread in its influence than his personal teaching has been that of the many editions of his text book. No volume on internal medicine has ever had a larger sale or

met with more universal commendation than Osler's 'Principles and Practise.' It is a model, at the same time, of brevity and comprehensiveness. Clear and practical, it reveals an unusual power to sift out non-essentials. It is rich in records of personal experience but it embodies also the pith of the wisdom of medical minds of all times and of all countries. Through marvelous industry and constant contact with young men in the various sci-

tific branches, the author has kept his ideas in every department of medicine abreast of the times.

As a practitioner the humanitarian side of the physician was fully as prominent as the intellectual. In the wards and among the out-patients, students were shown by example that qualities of the heart as well as those of the head are essential for the proper practise of medicine. Osler educated his patients more than he drugged them, many will agree, to their benefit. His private practise, confined to consultation, was small at first, but gradually assumed proportions which made it a burden. No small percentage of it consisted in the non-remunerated examination and treatment of physicians and members of the physician's families from all parts of the United States and Canada. He gained a great reputation in the profession for accuracy of diagnosis, and for acquaintance with the rarer syndromes, and while he was thought by some to be unduly pessimistic regarding pharmaco-therapy, it is probable that his influence in combating its excesses has more than compensated for any inadequate appreciation he may have had of it. A foe to quackery and graft in all forms, Dr. Osler is also an enemy of the commercial spirit in medicine. Though he has attained a competence, he has reaped no financial reward commensurate with his services, nor does any man animated by similar ideals.

For those who know Professor Osler, the strength, charm and influence of his personality are fully as important as his scientific contributions. His example of fine living and high thinking, his hospitality, his sense of social duty, his devotion to the profession and all that pertains to its dignity and elevation, his sacrifice of comfort, time and energy for the upbuilding of medical libraries and medical societies, his interest in and support of humanitarian movements, including crusades against tuberculosis and antivivisection, his generosity to, and sympathy with,

struggling young medical men, especially those with scientific bent, his honoring of the master minds of medicine and medical heroes, his love of literature—especially of Plato and of Sir Thomas Browne—his fondness for old books, his humor, his philosophy of cheerfulness, his respect for age, despite newspaper calumnies of him, and, above all, his never-failing charity have had a deep influence upon those who have come in contact with him. By means of the recently published volume entitled 'Æquanimitas and other Addresses' and through his farewell message to the medical profession of this country,* some idea of this side of Dr. Osler may be gained, even by those who have not had the privilege of knowing him.

It must be pleasing to Americans to know that the portrait of Professor Osler recently presented to the University of Pennsylvania and the portrait of the group of four Johns Hopkins medical men, including him, painted this summer by Sargent, a gift from Miss Garrett to the medical school of Baltimore, will preserve for succeeding generations the features of this distinguished medical man, of whom the citizens of a country, his more than twenty years by adoption, are justly proud. The photograph here reproduced is an excellent likeness.

PROFESSOR WILHELM OSTWALD.

UNDER the new arrangement by which Harvard and Germany exchange professors, Wilhelm Ostwald, of Leipzig, is to lecture at Cambridge for half of the coming academic year. Ostwald was born in Riga, in 1853. At the University of Dorpat he studied chemistry and physics, receiving the first degree in 1875 and the doctor's degree in 1878. From 1875 to 1880 he was assistant in the physical laboratory. The salary was not large, and during part of this period Ostwald made both ends meet by giving lessons in music

* 'Unity, Peace and Concord.' *J. Am. M. Assoc.*, Chicago, XIV., 1905, p. 365.



PROFESSOR WILHELM OSTWALD.

and painting. In 1881 he was called to Riga as professor of chemistry in the polytechnic institute. The inspiring effect of Ostwald's teaching was shown in the rapid growth of the laboratory, the number of students much more than doubling in six years. In 1887 Ostwald went to Leipzig as professor of physical chemistry. The first year was a discouraging one; but Ostwald's ability was recognized before long. The old laboratory was soon filled to overflowing, and the building of a new laboratory remedied this for a few years only.

From the first, Ostwald's scientific work has been in the field of what is now called physical chemistry. Feeling the need of a systematic presentation of the subject he began in 1884 the

publication of the first edition of his 'Lehrbuch der allgemeinen Chemie.' The modern physical chemistry may be said to date from this time. In 1886, Ostwald decided that a special journal was necessary and in 1887, while still at Riga, he started the *Zeitschrift für physikalische Chemie* which is now in its fifty-third volume.

Ostwald is essentially a leader of men. He has the personal magnetism which attracts and inspires people; he is always a little in advance of the majority, and he has the power of expressing himself in such a way as to interest and convince others. It is to Ostwald that the wonderful development of physical chemistry in the last twenty years is due. We owe the osmotic theory of solutions to van't

Hoff; the theory of electrolytic dissociation to Arrhenius; and the theory of the voltaic cell to Nernst; but it is Ostwald who has taken these theories, has developed them and has forced the world to accept them. No one else could have fought the good fight as Ostwald has done. He has founded a distinct school, the Leipzig school as it is sometimes called. A large majority of the active physical chemists of today have worked in Ostwald's laboratory at one time or another; but his influence is not confined to his pupils. There is probably no man living whose opinions have so much immediate weight in the world of chemists as does that of Ostwald.

Ostwald's record during the last twenty-one years is an extraordinary one, whether judged by quality or quantity of work. The first edition of the 'Lehrbuch der allgemeinen Chemie' consisted of two substantial volumes; but it is dwarfed by the second edition which runs to over thirty-four hundred pages and is not yet finished. The other books on chemistry include a short introductory volume on physical chemistry, a laboratory manual of physical chemistry, a history of electrochemistry, a volume on the scientific principles underlying analytical chemistry, a text-book of inorganic chemistry, and an elementary book in dialogue form. All this is in addition to lectures, laboratory work and editorial duties. This last item is a serious one, because a large percentage of the papers published in the *Zeitschrift für physikalische Chemie* come from Ostwald's laboratory and because he reviews all the new books, and has, until the last few years, written critical reviews of many of the current articles on physical-chemical subjects appearing in other journals. Over and above this, Ostwald is the editor of a series of reprints of important chemical papers.

Mention has already been made of the fact that Ostwald at one time gave lessons in music and painting. As

results of this we have an unpublished course of lectures on the theory of harmony and a book on painting. Every year Ostwald spends a large part of his vacations in sketching, using a modified form of pastel which is his own invention.

A very natural result of Ostwald's literary work in chemistry has been his growing interest in the theory of knowledge. Beginning as an ardent admirer of Mach, he has devoted more and more time in recent years to philosophy. With characteristic energy he has started a journal of philosophy and has published in book form a course of lectures on philosophy delivered in Leipzig in 1901. It must be admitted that Ostwald ranks higher at present as a chemist than as a philosopher; but it was as a philosopher that Ostwald attended the International Congress of Arts and Science at St. Louis, and he is to lecture at Harvard both on chemistry and on philosophy.

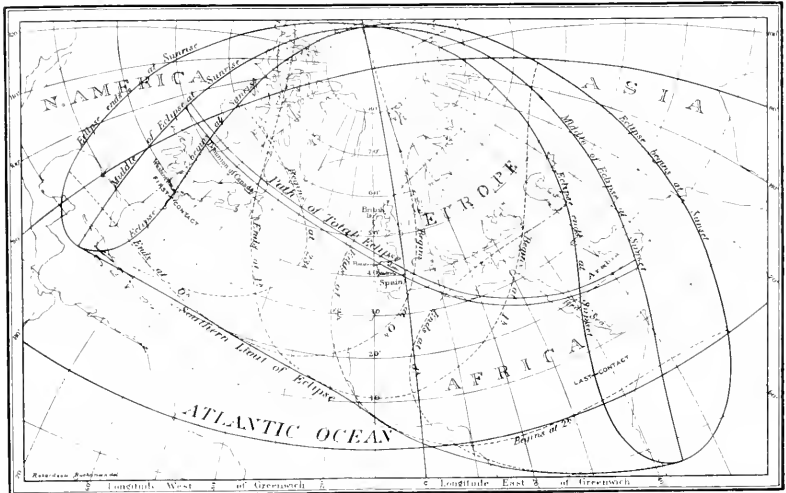
THE ECLIPSE OF THE SUN.

A TOTAL solar eclipse is an event which appeals in equal measure to the scientific investigator and to the popular imagination. Yet the interest is not only different, but to a certain extent conflicting. The astronomer is concerned with certain technical problems, such as the composition of the corona, which have less connection with human welfare than most scientific questions. The popular interest is largely due to the awe-inspiring character of the event, a survival perhaps from the time when this was the occasion of portents and omens. It may be assumed that the simple explanation of the moon's shadow will gradually do away with the apparent marvel of this phenomenon, though the accuracy with which it can be foretold will continue to impress the unlearned with the wonders of the science, which has been called both 'the queen of the sciences' and the 'science of pure curiosity.'

The eclipse of August 30 was for

several reasons of more than usual interest. The path of the shadow passed over accessible regions, in part of which at least the weather conditions were likely to be favorable; stations could be chosen as far apart as Labrador and Egypt; the period of totality was com-

land, Switzerland and Spain. Two of the most elaborate of the expeditions were from this country—that of the Naval Observatory, under Rear Admiral Chester, which was carried on a warship to Algeria with very complete equipment, and that from the Lick Ob-



PATH OF TOTAL ECLIPSE.

paratively long, and there will be no eclipse for seven years. As is shown in the illustration, the long shadow which the moon casts in space, struck the earth south of Hudson's Bay. The spot of darkness, about 120 miles broad and traveling at the rate of about 2,000 miles an hour, passed over Labrador and the Atlantic Ocean, and struck the Spanish coast at the Bay of Biscay. It traversed Leon, Burgos and Valencia, the islands of Majorca and Iviza, reached the Algerian coast near Philippeville, thence struck inland across Tunisia, skirted Tripoli, crossed the Nile at Assuan, and finally in Arabia, passed away from the earth into space again.

Along this line there gathered during the month of August numerous parties from America (including Canada and Mexico), Great Britain, France, Germany, Russia, Italy, Hol-

servatory, the expenses of which were paid by Mr. William H. Crocker. The latter consisted of three parties, one in Labrador, one in Spain and one in Egypt, each equipped with a 40-foot photographic telescope, the object being to take similar photographs, to determine any change that may occur in the corona in the course of the two and a half hour interval between the observations in Labrador and in Egypt. English observers also had stations in Labrador and Egypt, with similar objects. It appears, unfortunately, that the sky was completely clouded in Labrador, and that there were haze and floating clouds in Spain and the north of Africa, except at Assuan. No definite information in regard to the results of the observations is as yet available. Director Campbell and Professor Perrine, of the Lick Observatory, in Spain, and Professor Hussey, at

Assuan, took extensive photographs in search for a possible planet between the sun and Mercury. The photographs have probably not as yet been examined, but Professor Perrine's results in Sumatra make the existence of such a planet unlikely.

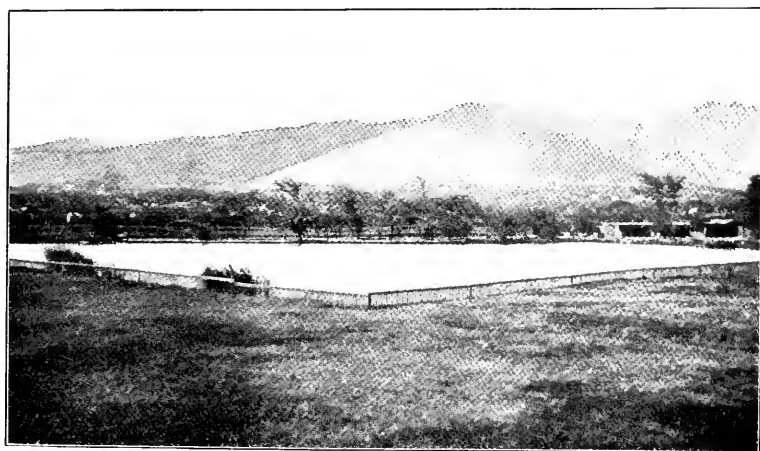
As events of general interest in connection with the eclipse, it may be noted that the Spaniards made special arrangements when the circumstances were so auspicious for them. Thus the Jesuit Observatory, at Tortosa, was in the line of the shadow, and no fewer than eighty Jesuit fathers skilled in astronomy assembled there. Japan has been justly praised for not letting its scientific and educational activities be interrupted by the war, and it seems fair to note that Russia was represented by several expeditions in Spain and Egypt. A large party, chiefly of amateur astronomers, observed the eclipse from the steamer *Arcadia*.

As it will be some time before the scientific results will be made public, readers of this JOURNAL may be referred to the article by Director Campbell, of the Lick Observatory, printed in the issue of June of last year for an admirable account of the problems of the present eclipse. It may also be

well to mention the articles on the two preceding eclipses that were observed, that by Professor Perrine on the eclipse of 1901 (August, 1905), and that by Secretary Langly on the eclipse of 1900 (July, 1900).

THE FISH PONDS OF THE HAWAIIAN ISLANDS.

THE last part of an extensive study of the fishes of the Hawaiian Islands, by President David Starr Jordan and Dr. W. Barton Evermann, published by the United States Fish Commission, contains a discussion of the commercial fisheries by Mr. John M. Cobb. He describes the fish ponds of the islands, which are on a much larger scale than can be found elsewhere in the United States. Some of the ponds are supposed to have been built as long as two hundred and fifty years ago, and are attributed by the natives to a mythical race of dwarfs, distinguished for cunning industry and engineering skill. The ponds are mostly in the bays indenting the shores of the islands, but there are also many ponds in the interior, and at least one is an old volcanic crater. In the sea ponds the walls are about five feet in width, and are built loosely to let the water per-



INTERIOR FISH POND, WAIKIKI, OAHU.

colate. They have sluice gates and the fish come in from outside. They are also caught in the open sea and brought to the enclosures, but practically no attempt at fish culture is made. The fish in the sea-ponds are mostly amama, or mullet, and the awa, but a larger variety is found in the fresh and brackish water ponds. There are probably not more than half as many ponds in use now as there were thirty years ago, owing chiefly to the disappearance of the native population, but partly because the interior ponds can be used for the culture of rice and taro. There are, however, still on the Island of Oahu fish ponds, several of which are a hundred acres or more in size. These ponds supply annually more than half a million pounds of fish, valued at \$140,000.

SCIENTIFIC ITEMS.

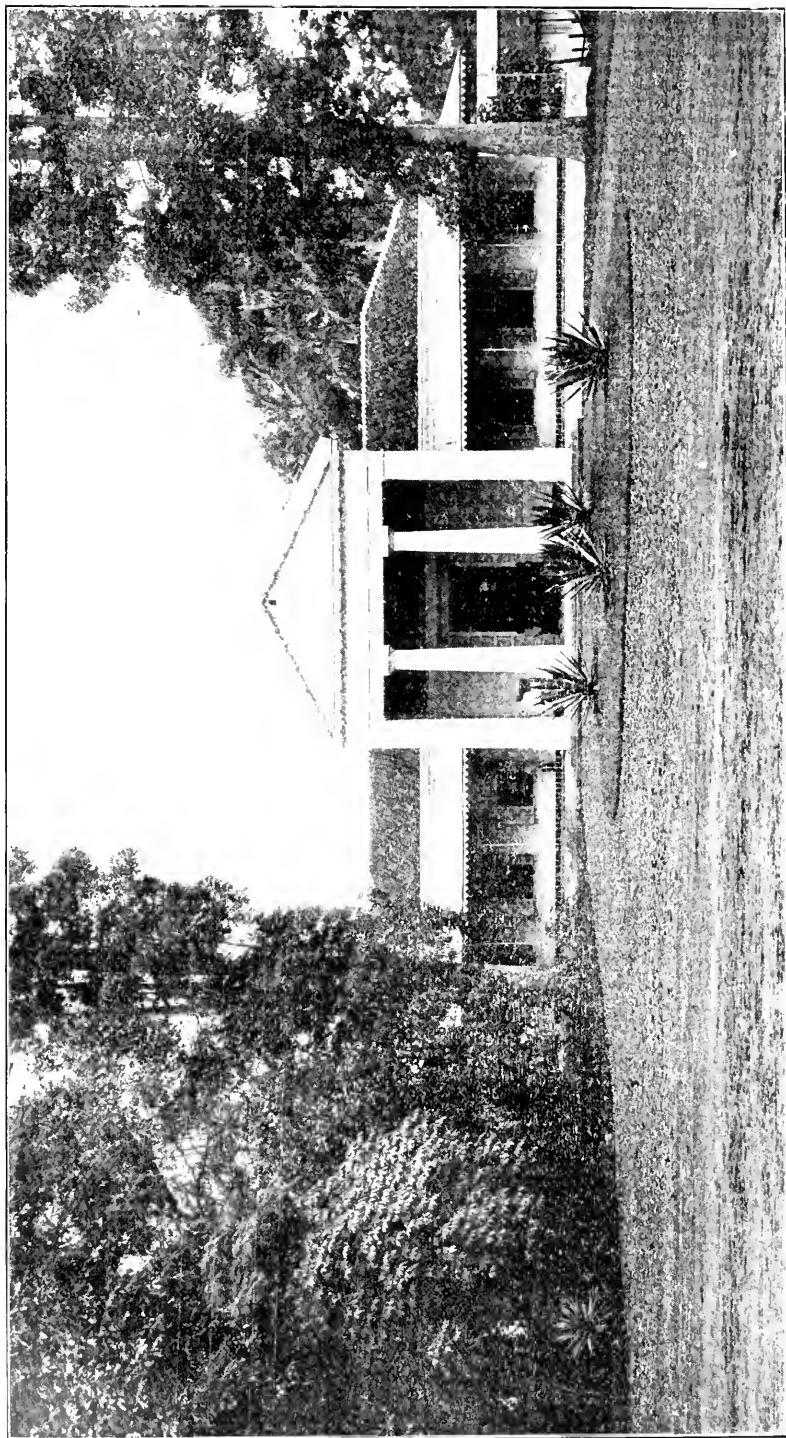
THE British Association for the Advancement of Science has held a successful meeting in South Africa under the presidency of Professor George H. Darwin, of Cambridge. Professor E. Ray Lankester, director of the British Museum of Natural History, has been elected president for 1906.—The seventy-seventh meeting of German Men of Science and Physicians was held in Meran last month under the presidency of Dr. Franz von Winckel, professor of gynecology, at Munich.—The American Anthropological Association has met at San Francisco under the presidency of Dr. Frederic Ward Putnam, of Harvard University and the University of California. The program contained the titles of thirty-nine papers.

PROFESSOR T. C. CHAMBERLIN, of the University of Chicago, has been ap-

pointed a member of the Illinois Geological Survey Board. The other members are *ex-officio* Governor Deneen and President James, of the State University.—Dr. Rubert Boyce, of the Liverpool School of Tropical Medicine, has come to this country to cooperate with the authorities at New Orleans in suppressing the epidemic of yellow fever.—Sir Patrick Manson, medical adviser to the English colonial office, has arrived at San Francisco, to deliver a course of lectures on tropical diseases at the Lane Hospital.

THE arctic steamer *Terra Nova*, which went to the relief of the Ziegler polar expedition, has rescued Capt. Fiala and all the others connected with the expedition. Mr. W. J. Peters, of the U. S. Geological Survey, who, on the nomination of the National Geographic Society, was placed in charge of the scientific work of the expedition, reports that a considerable amount of scientific work has been accomplished.

WHEN the POPULAR SCIENCE MONTHLY was established in 1872, the first number was issued in November, and for the past thirty-three years the volumes have begun with the November and May numbers. Most subscriptions to the MONTHLY, however, begin with January, and it is in the interest of subscribers to receive complete volumes. It is also more convenient in quoting a journal for the year to correspond with the volume. We shall consequently include eight numbers in the present volume. The index will be given in the December number and volume LXVIII. will begin in January, 1906.



HERBARIUM AND BOTANICAL MUSEUM AT THE BUITENZORG INSTITUTE.

THE POPULAR SCIENCE MONTHLY.

NOVEMBER, 1905.

THE BOTANICAL GARDEN AT BUITENZORG, JAVA.

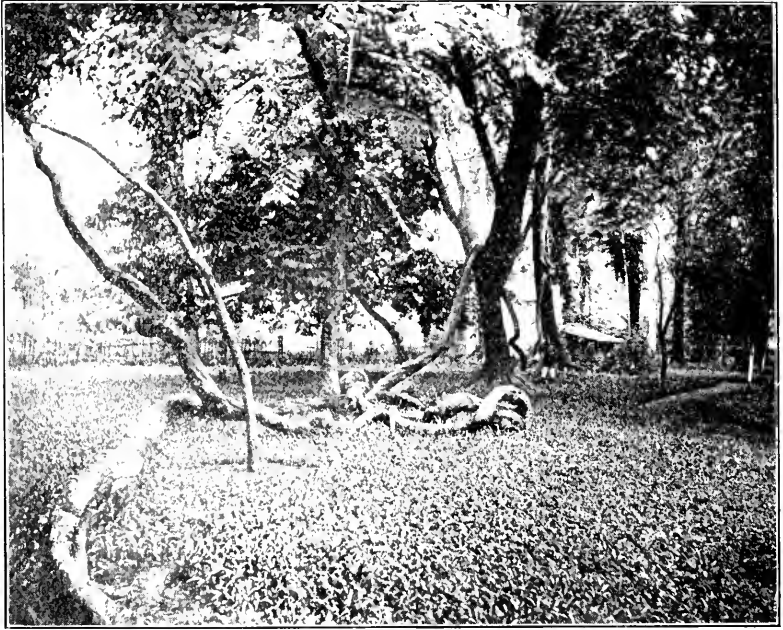
BY PROFESSOR FRANCIS RAMALEY, PH.D.,
THE UNIVERSITY OF COLORADO.

PROBABLY the term 'botanical garden' brings to the minds of most people something in the style of a cemetery with a few trees and a great many oblong beds of herbaceous plants, each bed with a white label suggesting a small gravestone. In a properly appointed botanical garden most people expect to see also some hot houses for orchids and a tank with warmed water for tropical water lilies and lotus.

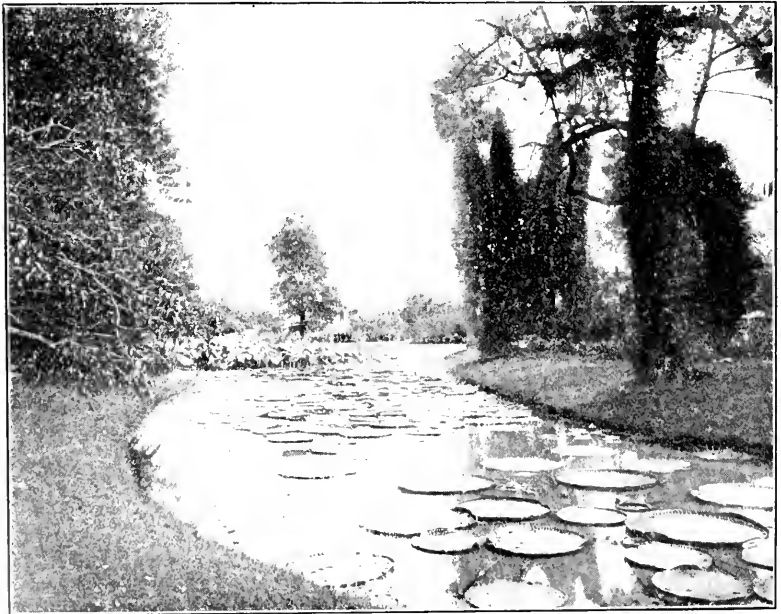
Should an ordinary mortal, or even a botanist, be dropped from a balloon into the middle of the garden at Buitenzorg, he would, for a time, hardly appreciate that he was in a botanical garden. The usual 'ear marks' of such an institution are certainly not apparent at first glance. The plants are mostly trees, no warm tanks are necessary, and there are cool houses instead of hot houses. The botanist, in looking at the names of trees would only now and then recognize one he had run across somewhere in a text-book. Were it not for a very few names, he might believe he had landed on some other planet. Certain it is he would see few plants he had known before in the temperate zone.

After a time spent at Buitenzorg the term 'plant' no longer suggests a small green creature with pretty flowers—something which dies down in autumn and comes up at Easter time. The plants at Buitenzorg are trees, and there are hundreds, nay, thousands, of these; while only a trifling space is allotted to puny little herbs—the things that we of the temperate regions know as 'plants.'

Of course the well informed naturalist knows the tropical world as the 'mother of life,' and he expects to see a wealth of green, a super-

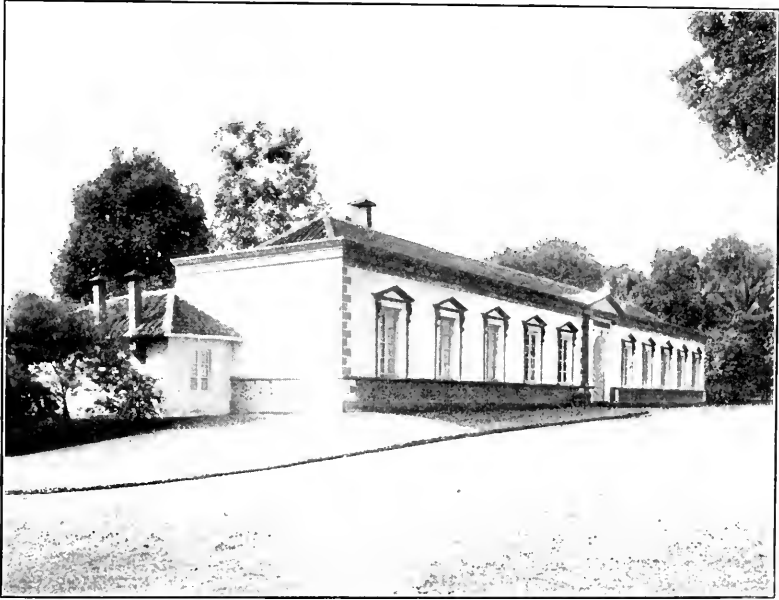


A LARGE LEANA (*Entada scandens*) NEAR THE ENTRANCE OF THE BOTANICAL GARDENS.



VIEW ACROSS THE POND TO THE GOVERNOR GENERAL'S PALACE AT BUTENZORG.

abundance of plant individuals and plant species. Still I doubt if any one who has not actually visited a wet tropical region can have a very clear idea of the real luxuriance of Buitenzorg. In an ordinary temperate forest the number of species of trees can almost be counted on the fingers of two hands; the species in a northern coniferous forest might be counted on the fingers of a single hand. In a west Java forest there may easily be fifty species of trees within a distance of as many feet from an observer. In the whole island of Java there are



LABORATORY FOR RESEARCHES.

probably a thousand different kinds of arborescent plants—perhaps more.

In the botanical garden an attempt is made to assemble the various plants of the Dutch East Indies and also to get the more notable species from other lands. This garden should be especially useful at this time to American botanists who may be intending to work in the Philippines. Java belongs to the same floral region as the American East Indies, and our islands will doubtless show some likenesses and differences in flora, which will be of great interest. At Buitenzorg the visiting botanist has before him, in well organized form, an epitome of all tropical botany.

Aside from any special interest which American botanists might have in Buitenzorg, there are countless objects of general botanical interest to be seen there. One who keeps in touch with modern bot-

anical literature can not but be struck with the fact that in these days tropical botany is becoming more and more important. The ordinary text-books still illustrate most points in physiology and morphology by reference to plants of the temperate zone, yet there is an increasing tendency to refer more often to tropical plants. The modern botanist needs to know something of the tropics—the more the better. At Buitenzorg he can learn a great deal in a short time.

The visitor, on going through the gate of the garden, enters at once a long avenue planted with canary trees (*Canarium commune*). Here is something with no counterpart anywhere else in the world. As one walks down Canary Avenue in early morning he notices perhaps, first the darkness, then looking up he sees the branches above, over-arched, as it were, to form the vaulted roof of a Gothic cathedral. Here and there a few stray sunbeams, stealing through, make bright patches of light on the moist roadway; the lianas, climbing up the great tree trunks, are covered with dew and their huge leaves glisten as they are gently waved by the morning breeze. Their long, aerial roots sway to and fro as slow-moving pendulums. The great buttressed



A PATH IN THE JUNGLE.



JUNGLE SCENE. A SPECIES OF *PANDANUS* WITH LONG GRASS-LIKE LEAVES.



A PLANT (*ZLATOSTENIMA*) WITH LONG POINTED DRIP-TIPS.

roots of the canary trees, covered with epiphytic ferns and orchids, seem almost too picturesque to be quite natural. Everywhere the eye feasts on a wealth of green. It is hard to escape the thought that this is fairy land.

When the visitor passes onward to the lake and looks across at the wooded island where are planted magnificent flowering trees, shrubs of wonderful foliage, and, more striking than all else, the red stemmed 'sealing wax palm'—when he looks across the lotus and *Victoria regia* to all this tropical luxuriance he must perforce become enthusiastic, even though he be by nature the most cold-blooded of men.

The garden has an extent of about one hundred and fifty acres. Through one end of it passes the Tjilwong River and along here is some low ground, while further back is higher land with more undulating surface, where, from certain vantage points, good views may be had of the neighboring mountains. Only a few avenues are open to carriages, but there are many neatly paved foot-paths usually following a somewhat winding course. These foot-paths form the boundaries of the different sections in which are trees of the various plant families arranged in systematic and orderly fashion. To a botanist, interested in a given group of plants, this is a most useful arrangement. It is much better than the more common plan of grouping trees according to the kind of soil in which they do best, and still better than the even more usual plan of scattering them about, hit or miss, wherever there happens to be room.

A visitor to the garden who is not a botanist will be disappointed that the labels give only the scientific names of trees. He who may

wish to see teak, satin-wood, ebony, the mango, nutmeg, rambutan and other notable trees must first find out for each the two many-syllabled Latin words which are used to designate a plant for scientific purposes. As these words are painted on the labels in a sort of modified German script they are not quickly read. Besides this the labels are narrow and frequently the name will not go in one line, but must be divided. The division is often made, not with regard to the nature of the word, but to the convenience of the native who does the painting. So one may see such divisions as 'flavesce-ns,' 'co-mmune,' 'macrant-hum,' 'integrif-olia,' and some others quite as startling.

If there were signs up showing the families in a given lot, and if the labels gave the common names and native home of some of the more important trees, even the professional botanist would be pleased; to the ordinary visitor there would be added an interest now quite lacking. The guide books give a bad English translation, from the Dutch, of directions for seeing the garden. No one, however, unless gifted with second sight, could even keep to the course mapped out, let alone see the various objects mentioned. During my stay in Buitenzorg I used to get out the guide book most religiously every Sunday. But although I spent some hours every week day in systematic study of the gardens, I was never able to follow with ease the official itinerary.

But even if the guide book be maddening, one can find many interesting things without great trouble. The Canary Avenue is something which never palls. The fine collection of palms is a joy to look upon. There are all sorts of queer-looking and strange plants to attract attention. Screw pines with their curious prop roots interest every one and cycads and tree ferns deserve more than a passing glance.

One is sure to be impressed with the great number of trees bearing conspicuous flowers. More than one man has asked me, on finding me to be a botanist, whether our northern trees would blossom out handsomely if grown in the tropics. Of course I have to say 'no'; that a leopard would more easily change his spots. It so happens that trees with large, showy flowers are more common in the tropics than in our part of the world. But we have the catalpa and tulip tree. There are plenty of trees in the tropics with inconspicuous flowers, too, but these the non-botanist does not notice.

The climate of Buitenzorg is very moist, there being a yearly rainfall of two hundred inches, or about six times that of New York. Dry spells seldom last long and the atmosphere is nearly saturated with moisture at all times. Correlated with the wet climate we find that many trees have leaves with long pointed drip-tips. The water from the surface of the leaf collects on these pointed tips and runs off quickly. Trees do not need a thick covering of cork to protect them from drying out or to save them from cold. So we find, instead of the



CANARY AVENUE AT BUTENZORG



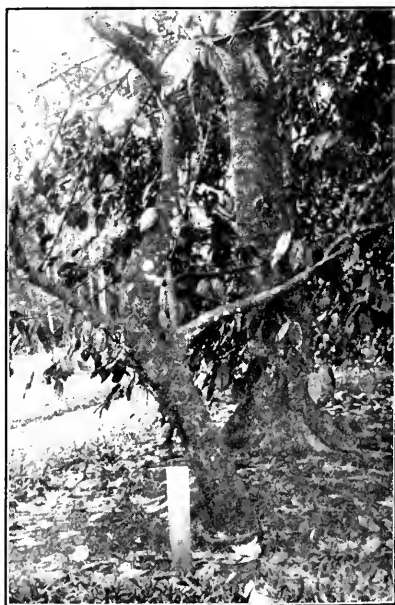
THE SAUSAGE TREE.

exposed, and hence in less danger of injury by excessive light and heat.

A moist climate, such as that of Buitenzorg, favors the growth of epiphytic or perched plants—also of parasites. Seeds or spores, carried by the wind or birds, find lodgment in the forks of trees. With plenty of moisture in the air and a constant warm temperature they grow luxuriantly. Thus it happens that trees are covered with moss. Even the very leaves are often marked with delicate patterns of moss and lichen. Orchids and ferns in great number are perched upon the horizontal branches and the smooth trunks also serve for the lodgment of many plants as well. Since Darwin's time every one has known something about orchids: plants with curious flowers adapted

thick, rough, furrowed bark of our own forests, only smooth trunks even in the case of large and old trees. This often leads strangers to underestimate the size of tropical trees, for they have come to think of smooth bark as belonging only to small trees.

The limp, dangling leaves of some tropical trees are most curious. They are frequently quite red, just as are the young leaves of maples in temperate climates. It is not easy to say just why some plants have adopted this peculiar habit of letting the leaves grow full size before they are strong enough to stand out in proper fashion. Certain it is, however, that by hanging down in this way the young, tender leaves are much less



CHOCOLATE TREE, SHOWING CAULANTHY.

to insect visits—flowers of handsome colors and strange shapes. But many orchids have small greenish or white flowers, and these are the ones most common in the Buitenzorg garden. There is also a good collection of species which have been ‘planted,’ not planted in the ground, but simply tied to tree trunks. Here they get along very well without drawing any water from the soil. There is plenty of moisture in the air and these plants are provided with absorbing tissues to take in what they need.

Things grow on a large scale in the tropics. Many of our tiny herbs at home have tropical relatives which are large trees. There



INDIA RUBBER TREE.

are tree ferns, the tree-daisy and the tree-tomato. In our own part of the world the sunflower is the largest plant of the composite family, but in the tropics there are many shrubs and trees belonging to this order of plants. Fruits of great size are common. A good example is seen in the ‘sausage tree,’ the fruits of which are great sausage-shaped structures two feet long, weighing many pounds. The jak tree has a fruit which looks something like an enormous watermelon, except for the roughened warty outer rind. The flowers, and hence the fruit, are on old wood—not developed at the tips of young branches as are the apples, peaches and other fruits familiar to us. Such production of flowers and fruits on the older parts of the tree is known as ‘cauli-

floric' or 'caulanthy,' the terms meaning 'flower on the stem.' Caulanthy may often be seen in the tropics, while among trees of temperate regions it is almost unknown.

Plants inhabited by ants are sure to strike the attention of visitors. There are many of these so-called 'myrmecophilous' plants in the garden at Buitenzorg; some brought in from the neighborhood, while others, behaving like Topsy, 'just grew.' The commonest are species of *Myrmecodia*, woody plants about two feet tall, with the base of the stem much swollen and containing large winding passages swarming with ants. These plants do not grow on the ground, but are at-



WARINGIN TREE, BATAVIA.

tached to the branch of some tree, a habit of life very common in moist climates. A handsome tree known as *Humboldtia* is also myrmecophilous. The flowering twigs are swollen and hollow—the cavity opening to the outer world by a small hole through which ants enter. Apparently in these various cases the ants do not serve the plants in any way. There are, however, certain species of *Acacia*, which produce a sweet substance attractive to a certain kind of warlike ants, and these ants protect the tree from the attacks of the leaf-cutting ants. Other kinds of *Acacia*, not provided with ant police, are often seriously damaged by the leaf-cutters.

In our school geographies we have all read about the wonderful banyan tree which sends down roots from its outspread branches and

eventually covers a great area. A whole avenue of such trees is to be seen at Buitenzorg. The trees are the 'waringen,' a sort of banyan, and the avenue is called the 'Waringen Alle.' Other trees, such as the India rubber plant, have the same habit of putting forth aerial roots which grow down and penetrate the soil and eventually cause a wide spreading of the tree.

A short magazine article can not bring the reader very close to tropical plant life as shown in the Buitenzorg garden, but the illustrations may help to make clear some of the features I have mentioned. It must be understood that the gardens are maintained primarily for scientific purposes and that there are countless objects, interesting to the botanist, the enumeration of which would be wearisome to the general reader.

It is the wish of the director of the gardens that botanists from all countries should make use of the garden for study. At his suggestion the government erected some years ago a commodious laboratory for the exclusive use of visiting men of science. Naturally enough, since Java is a Dutch dependency, most of the visitors thus far have come from Holland, but many Germans have also been there. Almost no Americans have studied in Buitenzorg. This is the more strange, since our botanists are accustomed to travel long distances and many have worked in Europe. With the increased importance of the tropics which has come in recent years, there should be a greater interest developed in the study of tropical life. It is much to be desired that our own botanists make use of this and other tropical gardens in order that we may not remain behind other nations in this important branch of natural science.



MARKET PLACE IN BUITENZORG.

HYPNOTISM, ITS HISTORY, NATURE AND USE.

BY HAROLD M. HAYS,

COLLEGE OF PHYSICIANS AND SURGEONS, NEW YORK CITY.

IT is perhaps unnecessary to state that the word hypnotism brings to the mind of the average person timid recollections of many criminal acts. That is because few people hear of hypnotism in its proper sphere. It is clothed with the garb of shame; it is surrounded with all the horror belonging to the age of witchcraft. Newspapers delight in depicting its bad sides, in painting to the world the crimes that have been committed under its influence, the fearful results of its all powerful spell. To most it means a giving up of one's will to another who is superior, the crushing of one's entity by the power of another, the total abstinence of individual self-control, the entire weakening of one's higher intelligence. Vivid imagination supplies the result—suffering, hardship, labor and total subservience.

The question arises, 'Why should hypnotism have been thus derided?' Simply and plainly because the ignorance of people in general has given it no opportunity to show its good sides. Unfortunately people are always looking for the 'eternal gullible' and are not satisfied until they get a taste of it. And as hypnotism was first practised solely and is now practised mostly by men who have made the world their dupes, the world has had to suffer in the advancement of hypnotism on a scientific basis. But it has been so with other sciences. Astrology and alchemy are now things of the past; but astronomy and chemistry are their results—two great and everlasting sciences. There is therefore still great hope for hypnotism; for, although known under different names for so many hundreds of years, it is still in its infancy and the scientific aspect of the subject is yet in embryo.

Before, however, proceeding to cases in point, we may review briefly the history of hypnotism up to the present day. Call it what we may, since the beginning of the world, before Noah ever went on the Ark or the whale swallowed Jonah (much to the discomfort of both), hypnotism has been practised. The influence of one man over another by a certain innate quality or by personal magnetism has always been. Even Eve exerted an influence over Adam which has precipitated the world into misery and kept it there ever since. As time went on, people recognized this influence, gave it a name and called it the influence of the gods, the result being that those who were ordained

with this wonderful power were called God's ministers. Soothsayers, divine healers, the oracle ministers, all made the oriental people construe this power by religious means. Among the Chaldeans, Babylonians, Persians, Hindoos and other ancient peoples, there were priests who, because of their power of exerting a superhuman influence over others, were considered divine. To this day the *vogis* and *fakirs* of India use this power and throw themselves into a state of hypnotic ecstasy and reverie. In the eleventh century it was used in the Greek church, as it is now by the *omphalopsychics*. In the middle ages it was practised by Paracelsus, who maintained that the human body possessed a double magnetism, the first magnetism coming from the planets, the second from flesh and blood. All through the middle ages, hypnotism was practised under different names such as witchcraft, divinations, etc. It was supposed to be a supernatural power derived from Satan himself, and, therefore, the user of this power was expelled from society and sometimes put to death. Magic spells where people went into trances or out of their head were of common occurrence. Religious ecstasy, demon-possession, cures by shrines and relics, the cure by the king's touch, etc., were all phenomena of this same sort.

During the seventeenth century, a number of faith-healers sprang up all over the continent and British Isles. Many of these men were noted for their skill, but the one who attained the greatest reputation was one by the name of Greatrakes, who was born in Ireland about 1628. This 'healer' was sent for by a Lord Conway who expressed his message in the following language: "to cure that excellent lady of his, the pains of whose head, as great and unparalleled as they are, have not made her more known or admired abroad than have her other endowments." At Lady Conway's was a miscellaneous gathering, chiefly engaged in mystical pursuits, 'an unofficial but active society for psychical research, as that study existed in the seventeenth century.' Says Mr. Lang: Greatrakes' special genius in these mystical pursuits was of divine agency; for he tells us that at one time "he heard a voice within him (audible to none else), encouraging to the tryals: and afterwards to correct his unbelief the voice aforesaid added this sign, that *his right hand should be dead, and that the stroaking of his left arm should recover it again*, the events whereof were fully verified by him three nights together by a successive infirmity and cure of his arm." We are told that he failed to cure the lady's malady but that he worked some wonderful miracles of healing among the sick of the neighborhood.

Henry Stubbe, a physician of Stratford-on-Avon, thus comments on Greatrakes' miracles. He says "that God had bestowed upon Mr. Greatrakes a peculiar temperament, etc., composed his body of some particular ferments, the effluvia whereof, being sometimes introduced

by a light, sometimes by a violent friction, should restore the temperament of the debilitated parts, reinvigorate the blood and dissipate all heterogeneous ferments out of the bodies of the diseased, by the eyes, nose, mouth, hands and feet." Indeed, he recognized the difference between functional and organic complaints; and he only meddled with such diseases as 'have their essence either in the masse of blood and spirit (or nervous liquors) or the particular temperament of the part of the body' and attempted to cure no disease 'wherein there is a decay of nature.' "This is a confessed truth by him, he refusing still to touch the eyes of such as their sight has quite perished." None the less his cures were regarded as miraculous, and Dr. Stubbe tells us that 'as there is but one Mr. Greatrakes, so there is but one Sonne'; Greatrakes' method consisted principally in *stroaking* and *passings* and in driving the pains from one point to another until they went out at the fingers or toes.

In the latter half of the eighteenth century many fakirs, alleged philosophers, quacks and cosmongerers came to the front. Swedenborg, with his inspirations; Cagliostro, with his idea of personal power; Schrepfer, with the beginning of spiritualism; and then Gassner, the priest healer, who gave to Mesmer later on some of the ideas for the foundation of his theories.

Johann Joseph Gassner, a Swabian priest, appeared upon the scene in 1773. He was a forerunner of our modern spiritualist in a way, but had the added distinction of attributing all diseases to the devil. So his object was to pray for the expulsion of this satanic being. The patient had to have implicit faith and was made to give a detailed account of his malady. Gassner's next procedure was to chant various symptoms such as pain, weakness, stiffness, etc., and at his peremptory command to 'stop,' these symptoms would disappear and the patient be well again. At the words 'You will cease being disabled,' the patient's symptoms vanished. 'Your right hand and arm will become somewhat weak,' he says; and no sooner are the words out his mouth than the right hand is cold and numb and the pulse is accelerated. 'Your left hand will become as your right one was and this one will be normal,' is his next invocation, whereupon the left hand is cold and numb and the right returns to normal. Gassner keeps up these incantations until the patient is entirely cured, each prayer being accompanied by the invocation that 'this is accomplished in the name of the Lord, Our Father.' Gassner's cures in theory and practise were identical with those of Greatrakes, except that the mystery was now clothed in a religious garb. In both, the predominant idea was the suggestion to the patient that he would get well.

The reason why hypnotism was not studied scientifically until the middle of the eighteenth century was that there was too much of an air of mystery surrounding the workings of the phenomena. Whenever

hypnotic power was discovered in a person, he at once considered himself as one who possessed attributes which placed him above the plane of society. Suggestion was of course practised as it always has been, but the true idea of what the power consisted of was unknown. At last, toward the close of the century, Frederick Anton Mesmer rose before the world as a disciple of a new force which was destined to turn the scale on to the side of science and forever after to present hypnotism in a new light.

Frederick Anton Mesmer was born at Weil, near the point at which the Rhine leaves the Lake of Constance, on May 23, 1733. He studied medicine at Vienna under eminent masters, although at first his parents had destined him for the church. Interested in astrology, he imagined that the stars exerted an influence on beings living on the earth. He identified the supposed force first with electricity and then with magnetism; and it was but a short step to suppose that stroking diseased bodies with magnets might effect a cure. In 1776, meeting Gassner in Switzerland, he observed that the priest effected cures without the use of magnets, but by manipulation alone. This led Mesmer to discard the magnets, and to suppose that some kind of occult force resided in himself by which he could influence others. Mesmer's first practical work with magnets was in 1779, when he magnetized a young lady complaining of various functional disorders. This emotional young lady 'felt internally a painful streaming of a very fine substance, now here, now there, but finally settling in the lower part of her body and freeing her from all further attacks for six hours.' She was extremely sensitive to any of Mesmer's suggestions, but would obey no one but him. Thus we see the primeval workings of animal magnetism, afterwards called hypnotism.

Mesmer removed to Paris in 1778, and in a short time the French capital was thrown into a state of great excitement by the marvelous effects of what he called mesmerism. Mesmer soon made many converts; controversies arose; he excited the indignation of the medical faculty of Paris, who stigmatized him as a charlatan; still the people crowded to him.

While at Paris his practise became so enormous that it was impossible for him to handle all his patients. So he invented a scheme by which a number of his patients could be magnetized at once. He had troughs filled with bottles of water and iron filings, around which the patients stood holding iron rods which issued from the troughs. All the subjects were tied to each other by cords so that they could not break away and thus spoil the contact. Perfect silence was necessary and soft music was heard. The patients were affected variously, according to the suggestion Mesmer gave them. Some became hysterical, others crazed, some became affectionate and embraced

each other, while others laughed and became repulsive. This lasted for hours and was followed by states of dreaminess and languor. A picture given by Binet and Feret, two eminent French scientists, will present an idea of these meetings.

Mesmer, wearing a coat of lilac silk, walked up and down amid this agitated throng accompanied by Deslon and his associates whom he chose for their youth and comeliness. Mesmer carried a long iron wand, with which he touched the bodies of the patients and especially the diseased parts. Often laying aside the wand, he magnetized the patients with his eyes, fixing his gaze on theirs, or applying his hand to the hypochondriac region and to the abdomen. This application was often applied for hours, and at other times the master made use of passes. He began by placing himself 'en rapport' with his subject. Seated opposite to him, foot against foot, knee against knee, Mesmer laid his fingers on the hypochondriac region and moved them to and fro, lightly touching the ribs. Magnetism with strong electric currents was substituted for these manipulations when more energetic results were to be produced. The master, raising his fingers in a pyramidal form, passed his hands all over the patient's body, beginning with the head, and going downward over the shoulders to the feet. He then returned to the head, both back and front, to the belly and the back and renewed the process again and again until the magnetised person was saturated with the healing fluid and transported with pain or pleasure, both sensations being equally salutary. Young women were so much gratified by the crisis that they wished to be thrown into it anew. They followed Mesmer through the halls and confessed that it was impossible not to be warmly attached to the person of the magnetizer.

Mesmer was not an impostor by any means. He had deceived himself and had thus deceived others. But the Academy of Sciences in Paris believed that he was a mystic and a fanatic, and made it so hot for him that he was finally forced to leave France, where, however, he returned later. He died in 1815, and for a time animal magnetism fell into disrepute and Mesmer was denounced as an impostor.

Before Mesmer's death, he moved from Paris to a secluded spot among the hills. We see him at the last—bitterly complaining of the treatment he had received, thoroughly convinced as to the truth of his pet theories, performing various cures for the peasants about him, and living the simple life of a hermit.

Throughout Mesmer's career, the streets were not paved with gold. Many people died under his treatment, giving the belief that the treatment itself was the cause of death. He was treated with ridicule wherever he went. Papers, plays, etc., brought him even more prominently before the public in a more ridiculous light than his own hypothetical and mystical performances. A comedy, 'Docteur Modernes' brought his procedures on the stage. It severely criticized his 'fanatical' enthusiasm for a quondam science and portrayed the supposed abuses of his treatment. In England notices like the following appeared in the leading journals:

The Wonderful Magnetical Elixir. Take of the chemical oil of Fear, Dread and Terror, each 4 oz.; of the Rectified Spirits of Imagination, 2 lbs. Put all

these ingredients into a bottle of fancy, digest for several days, and take forty drops at about nine in the morning, or a few minutes before you receive a portion of the magnetic Effluvia. They will make the effluvia have a surprising effect, etc., etc.

Once, in 1785, a mock funeral oration upon Mesmer took place, making his exhibitions and theories seem more ridiculous than ever. Thus he was tossed about between ridicule and praise until, as we have seen, his life was hardly one of harmony or joy.

Braid.

Although a number of men followed Mesmer, appropriating his method, enlarging upon it and changing it somewhat—such men as de Puységur—it will be impossible in such a brief essay to tell of all of them. However, there is one man who rose up in the chaos of the times and again added new facts and theories to the science. This man was Braid, a surgeon of Manchester, England. Braid was born in the year 1795 on his father's estate in Fifeshire. He received his education at the University of Edinburgh, later being apprenticed to Dr. Chas. Anderson, of Leith. After graduating, he was appointed surgeon to the Hopetown mining works in Lanarkshire, later moving to Dumfries, where he engaged in practise with a Dr. Maxwell. An accident happening at that time brought to his town a Mr. Petty, who finally persuaded him to move to Manchester. It was here that he carefully worked on his new discovery and practised his cures. He died on March 25, 1860.

There is very little in Braid's life of especial interest, except his investigations in animal magnetism. His life seems to have been particularly free from the early struggles of a young practitioner. His interest in animal magnetism dates from the time he witnessed a séance by a M. Lafontaine, a traveling mesmerist. He was extremely skeptical, but this one urged him to try experimenting himself.

In 1866 this M. Ch. Lafontaine, a traveling mesmerist, published his 'Memoirs of a Magnetizer.' If it had not been for this, the electro-biologists of America, under one named Grimes, might have claimed prior right to the discovery of hypnotism. M. Lafontaine thus describes the state of affairs at that time.

Having accomplished the cure of numerous deaf and blind persons, says he with modest assurance, as also numerous epileptic and paralytic sufferers at the hospital (this was in Birmingham), I repaired to Liverpool, but only to meet with disappointment; few persons attended the séance; and on the following day I proceeded to Manchester in which city my success was conspicuous. The newspapers reported my experiments at great length, and to give some idea of the sensation I created, I may say that my séances returned me a gross total of 30,000 francs. I put to sleep a number of persons who were well-known residents of Manchester. I caused deaf mutes to hear, operated a number of brilliant cures. After my departure, Dr. Braid, a surgeon in Manchester, delivered a lecture in which he proposed to prove that magnetism was non-existent. *From this lecture Braidism, afterwards called*

hypnotism, originated, ardent discussions arising, even from the beginning over this pretended discovery. I received letters from Manchester entreating me to return, and I did so on a date when Dr. Braid had announced a demonstration. His experiments were given but unfortunately, on this occasion none of them succeeded; neither sleep nor catalepsy was obtained, and every moment I was appealed to. In the facts that were advanced on this occasion by Dr. Braid, there was in my opinion, absolutely nothing that was remarkable, and had not that gentleman been honorably known in the town, I should have supposed that he was mystifying his audience. The next day, and for six days consecutively, I experimented after his own fashion on fifty or sixty subjects and the results were practically *nil*. I then gave a magnetic séance and the results on Eugene and Mary were marked and positive.

The value of the quotation rests solely on the opportune remark that Braid was the first to apply the name hypnotism to animal magnetism. One should not forget that Eugene and Mary were two subjects whom Lafontaine carried with him from town to town and on whom he could rely for phenomena.

Though Braid survived his discovery by not more than eighteen years, he lived to know that it was well on the road to acceptance by the competent opinion of the time. In the latter part of his life he said, "I feel no great anxiety for the fate of hypnotism, provided it only has 'a fair field and no favour.' I am content to bide my time, in the firm conviction that truth for which alone I most earnestly strive, with the discovery of the safest, and surest, and speediest modes of relieving human suffering, will ultimately triumph over error" ('Magic, Witch,' p. 53).

The enemies of Braid were as vociferous in their denunciation of him as his friends were earnest in their praise. And what may seem the greatest surprise and yet what seems to be a natural consequence of opposition, the Mesmerists themselves were the ones who were the loudest in opposing him. However, his method has stood the test of years and still prevails among those who practise the art now-a-days.

As was said before, the first exhibition that Braid ever attended was one given by this same Lafontaine. One fact, *the inability of the patient to open his eyelids*, arrested his attention. He considered this a real phenomenon and was anxious to discover the physiological cause of it.

In two days afterward, he says, I developed my views to my friend Captain Brown, as I had previously done to four other friends; and in his presence and that of my family and another friend, the same evening, I instituted a series of experiments to prove the correctness of my theory—namely that the continued fixed stare, by paralyzing nervous centers in the eyes and their appendages and destroying the equilibrium of the nervous system, thus proved the phenomenon referred to. The experiments were varied so as to convince all present, that they fully bore out the correctness of my theoretical views. My first object was to prove, that the inability of the patient to open his eyes was caused by paralyzing the upper muscles of the eyes, through their continued action during the protracted fixed stare, and thus rendering it

physically impossible for him to open them. With the view of proving this, I requested Mr. Walker, a young gentleman present, to sit down, and maintain a fixed stare at the top of a wine bottle, placed so much above him as to produce a considerable strain on the eyes and eyelids, to enable him to maintain a steady view of the object. In three minutes his eyelids closed, a gush of tears ran down his cheeks, his head drooped, his face was slightly convulsed, he gave a groan and instantly fell into a profound sleep, the respiration becoming slow, deep and sibilant, the right hand and arm being agitated by slight convulsive movements. At the end of four minutes, I considered it necessary, for his safety, to put an end to the experiment.

Braid became so convinced that his interpretation of the phenomena was the correct one that he used it universally, succeeding in a remarkable number of cases. His method was as follows:

He would take any bright object, most often his lancet case, and holding it about fifteen inches from the eyes and in such a position as to strain them and still allow the patient to gaze steadily at it, he would carry it slowly toward them until the eyelids closed involuntarily. After a preliminary contraction of the pupils, they would dilate, and finally a tremulous motion of the iris would take place. If this did not succeed after a few minutes, he would try again, letting the patient understand that his eyes and mind had to be riveted on the one idea of the object before him. The primary fact was the fixation of the mind on a certain object. Nay, even the hypnotist himself, if he use the method of attraction, may be hypnotized, as Braid shows in the following example. Mr. Walker, Braid's friend, offered to hypnotize a certain person. When Braid went into the room where the experiment was going on, he saw the gentleman sitting staring at Mr. Walker's finger. Mr. Walker was standing a little to the right of his patient with his eyes fixed steadily on those of the latter. Braid passed on, and when he returned he found Mr. Walker standing in the same position fast asleep, his arm and finger perfectly rigid and the patient wide awake, staring at the finger all the while.

After Braid, many men pursued the scientific investigation of the phenomena. The interest in the new science since 1875 has spread quickly over Europe. In Belgium, the eminent psychologist Delboeuf of Liège, made a path for it. In Holland such men as Van Reuterghem, VanEiden and De Jong used hypnotism for curative purposes; in Denmark, Norway and Sweden, there were Johannessen, Sell, Frankel, Calsen and Wetterstrand, of Stockholm, and finally Swedenborg. In Russia were Strembo and Tokarski; in Greece, Italy and Spain, hypnotism has greatly come into play in medical treatment. In England, Carpenter, Laydock, Sir James Simpson, Lloyd-Tuckey, Mayo and others have used it for curing the sick. In America, the science also has its advocates. It is one of the subjects constantly appearing before the Society for Psychical Re-

search. In South America, it numbers among its adherents, David Benavente and Octavio Maria, of Chili. The interest in hypnotism in France centered around two schools, the school of Salpêtrière and the school of Nancy. The former was led by Charcot, whose luminous researches in this subject are epoch-making.

The Paris school held that hypnotism is the result of an abnormal or diseased condition of the nervous system; that suggestion is not at all necessary to produce the phenomena; that hysterical subjects are the most easily influenced; and that the whole subject is explainable on the basis of cerebral anatomy and physiology. But lately the followers of Charcot, who had been numerous in the beginning because he was so highly reliable a man, have begun to dwindle away and have turned to the school of Nancy. The reason for this is obvious to any one who has studied hypnotic phenomena. The first objection to the school of Salpêtrière is that most of the experiments have been made on hysterical women. In the second place, this school ignores suggestion, which has been found to be one of the most important factors in hypnotism. They appreciate of course that it can be used, but assert that it is not necessary.

The school of Nancy, led by Bernheim, met with equal success and is now upheld by more people than the other school. The theory of the school of Nancy may be summed up in a few words: first, the different psychological conditions in the hypnotic state are determined by mental action; secondly, people of good sound physical health and of perfect mental balance can produce the best results; and thirdly, all the mental and physical actions are the result of suggestion. In fact suggestion is the all important factor in producing the various phenomena.

Liebault, and Bernheim, his pupil, by bringing forth the idea of suggestion, have made themselves in a way the equal of Braid, for in continuation of the latter's method, the method of the former is always used now-a-days. The influence of Bernheim over his patients is remarkable. His great success may be accounted for by the confidence his patients have in him. Of course the low intellectual state of the peasant class of France may have something to do with it, for one can hardly think that in any ordinary community this supreme belief and trust in a human being could exist. To Nancy people come from all over the provinces to visit this 'Man of God,' who performs experiments and cures which seem divine. Bernheim goes from one patient to another, shouting 'sleep.' Many of them having been hypnotized by him often fall into the state immediately. When the experiments are over he goes the rounds of his patients, snapping his fingers, in which way he awakens them.

To sun up then, we may say the history of hypnotism may be divided into five epochs. The first before the time of Mesmer; the

second, the age of Mesmerism, when personal magnetism was supposed to be the attractive power; the third, the age of Braid, when the science was put on a physiological basis; the fourth, the age of Bernheim and Charcot, when the idea of suggestion was brought to the front and hypnotism was used indiscriminately; and lastly, the fifth, the age we are in now, where the tendency is to restrict hypnotism and to classify it for specific uses.

The Nature of Hypnotism.

Each individual has a separate state of consciousness which changes as do the thoughts therein. It is in the waking state that we have separate individualities. Now let us see the gradations of this consciousness. At this present moment we shall say we are listening intently to a sermon. That is the thing uppermost in our minds, and as long as our minds are upon it we are exercising acute consciousness. But, even if our attention to this sermon is the central thing, in the fringe of our mental picture a number of other thoughts are jumping around, any one of which may be powerful enough to force its way into the middle of the picture and to usurp its place. For example, all the while we are listening to this sermon we are more or less conscious that the seats we are in are hard, that somebody is talking next to us, etc. Our seats may become so uncomfortable that it may occupy our whole attention, or something outside may seem of more interest. If our attention jumps from one thing to another, it is called diffused consciousness. The next step to diffused consciousness is the dreamy state where the mind is half way between waking and sleep. Anything may come into the mind while in this state and be the predominant idea, to be chased out again by a next idea. It is for this reason that dreams usually present such a chaos and jumble. Our thoughts tumble over one another to get from the fringe of consciousness to the foreground. Any external sensation will be greatly exaggerated and may turn the trend of our thought. A warm bed might feel like the fire of hell, a heavy dinner with indigestion like the battles of heroes using our poor bodies as the fighting ground. As dreams gradually fade away we approach our first hypnosis or sleep, which, in the beginning, is slight, but gradually deepens, finally consciousness being entirely lost.

Thus we have traced the process of natural sleep to which hypnotic sleep is closely akin. The person at first has a diffused attention, he then confines his attention to sleep, he next passes into a dreaming state, then into a light sleep and lastly into a deep sleep.

The differences between it and natural sleep are as follows: first, the state ordinarily is produced by another; secondly, the person must have faith; and thirdly, the phenomena in the sleep must be produced by suggestion. The two latter were fully recognized years ago and

have formed the basis of all psychical cures ever since. How the sleep can be produced by another was seen in the experiments of Braid, where one appreciates fully that the person really hypnotizes himself by gazing at an object. The full understanding between hypnotized and hypnotist has never been really understood, and so here we are stopped short.

The theory of Dr. Hudson may put us on the right track. Because it is so convenient a theory and tends to make plausible a number of things which otherwise could not be understood, I am going to take the liberty of detailing it here. Dr. Hudson claims that every normal person is possessed of two minds, a subjective one and an objective one. The objective mind is the one we use every day, a mind fully capable of forgetting and the only one of which we are ordinarily cognizant. The subjective mind is the *perfect* mind wherein are stored up all the numerous thoughts that have ever come into it, there lying dormant, only to be reawakened when a new set of associations brings them forth.

It is this mind which we may say is used in hypnotism, in somnambulism, the one which shows itself in altered personality and in various other abnormalities. Some authors consider this the subliminal or subconscious mind.*

That there is another mind far more perfect and which brings to our recollection many things forgotten, seems to be an undisputed fact. When a drug like Cannabis Indica is used or when a person is drowning, there come before his mind's eye, in a single moment, the doings of years. And so in some recorded cases of trance states the same thing is proved. A highly interesting case is given by Mr. Coleridge in his 'Biographica Literaria.'

Mr. Coleridge says:

It occurred in a Roman Catholic town in Germany, a year or two before my arrival at Göttingen, and had not then ceased to be a frequent subject of conversation. A young woman of four or five and twenty, who could neither read nor write, was seized with a nervous fever, during which, according to the asseverations of all the priests and monks of the neighborhood, she became possessed and as it appeared, by a very learned devil. She continued incessantly talking Latin, Greek and Hebrew, in very pompous tones, and with a most distinct enunciation. This possession was rendered more probable by the known fact that she was, or had been, a heretic. The case had attracted the particular attention of a young physician, and by his statement, many eminent physiologists and psychologists visited the town and cross-examined the case on the spot. Sheets full of her ravings were taken down from her own mouth and were found to consist of sentences, coherent and intelligible each for itself, but with little or no connection with each other. Of the Hebrew, a small portion only could be traced to the Bible; the remainder seemed to be in Rabbinical dialect.

* One can not help realizing that this theory will never be fully accepted. Most psychologists are still quarreling over concepts, and no two will agree as to what is meant by a subjective or an objective mind.

All trick or conspiracy was out of the question. Not only had the young woman been a harmless simple creature, but she was evidently under a nervous fever. In the town in which she had been resident for many years as a servant in different families, no solution presented itself. The young physician, however, determined to trace her past life, step by step; for the patient herself was incapable of returning a rational answer. He at length succeeded in discovering the place where her parents had lived, travelled thither, found them both dead, but an uncle surviving, and from him learned that the patient had been charitably taken by an old Protestant pastor at nine years old, and had remained with him some years, even till the old man's death. Of this pastor the uncle knew nothing, but that he was a very good man. With great difficulty and after much search, our young medical philosopher discovered a niece of the pastor's who had lived with him as housekeeper and had inherited his effects. She remembered the girl; related that her venerable uncle had been too indulgent, and could not bear the girl scolded; that she was willing to have kept her, but that, after her parent's death, the girl herself refused to stay. Anxious inquiries were then, of course, made concerning the pastor's habits; and the solution of the phenomenon was soon obtained. For it appeared that it had been the old man's custom for years to walk up and down a passage of his house into which the kitchen door opened, and to read to himself, with a loud voice, out of his favorite books. A considerable number of these were still in the niece's possession. She added that he was a very learned man and a great Hebraist. Among the books was found a collection of Rabbinical writings, together with several of the Greek and Latin fathers; and the physician succeeded in identifying so many passages with those taken down at the young woman's bedside that no doubt could remain in any rational mind concerning the true origin of the impression made on her nervous system.

The same power of the subjective mind is many times seen in hypnotic phenomena. The case cited is but one of a number, all of which are just as wonderful. Being a mind so perfectly endowed, it is hardly too audacious to say that this mind exercises its influence over all bodily functions, so that any function may be inhibited or accelerated by its influence. For example, the following is related of Henry Clay.

On one occasion he was unexpectedly called upon to answer an opponent who addressed the Senate on a question in which Clay was deeply interested. The latter felt too ill to reply at length. It seemed imperative, however, that he should say something; and he exacted a promise from a friend, who sat behind him, that he would stop him at the end of ten minutes. Accordingly, at the expiration of the prescribed time the friend gently pulled the skirts of Mr. Clay's coat. No attention was paid to the hint, and after a brief time it was repeated a little more imperatively. Still Clay paid no attention and it was again repeated. Then a pin was brought into requisition; but Clay was by that time thoroughly aroused, and was pouring forth a torrent of eloquence. The pin was inserted deeper and deeper into the orator's leg without eliciting any response, until his friend gave up in despair. Finally Mr. Clay happened to glance at the clock and saw that he had been speaking two hours; whereupon he fell into his friend's arms, completely overcome by exhaustion, upbraiding his friend severely for not stopping him at the prescribed time.

The fact that Mr. Clay, on that occasion, made one of the ablest speeches of his life, two hours in length, at a time when he felt almost too ill to rise to his feet, and that his body was at the time in a condition of perfect anaesthesia, is a splendid illustration of the synchronous action of the two minds, and also of the perfect control exercised by the subjective mind over the functions and sensations of the body ('Law of Psychic Phenomena').

I now propose to attempt to explain some of the phenomena of hypnotism by reviewing thoroughly a specific example.

On November 23, 1901, I was asked by a young lady to try to cure her of biting her finger nails. She was then about 18 years of age. I immediately replied that I should be glad to do so if I had her full permission. Besides her and myself, there were four or five other persons in the room, including her father and mother. Getting her perfectly composed, I placed my hand on the top of her head, and told her to turn her eyes in the direction of the hand. This tired her eyes very readily. They became heavier, the eyelids twitched and inside of five minutes they fell and she was sound asleep. I first placed her in a cataleptic condition. I told her her arm was a piece of stone and therefore could not be bent. Two or three of those assembled tried to bend it, but failed. Then by more suggestions I placed her in an anesthetic condition and rubbed the ball of her eye. She neither winked nor flinched. I then gave her a few post-hypnotic suggestions. For example, I told her that when she awakened she would go over and close the window, that she would then thank me for what I had done, and would feel no bad effects and also would remember nothing. Then I told her that the following Sunday I would come over, and, as soon as I told her to go to sleep, she would do so. When she awoke, she went over and closed the window, and then thanked me for what I had done. She remembered nothing and felt much rested. Of course, suggestions were constantly given that she would not bite her nails.

The following Sunday, I went over there again. She had not bitten her finger nails since the last time I saw her. I told her to lie down and that in three minutes she would be sound asleep. I used no method whatsoever. In fact, I was in another room. When the three minutes were up, I went in to her and found her in a deep sleep. I impressed on her a number of times that she would never bite her finger-nails again. I placed her in a chair, telling her to open her eyes. She was to see or hear nobody but me. A number of people stood before her, but she could not see them. I asked her a question which she readily answered. Then somebody else asked her the same question, but no answer could be got from her. She seemed perfectly deaf to their words. I asked her if she heard anybody else and she answered 'No.' I next procured a needle which was perfectly clean, and telling her she would feel no pain, I ran

it into her forearm for over half an inch. Very little blood appeared, as I had suggested, and she felt nothing. In fact, after the experiments were over she did not know anything about the wound. Taking a glass of water, I told her it was whiskey. She took a little with some show of difficulty in swallowing and when I told her to walk about the room, she reeled around as though she were overcome by the liquor. I then procured some salt, telling her it was sugar and that it would cure her of her dizziness immediately. She took the salt, a half teaspoonful, said it tasted sweet, asked for more, and was entirely herself again. Finally I placed her between two people putting her head on one's lap and her feet on the other's. She became cataleptic on my suggestion and when two hundred and fifty pounds were put on her body she sustained them very readily.

Before she awakened, I gave her three suggestions: (1) That as soon as she awoke she would go into the front room and lie down on the sofa for a few minutes; (2) that she would go up to her parents and tell them that she was never going to bite her nails again; and (3) that two weeks from that night she would sit down after supper and write me a letter, thanking me for what I had done. All these suggestions were carried into effect.

On Monday, December 9, two weeks and a day after the experiment had been made, I received the following letter:

Dec. 8th, 1901.

DEAR MR. HAYS:

I feel as though I owe you a note of thanks for the wonderful cure you have effected on me. I have not bitten my nails since three weeks ago to-night and I am very proud of them. I am writing this to try to let you know how much I thank you. It seems remarkable that a little thing like hypnotism can do so much good and I shall always feel grateful and indebted to you for this.

Yours sincerely,

E.

Not until after the letter had been sent did she find out that it had been I who prompted her to do it. This young lady has not bitten her finger nails since and is entirely cured.

We have already found the primary cause of the sleep when produced by the tiring of the eyes. The eyelids droop because the muscles become temporarily paralyzed. There is one advantage in placing the hand on top of the head. It is that it rolls the eyeballs upward, thus putting them in a natural position for sleep. The various other processes after the sleep has been produced are all dependent on the workings of the nervous system. Let us first try to explain the cataleptic state—how it is that the arm becomes so rigid that the bones can be broken before the arm will bend. The most plausible explanation to my mind is that impulses are sent from the brain which make one set of muscles counteract the influence of another set. For

example, let us say that two men of equal strength are pulling with all their might on a thick stick. As long as the pull is the same on both sides, the stick won't move. How the mind can exert such an influence we do not know. This same idea of the counter-action of various muscles applies to the whole body as well as to one arm. Yet some one may ask how these muscles can have the power to stand more strain than they do in the waking state. It is only that as our normal selves we never use our full muscle power. This is because not enough stimulation is ever given to the muscle to make it work to its full extent. But in cases of great excitement or danger, even the weakest seem to have superhuman strength.

The loss of the sense of pain or anesthesia can also be accounted for by the brain. When we say we have a pain in our finger, we don't really mean that. The cut is in the finger, but the pain is in the brain, and consciousness is necessary for us to have pain. Suppose a man is going to have an operation on his finger and is made unconscious. Now the finger is there, but the pain has disappeared, showing that pain is not located in various parts of the body, but in the domain of consciousness. So if, under hypnotic influence, you tell the patient that he will have no pain, he thinks the pain away, so to speak—knocks it out of his consciousness.

How we can run needles into people and produce no blood seems still more remarkable, but physiologically it *can* be explained. Let me say here that if any one should pierce a large artery with a needle, serious consequences might result. Let us say that we penetrate the skin in a place where there are thousands of little capillaries. Each one of these vessels is connected with the nervous system by two sets of nerve fibers—those which can dilate the vessels, those which can constrict them. Now, suppose I give the suggestion that I am going to run a needle through a certain part of the arm. An impulse, sent from the brain, constricts the blood vessels at this spot, inhibits the sense of pain, and the needle comes out again without a drop of blood following it.

The explanation of the dizziness from water supposed to be whiskey and the cure by salt supposed to be sugar is that both are the result of an unexplainable force whereby the patient takes every word of the hypnotizer as gospel, though it is contradictory to his own ideas. For example, in one case a patient told me that he knew the glass contained water and yet it tasted like whiskey, and he also knew that the cellar contained salt and yet it tasted like sugar.

The cure of the finger-nail habit and all the post-hypnotic suggestions may be summed up briefly. All we should do is to refer back to the perfect or subjective mind where all these suggestions are stored up and say that the objective mind draws nutriment from it, and in

this nutriment these suggestions given under the hypnotic influence come into play.

Before closing this portion of the essay I should like to say that I believe hypnotism is not an occult power, but is a simple, natural physiological process. And again, anybody can use the power just as any one can become a good piano player, or student or business man by training. Yet it is only those with the natural tendency toward personal power who will make the greatest success.

It would indeed be pleasing to me to cite a number of wonderful cases where hypnotism has been used experimentally in order to show the great influence of the mind over the body—how a horse can be ridden over the outstretched body of a man in a cataleptic state, how illusions and hallucinations can be produced, how we may even obtain negative hallucinations, how we can turn an adult into a child, how we can conjure before the mind's eye vistas grand and superb, panoramas gorgeous and elegant, how the commonest man may become an orator, a saint, an assassin perhaps. But all these things would be far beyond the scope of this essay. However, one case seems to be of especial interest as it shows how far hypnotism may be used in the cure of various inflammations.

The experiment is on a nurse 28 years old, who is not at all hysterical. She is a daughter of plain country people, and has been for a long time an attendant in the Zurich Lunatic Asylum, which Forel directs. He thinks her a capable honest person, in no way inclined to deceit. The experiments were as follows: A gummed label was fixed upon her chest on either side; the paper was square. In no case was an irritating gum used. At mid-day Forel suggested that a blister had been put on the left side; and at six o'clock in the evening a moist spot had appeared in that place; the skin was swollen and red around it, and a little inflammation also appeared on the right side, but much less. Forel then did away with the suggestion. On the next day there was a scab on the left side. Forel had not watched the nurse between noon and six o'clock, but had suggested that she could not scratch herself. The other nurses said that the subject could not raise her hand to her chest, but made vain attempts to scratch. Forel repeated the experiment later; he put on the paper at 11:45 a. m. and ordered the formation of blisters in two and one half hours. Little pain was suggested, and the nurse therefore complained but little. At two o'clock Forel looked at the paper on the left side, for which the suggestion had been made, and saw around it a large swelling and reddening of the skin. The paper could with difficulty be removed. A moist surface of epidermis was then visible, exactly square like the paper. There was nothing particular under the paper on the right side. Forel then suggested the disappearance of the pain, inflammation, etc.

In time everything disappeared.

Many investigators have been able to bring about a change in blood supply and other visceral changes of a similar kind. Changes in temperature have been made as much as three degrees centigrade. Bernheim found that by suggestion he could induce local reddening of the skin. This is undoubtedly a vaso-motor change. These local red

spots were often found in the middle ages on the hands of monks and nuns after they had been looking steadily at a cross for hours. At that time it was supposed to be a miracle and a message from the Divinity. In 1860, a woman was found with these spots or blisters caused by something unknown. It was learned that she got these while in the hypnotic state. The wounds healed in the normal way and all that remained to make it necessary for it to be commented upon, was that it gave the investigators the idea of trying to produce these spots by artificial means. Krafft-Ebing, a noted German physician, produced certain results analogous to those cited above. He would put something in the patient's hand and give him the suggestion that it was burning. A reddening would appear. He would take a scissors, a piece of metal and a postage stamp (saying it was a mustard plaster) and would produce the same results.

Wonderful as it may seem—that hypnotic suggestion can produce such grave organic changes—the physician has only to reflect for a moment on the powerful changes which the mind exerts over the course of a disease. He realizes only too well that the mental attitude of the patient toward his malady is of almost as much importance in the cure as the therapeutic measures he may advise. Processes of inflammation are purely physiological in the light of modern medicine and yet there can be no inflammatory process which can not be made worse by concentrated mental worry. A sore finger to the phlegmatic individual is a trifle: but the hysterical woman makes a 'mountain out of a mole hill' of it and thereby actually makes the inflammation worse.

The Uses of Hypnotism.

The general tendency has been in the last decade to use hypnotism indiscriminately; but like every therapeutic agent, it in time will become restricted and only used in certain complaints. It surely should be included by every physician in his 'therapeutic arsenal.' It has one thing in its favor which places it above all remedial agents and that is, that when it is used properly it can do no harm. We must recognize that in all the scientific literature on the subject, there has not a single death been reported from its use. The unscientific application is its abuse.

We must also recognize that there are many cases that are practically incurable by medical treatment, cases which defy the greatest physicians, cases which are surprising because of their persistency. When the last extreme has been reached, when physicians consult and pronounce the case as practically incurable, hypnotism may be tried.

Before the advent of ether or chloroform, the possibility of using hypnotism for anesthetic purposes was thought of and apparently its use in this direction met with success in a limited number of cases.

In 1859, Dr. Guérineau announced that he had amputated a thigh under hypnotic anesthesia. Some other reports are as follows: Jules Cloquent amputated a breast in 1845; Dr. Loysel of Cherbourg amputated a leg and removed some glands in 1846; a double amputation of the legs by Drs. Fanton and Toswel in 1845; amputation of an arm by Dr. Joly in 1845; and in 1847 a tumor of the jaw was removed by Drs. Ribaud and Kiaro of Potiers—all under hypnotic anesthesia (Bernheim's 'Suggestive Therapeutics').

But hypnotism was found to have more drawbacks than advantages in these cases of major surgery. In the first place, hypnotic anesthesia is a difficult state to produce and even a more difficult state to maintain. Secondly, there is always the possibility of the patient awakening unexpectedly and dying from the shock of the operation.

Although it has thus fallen out of use as an anesthetic in these serious cases, still it is used constantly, and more and more every day, in minor surgery. In dentistry it certainly has its place; in outpatient departments of our hospitals it is often of value, as it has no after effects.

The various medical cases that have been treated by the hypnotic method are too numerous to recount. They include nearly every form of mental non-equilibrium and also cases of general organic trouble dependent more or less on the mental attitude of the patient. They include habits of various kinds, such as onychophagie or finger-nail biting, excessive smoking, dysomania, nervous twitchings, etc., nervous headaches, insomnia and neuralgias; chronic nervous constipation and diarrhœa and dyspepsia; local and general pain, insomnia and neurasthenia. Nor is this all. Hypnotism's greatest blessing consists in the cure of psychic paralytics and psychic hysterics. In this connection we may say that it should be used unconditionally. Dr. Starr in a lecture at the College of Physicians and Surgeons cited a case of paralysis in the left arm from the shoulder to the elbow. A physician knows that it is impossible to get a true paralysis of this kind. Dr. Starr hypnotized the patient in his clinic and in less than three minutes the arm was in as good working order as ever. During the course of the past year, I have worked on a few hysterical cases for physicians where nothing but hypnotism could cure them. A remarkable case of true organic nature came to my notice over a year ago. A lady had a severe swelling on her finger which was so painful that I could hardly bandage it for her. I put her to sleep, suggested the pain away, told her the inflammation would subside the next day and awakened her. I could then do anything I wished to the finger without hurting her.

I have left aside the part that hypnotism plays in mental and moral culture—a phase of the subject so vast that it deserves more consideration than could be given here.

PHYSICIANS AND PHILOSOPHERS.

BY PROFESSOR CHARLES WILLIAM SUPER,
OHIO UNIVERSITY.

ALTHOUGH the initial assonance of physician with philosopher is purely accidental, it is nevertheless a fact that philosophy and the healing art or medical science have been closely associated with each other from their earliest beginnings. It can not but be regarded as a singular coincidence that for two and a half millenniums physic and philosophy, the practitioners of the healing art and the real or professed lovers of knowledge, have been more or less intimate friends. At the beginning they seem to have found themselves in each other's company almost by chance; then by a sort of elective affinity like that which often springs up between persons of opposite sex whose paths in the ordinary course of events incidentally crossed each other, to have discovered that they could make the rest of the journey together to reciprocal advantage.

Herodotus, the Father of History, was a native of Halicarnassus, and Hippocrates, the Father of Medicine, his younger contemporary, first saw the light on the island of Kos, only a few leagues distant. Born in the same year with Hippocrates was the philosopher Diogenes, of Apollonia in Crete, whose few literary remains not only attest his interest in human anatomy, but also furnish proof that he early came under the influence of the Ionian thinkers. Though never regarded as a physician, but only as a philosopher, he tells us in one of the very brief fragments that have been preserved that the veins of the human body are divided into two branches; that they pass through the abdominal cavity along the backbone, one on the right side, the other on the left, into the legs; and that two branches pass into the head. He then goes on to describe the course of the blood vessels and their ramifications as far as the ends of the toes, the fingers, and so on. It may safely be assumed from this fragment that Diogenes gave much attention to the structure of the human body.

In the southwestern portions of Asia Minor, the disciples of Aesclepias or Æsculapius had several therapeutic establishments, and it is in connection with these that we discover the first signs of what may be called the healing art in the entire ancient world.

It was especially the priests of the temples of Kos and Knidos who cultivated a primitive and simple medical science in connection with

their service of the god. In this part of Asia, also, philosophy took its rise. For not only was Hippocrates a philosopher as well as a physician, but the same affirmation can be made of a considerable number of Greek thinkers. Diogenes has just been mentioned. Moreover the two lines of investigation were often parallel in other parts of the ancient world. Empedocles who was a full generation older is supposed to have been a physician. Pythagoras, who lived still earlier, though perhaps not a physician in the strict sense of the word; gave, according to tradition, no little attention to the laws of health and formulated a number of precepts supposed to be conducive to its preservation. Plato, though not a special student of the healing art, shows in many passages of his Dialogues, a considerable degree of familiarity with the subject. Aristotle was the son of a physician and was indebted to his father not only for much of his knowledge, but also for his interest in natural history; while his pupil Theophrastus is regarded as the father of medical botany. Among the Romans we find Pliny paying a good deal of attention to facts or supposed facts in the realm of medicine. The same thing is true of Seneca and still more of Vitruvius, though it would perhaps be as far astray to call him a philosopher as a physician in the strict significance of the terms. Toward the latter part of the second century we are carried back again to Asia Minor to find in Galen of Pergamus, not only a distinguished writer on philosophical subjects, but a man whose reputation as a physician is fully equal to, if not greater than, that of Hippocrates, notwithstanding that he was a man of less native capacity. It may be confidently affirmed that Hippocrates, Celsus and Galen represent the entire healing art until modern times. With respect to Cornelius Celsus, who lived in the reign of Tiberius and who occupies an important place in the history of ancient medicine, it must be said that it is uncertain whether he was really a physician. It is rather more than probable that he was a *savant*. On the other hand, the question is raised, Why would any one but a practical physician compile a medical work? Could any other person do it successfully? Another singular fact that has added to the difficulty of defining Celsus' position is that even as late as the age in which he lived nearly all the physicians in Rome were Greek freedmen. At any rate the work of Celsus at once sprang into prominence, and though it is only part of an encyclopedic compilation, nothing else remains at the present day. As is the case with not a few other works of antiquity, its connection with modern times hangs by the slender thread of a single manuscript from which all later copies have been made. This portion of the encyclopedia of Celsus has also an important historical value since it gives brief sketches of more than seventy physicians who had lived

before his time and had attained a certain degree of eminence. It had not escaped his observation that only persons of mediocre ability are loth to admit errors, while the reverse is true of genius, since there still remains a large residuum of truth in its possession.

Apropos of the intimate relationship existing between the study of nature and the healing art, we find that the Romans as early as the time of Cicero called a natural philosopher *physicus*, while the science itself was called *physica*, both words having been borrowed from the Greek *physikos*, that which pertains to nature, from *physis*, nature, in the somewhat restricted sense of the term as used in antiquity. But in mediæval Latin *physica* had become the equivalent of *medecina* and *physicus* that of *medicus*. In the older English, *physic* means both natural philosophy, the modern physics, and the medical art as well as drugs. The restricted signification 'to purge' and 'a purge' is comparatively recent.

Shakspeare uses both doctor and physician, the former generally in the sense of teacher. Doctor also occurs in Middle English and later Chaucer speaks of a 'doctour of Physik.' In classical Latin the term *doctor* means teacher, a sense in which it is used by Cicero, Horace and others. It had no connection with medicine. In modern French *physicien* means one who occupies himself with physics, but in the older language it had the signification of the English physician. The French *médecin*, physician, is evidently from the Latin *medicinus* a derivative from *medicus*, while our medicine, a remedial drug, is from the same word in the feminine gender. In German the connection with the English physician is preserved by *Physikus* alone, a term used to designate an official whose functions correspond in the main with our health-officer. Here too the term *Doktor* has long since usurped the more specific *Arzt*, and *Doktorei* is occasionally used for medicine, 'doctor's stuff.' The Gothic word *lêceis*, which is the Anglo-Saxon *læce* and the English 'leech' has nothing in common with either except the meaning. This term doctor again brings to the physician the same title that is borne by the scholar. Although it is given in several departments such as law, theology, music, philosophy, and so on, to the common man both in German and in English countries the doctor represents only the physician. This is explained by the fact that in most communities the only man or men bearing the title were physicians. Of late years, however, especially in the United States, doctors of divinity have become so common, not to mention other doctors, that the designation has reached the stage of painful uncertainty. What it now represents can only be determined by an investigation of each individual on whom it has been conferred.

No more convincing testimony to the small progress made in the healing art from the earliest times until a little more than a century

ago need be asked for than is offered by a comparison of the average length of human life as given by Herodotus and that currently accepted until quite recently—three generations to a century. In fact most life insurance associations have not yet learned that this average is above forty years. Anatomy had made great progress and the structure of the body was minutely known, but until the germ theory of disease and antisepsis were established, therapeutics was largely a matter of tradition and routine; of empiricism and individual skill. When one reads of the incessant wars that kept a portion of the male inhabitants constantly occupied in military enterprises, directly or indirectly, one is inclined to believe that the average of human life must have been shorter than it was held to be twenty or twenty-three centuries ago. There is no room to enter upon a discussion of the problem here; suffice it to say, the loss from disease was probably no greater, and the losses in the armies probably much less relatively than in modern times. For it is well known that the killed in battle are but a small portion of those whom war deprives of life. It is probable that never before or since has any country suffered such ravages as did Germany during what is called the thirty years war. That the sanitary condition of ancient Greece must for the most part have been fairly good is attested by the rapid recuperation of most of the city-states after a disastrous war. But then there were no large cities like those of modern times, in which the population increases much faster than the adoption and enforcement of sanitary measures.

It will hardly be considered surprising that disease in any form should early have stimulated men to reflection. This is true at least of those living under conditions where there was more or less freedom of action and where affairs had not yet settled down into the lethal routine that characterized the social life of most of the people of the ancient world anterior to the appearance of the Greeks. The succession of day and night; the changes of season that follow each other regularly, and the meteorological conditions that accompany them, would be taken as a matter of course. But the vicissitudes of the human system, whether gradual, rapid or sudden, when not the result of accident or attributed to the malevolence of evil spirits, naturally led to inquiry as to their causes. The next step was in quest of prophylactics and curatives. This sort of reasoning, of philosophy, was not obnoxious to the charge that Socrates brought against the philosophy of his day, namely, that it was concerned wholly with things that were of no benefit to any one and with problems to which no answer could be found.

It will scarcely be denied by those best qualified to judge that of the three learned professions that of medicine is still the best fitted to stimulate thought and investigation. It is less hemmed in by tra-

dition, and is of immediate public interest. The man who conquers a dangerous disease or who performs a difficult surgical operation needs no other endorsement. Unless he allows avarice to draw him into a practise more extensive than his constitution will bear, he will have a fair degree of leisure for liberalizing his mind by the study of subjects outside of his particular sphere. The history of modern times no less than that of antiquity offers many examples of medical men whose interests were almost coextensive with those of mankind. That the physician, the investigator, the philosopher and the *litterateur* may be happily blended in one person is finely illustrated by the latest, though it is to be hoped not the last, volume either of the man or of his kind, the 'Aequanimitas' of Dr. Osler.

No one who is acquainted with human nature will be surprised when he learns that the class of medical practitioners known as 'quacks' flourished among the comparatively enlightened Greeks of ancient times. Often, however, the quack is one who strives after results by a method that has been tabooed by the corporation to whose regulations it is assumed that he ought to have subscribed. Though he is an outlaw, before the tribunal of mortals he may be just as good as if he were an in-law. That mysterious and apparently inscrutable part of our being known as the nervous system has always presented problems which medical practitioners have been unable to solve. Why should not a faith-cure be as legitimate as any other cure, provided it is genuine? And there have been faith-cures time out of mind. When persons can not control their own imaginations, the task would seem to be doubly difficult for any one else. Often the most important part of the physician's business is to arouse in his patient the will to get well, and whatever will accomplish this can not be stigmatized as fraud. When hope is lost all is lost. I have known not a few persons who died because they did not want to live or were at least indifferent; and probably an equal number who materially lengthened their lives by the mere determination not to die. My attention was drawn to this phase of pathology many years ago by a curious incident that came under my observation when I was a mere lad. I did not hit upon the explanation until long afterwards. I have seen the same thing repeated many times since then. A vender of medicaments of his own concoction used to visit our neighborhood about twice a year. One day as he was driving along he began to feel unwell, and, contrary to the proverb that doctors never take their own medicines, picked from his chest a vial containing what he believed would afford him relief, and drank some of its contents without looking at the label. Having occasion shortly afterward to leave his wagon to visit one of his customers, it occurred to him that he had drunk from a bottle containing a strong poison. He at once began to feel very sick. A sort of stupor

seized him and he became so weak that he could hardly walk. As soon as he could get back to his medicine-chest he looked at his bottles again, when, to his great joy and greater relief, he found that he had taken just what he intended. The man declared afterwards that he believed he would have died if he had not had the means of ascertaining the facts in the case.

Though the ancients knew little of the structure of the nerves, they were well aware of the influence of the imagination as a therapeutic agency. The walls of many of their temples were covered with tablets and votive offerings in testimony of gratitude to the god by whom the sick were healed. Faith-cures and christian science are therefore by no means a new thing under the sun, but something very old under new names. Though the ancients rarely, or not at all, dissected human bodies, they had a fairly definite knowledge of anatomy derived from the inspection of brutes. The bony structure could be readily studied with the aid of the skeletons that were plentiful enough in countries dotted with battlefields. The Persian invasion alone probably left tens of thousands of corpses strewn along the retreat of the great king. The aversion to the dissection of cadavers that was felt by many of the Greeks seems to have been connected with their reverence for the human form. It was regarded as a sacrilege to mutilate even a corpse. The treatment which the dead body of Leonidas received at the hands of Xerxes was due, as Herodotus expressly informs us, to the extraordinary exasperation he felt against the Spartan king for his fierce resistance to the Persian advance. Though Achilles had dragged the dead body of Hector many times around the walls of Troy, yet Apollo preserved it uninjured. This reverence for the 'human form divine,' like many other superstitions, interfered seriously with the progress of science. The favorite gods, Zeus and Apollo, were represented as physically perfect men. The effects of this sentiment are especially evident in the manner by which those condemned to death were executed. There seems to be no other explanation of the singular custom of administering the hemlock juice than the desire to leave the body after death as nearly as possible as it appeared in its living state. That the rule was departed from under special circumstances and in times of great excitement is no valid argument against the correctness of the explanation.

According to Homer and Herodotus, the healing art was discovered or invented in Egypt. The Odyssey tells us that there every man is a physician skilled beyond human kind. Mention is also made of the many plants possessing medicinal properties. Oculists are said to have been particularly numerous, and many prescriptions for diseases of the eye have been found among the papyri. Artificial and gold-filled teeth have also been met with both in Egypt and in Etrurian

tombs. The practise of medicine was, however, purely empirical, and the rules followed in the treatment of particular diseases were often of great age. The second king of Egypt is said to have been a physician, and another is reported to have written a book on anatomy. The private physicians of both Cambyses and of Darius were Egyptians. The name of the latter brings to mind that of his son Artaxerxes whose private physician was a man of considerable importance in his day, outside of his profession. Ktesias was a native of Knidos, a contemporary of Hippocrates, and no doubt personally known to him. Here we have again the philosopher and the physician in the same person. After acquiring considerable reputation in his own country he had the misfortune to fall into the hands of the Persians. Subsequently he was introduced at court, which proved the beginning of his good fortune. After the battle of Cunaxa he healed the wound inflicted upon his master by the brother of the latter. Later he was employed on a diplomatic mission to his native land; and thus after an absence of seventeen years returned home about 398 B.C., to remain for the rest of his life. That he was well treated by the master whose slave he became, according to Persian parlance, and had abundant opportunities for study, is evident from the fact that he compiled a 'History of Persia,' a work in which he charged Herodotus with frequent falsehoods in what he relates about that country. His scholarly tastes are evinced by this extensive collection, as it must have been, since it was divided into twenty-three books. He also composed a small work on India and one on geography. He is not known to have left any medical writings, and his reputation for impartiality as a historian is not very good. Still it must be regarded as a great misfortune that his extant remains are so meager.

In later times many Egyptian physicians practised in Rome; for to have studied in the land of the Nile, or, still better, to have been born there, was regarded as a special recommendation. Here too magic formulas of all kinds were in frequent use, not only in the compounding of medicines, but in their application. According to Pliny cadavers were dissected by order of the Ptolemies for the purpose of studying fatal diseases. But it can hardly be inferred from this statement that anatomy was regularly pursued in this way, or that dissection was a common practise.

Pliny, who had no very high opinion of the medical fraternity for reasons that will appear farther on, makes the assertion that Rome managed to get along six hundred years without physicians. This is manifestly an exaggeration, since many Greeks professed the healing art in the imperial city much earlier than 150 B. C. But neither did Rome produce a philosopher in the proper sense of the term; certainly no man who loved wisdom for its own sake. The Romans were, how-

ever, an exceptionally healthy people, owing to their fondness for outdoor life. This is demonstrated by the rapidity with which they recovered from repeated disasters. Once in a while their capital was invaded by a contagious disorder, then all who could do so left it until the scourge had spent its force, when affairs resumed their natural channel. In fact this was the usual course everywhere until very recently, when the real nature of such diseases was discovered. The ancient Romans were also a singularly hard-headed and practical people; consequently they were almost entirely free from the long list of complaints that are more or less due to the uncontrolled or uncontrollable imagination. Shortly after the Punic wars, but especially under the empire when luxurious habits due to the influx of wealth from the east had debilitated the naturally robust constitutions of the higher classes, nervous disorders, along with many others, were inevitable. Then quacks, charlatans, medicasters, soothsayers, magicians, astrologers and what not found a ready market for their wares. They played upon the credulity of the populace and preyed upon their purses because there was money in both the playing and the preying. No small portion of them probably were shrewd enough to disguise some real medical knowledge under a mass of hocus pocus in order to influence the imaginations of their patients. Well might Ovid say as others had said before him—and since, too—*mundus vult decipi* (people like to be deluded). Physicians still give to their patients who insist ‘on taking something’ bread pills, colored water and other equally potent or impotent remedies. It would be manifestly unfair to charge a physician with dishonesty because he practises a harmless ruse upon a patient who can be helped in no other way so easily.

“Dismissing faith in the confused creeds of the heathen world, he reposed the greatest faith in the power of human wisdom. He did not know (perhaps no one in that age distinctly did) the limits which nature imposes on our discoveries. Seeing that the higher we mount in knowledge the more wonders we behold, he imagined that nature not only worked miracles in her ordinary course, but that she might, by the cabala of some master soul, be diverted from that course itself. Thus he pursued science across her appointed boundaries into the land of perplexity and shadow. From the truths of astronomy he wandered into astrological fallacy; from the secrets of chemistry he passed into the spectral labyrinth of magic; and he who could be skeptical as to the power of the gods was credulously superstitious as to the power of man.” Such are the thoughts that Bulwer-Lytton, in the *Last Days of Pompeii*, puts into the mind of one of his characters, the Egyptian Arbaces. The reasoning by which such men justified the employment of their superior knowledge and insight to dupe the credulous was half philosophy, half knavery. If a man is the possessor of power

unknown to the multitude except in its effects, why has he not the right to use it?—to use it first of all to enhance his authority and to draw from such authority the advantages that seem to him most desirable? We may well admit that a man of this stamp may have had an inward feeling akin to what we call conscience that would justify his attitude toward his fellows—yet he did not consider these Romans fellow men of his—but it was wholly of the intellect. Such a man is as much a philosopher as were the sophists of an earlier age, and, we may add, of our own day. They apprehend clearly certain superficial verities, but cease to inquire farther after they have discovered what they think needful and sufficient for their own aggrandizement. Far different was the class of witches, one of whom is introduced in the same novel. Against these Horace frequently raises his voice, as do also others of the rationalizing Romans. They are ignorant, and, in most instances, as much the dupes of their own juggleries as their victims. Every man who goes through the world with his mind alert can see specimens without especially looking for them. It is doubtful whether any man has ever lived who had not at least a modicum of superstition in him. However much we may know and however far we may be able to pry into nature in some directions, there are others in which our vision is barred and the unknown is literally within arm's length. The mystery of life and death has always been so profound, as it still is though in a different way, that we need not wonder at the strange aberrations which so many persons fell into, who were in most matters little likely to be carried away by delusions. Sleep, 'the twin brother of death,' has from time out of mind been regarded as an excursion into the realm of departed spirits. If, as many believe, our consciousness is never coextensive with our personality, there are yet many discoveries to be made not dreamt of in the philosophy of most of us. Our will as an integral part of ourselves is the resultant of so many forces and, with the majority, is so little under control of rational motives, that it often plays fantastic tricks, not before high heaven alone, but almost anywhere.

The will of each individual as modified, at least in action from moment to moment, is like a ball thrown into a grove. It strikes one tree, then another and another, and no one can predict with certainty where it will come to rest. This element of chance, of Tyche, in the affairs of men, this incalculable calculus of probabilities, pervades in a remarkable degree the literature of ancient Greece and Rome. It made many feel that, do what they would, they were doomed to be thwarted in their plans. It was only those who, like Socrates, Epictetus and a few others, maintained that the chief end of man is to be found in motives rather than in outward results, who were never thrown out of their philosophical poise by the strange vicissitudes of life.

It is a far cry from the Greeks to the Saracens, though farther in time than in space. Here we find philosophy, or rather metaphysics, and medicine more intimately associated than at any other time or among any other people. Every one of the ten or twelve men who became prominent in Arabian philosophy was a physician. In fact the Arabs treated philosophy as a branch of astronomy and the healing art. The latter served a practical purpose, as did also the former in so far as it was dealt with as astrology. Arab philosophy was, however, something very different from the science that bore the same name among the Greeks. They studied philosophy, or rather they philosophized, as a man would study navigation on a ship lying at anchor. Albeit they were in this respect at no greater disadvantage than the schoolmen. The one party was chiefly concerned to make any discoveries they might light upon harmonize with the Koran and Aristotle; the other with the Bible and Aristotle, with a little spice from Ptolemy thrown in. Al-kindî, the philosopher *par excellence* of the Arabs, flourished in the tenth century. He wrote on almost every imaginable subject from arithmetic to astronomy, though under the former he discusses the unity of God; his arithmetic was therefore something totally different from that which forms the schoolboy's triangle with readin' and 'ritin'. So far as is at present known all his works are lost, except those on medicine and astrology. Roger Bacon ranks him in some respects close to Ptolemy. Al-farabi was a contemporary of the preceding and is generally regarded as the earliest of the Arabian philosophers. However, medical science and even surgery could make little progress where the knowledge of human anatomy was so inadequate. The Koran denounces as unclean every person who touches a dead body, and an article of Mohammedan faith forbids dissection. We should remember, nevertheless, that the founder of anatomy, Vesalius, was sentenced to death by the Inquisition as a magician, and only pardoned on condition that he make a pilgrimage of penance to Jerusalem. This journey cost him his life. And it is probable that he would not have got off even on these relatively hard terms had he not enjoyed the favor of Philip II. of Spain, who esteemed him highly for his medical skill. We have the name of one Arab physician, Abdallatif of Bagdad, who was well aware that anatomy could not be learned from books, strange as it may seem that historians have thought it worth while to place to any man's credit a truth so easily apprehended. The same authority avers that Moslem doctors studied that branch of anatomy known as osteology by examining the bones of the dead found in cemeteries. Averroes of Cordova fills a large place in the history of Moorish philosophy in Spain about the middle of the twelfth century. But in medical renown he ranks far below Avicenna of Bokhara, who flourished about a century and a half earlier. He was teacher of both philosophy and medi-

cine in Ispahan. His medical works seem to have been the chief guide in this branch in Europe for almost five centuries; their sway was not broken until the beginning of the seventeenth century. It is strong and yet painful testimony to the inherent stupidity of mankind, physicians not excepted, that the doctrines of Avicenna are little more than what is found in Galen somewhat modified by Aristotle; and, as we have seen, Galen represents no great advance upon Hippocrates. Alas for the human race that it has always been so much easier to memorize than to think and to investigate! The medical science and practise of the Arabs was confined chiefly to surgery and the empirical treatment of internal diseases. There was no lack of victims in view of the constant wars in which the califs were engaged, and no lack of opportunity for the study of disease in its various forms in the hospitals which some of them founded in various parts of their domains.

Both medical science and philosophy, though not metaphysics, had run their course by the time the Alexandrian era opened. A not inconsiderable number of new facts were collected in Alexandria, but the ability or the will to arrange them into an orderly system was lacking; at least we must adopt this view with the scant evidence to the contrary before us. For more than a thousand years the one question asked was not, What does nature say? What are the facts in the case? but, What does the master say? Beginning with the first christian centuries, Europe and western Asia more and more became organized into a society to suppress the increase of knowledge. It would not be easy to say in which century this organization did the most effective work, though there is no doubt that its most effective instrument was the inquisition. As everybody knows, it was not theology alone that was conservative; law and medicine were equally so. Goethe pays his respects to this attitude of mind when he says in Faust:

Hear, therefore, one alone, for that is best, in sooth,
 And simply take your master's words for truth.
 On *words* let your attention center!
 Then through the safest guide you'll enter
 The temple-halls of certainty.

And again:

Prepare beforehand well your part
 With paragraphs all got by heart,
 So you can better watch and look
 That naught is said but what is in the book:
 Yet in this writing as unwearied be
 As did the Holy Ghost dictate to thee.

This conservatism was a characteristic of the times; the protestant revolution was hardly more than the beginning of a struggle for emancipation in a single direction. It did not enlarge the intellectual horizon of the lawyer or the physician. There is much evidence to show that

with the rise of the belief in witchcraft, medical science, using the term in a very loose sense, received a distinct check. What was the advantage of familiarizing one's self with the nature or usual progress of a disease if its course was constantly liable to be interrupted by the will of some malevolent being possessed of supernatural power? What was to be gained by administering remedies that might at any time be rendered nugatory by the same demoniacal interference? Those who embraced the new faith promulgated by Luther were in some respects worse off than those who clung to the old religion. While catholics and protestants alike believed in witches and other agents of the devil, the former had also their saints and the virgin, to whom they could appeal in time of temptation and distress and who were rarely appealed to in vain. For the latter, Satan and his emissaries were no less real; but he had given up his faith in the efficacy of the intercession of the saints and the virgin. His only resource, therefore, was to protect himself as best he might by dealing mercilessly with those who had anything to do with the black art.

The late Herbert Spencer is said to have reached the conclusion toward the close of his life that man is not a rational being. One can hardly help subscribing to this creed when he learns the attitude of the public toward medical practise. We can understand why there should be a great deal of hazy thinking in matters of law and theology, since they have to do with problems that are at best more or less abstract. But why the public should willfully shut its eyes to practical benefits in every-day matters, matters that so vitally concern its life and health, is hard to understand. Yet it is no harder to understand than why a stone will not of itself roll up hill. We can only realize this mental asphyxiation in the face of overwhelming evidence. It is explicable only from the standpoint of the universal belief in the utter powerlessness of man in the presence of the spirits that surround him and dwell within him. Though the scriptures have much to say about casting out devils, the belief in them is human rather than christian, since it is found among all the peoples of the globe, except among that small class who may be called rationalists; or who, if not themselves entitled to this designation, have inherited a rationalistic creed; for a rationalist is simply one who refuses to believe anything except on such evidence as his reason approves.

There are grounds for believing that Aristotle dissected human bodies; at least on no other grounds can his correct information with regard to certain points in anatomy be explained. But for prudential reasons he did not deem it wise to make public how this knowledge was obtained. Salerno seems to have been the first medical school in Italy outside of Spain, that is, the earliest in charge of christians, and the probability is that its origin has some connection with the Arab

domination. Bologna came into prominence in the thirteenth century and retained its preeminence for a long time. Here we have some definite statements by Mondino that he dissected several cadavers. But his writings also furnish the proof that he was not able to emancipate himself wholly from the authority of Galen and the Arabians. For some reason there were fewer obstacles in the way of the anatomist in Italy than in any other country in Europe; Berenger of Carpi is said to have performed more than a hundred dissections. In Italy too we meet with a number of names that are immortalized by their discoveries in the human body. The chief merit of Vesalius lies in the fact that he clearly recognized for the first time many of the errors that had come into current belief by the authority of Galen.

Hippocrates, Celsus, Galen, these three names sum up the science of ancient medicine; but the greatest of these is Hippocrates. It is perhaps not putting the case too strong if we say that they embrace substantially the entire healing art until not much over a century ago. The medical works of these three authors were printed in Italy before the end of the fifteenth century in Latin translations from the Arabic. This is striking testimony to the completeness of the rupture between ancient Greece and dawning era of modern times. When these Latin translations from the Arabic were made is not known; but it is known that they were very imperfect and that they were as blindly followed as were the writings of Aristotle. Galen's prestige was more due to his ambition and industry than to his individual merit. The great mass of medical knowledge was still accessible in manuscripts. This he carefully examined, and wrote comments upon much of it with remarkable discrimination for his age. Like Aristotle he would have been the first to repudiate the utterly senseless homage paid to his writings. One can not read the works of Hippocrates without being impressed with the extraordinary acumen of the man. Much that now passes current under his name is doubtless not genuine, in the strict sense of the word; but is at least evidence to the prestige of the master's name. The thinker constantly appears along with the practitioner. And we must always keep in mind that chemistry was unknown and the microscope non-existent. He tells us, among other things, that rain water is the purest, while ice and snow water are the worst for all purposes. He had carefully noted the radical differences between the people of Asia and of Europe, so far as he knew these parts of the world. What he says concerns the physician but little, the philosopher a great deal. He directly contravenes popular belief when he tells his readers more than once that there is no such a thing as a sacred disease; that no disorder is sent by a god, and that all ailments are due to natural causes. How heterodox this was may be seen by any one who reads the first book of the Iliad, where Apollo is repre-

sented as having sent a pestilence upon the Greek host. In his discourse on ancient medicine—a singular title for a book written more than four centuries before the christian era, whether by Hippocrates or some one else—we find the idea of the survival of the fittest clearly indicated; in fact, many of the Greeks had more than an inkling of it. His apprehension of gradual evolution is also shown by the assertion that the vegetables used for food are the outcome of experiments with coarser kinds and the deleterious effects upon the health of those that were rejected. He takes the ground that a man can not understand the medical art unless he knows, as far as that is possible, what man is. He holds that the physician should be skilled in nature; but what he defines as ‘nature’ is not cosmological, it is rather the etiology of disease and the laws of hygiene. He also speaks of the ‘common herd of physicians.’ Evidently professional pride is not the latest born of time’s offspring. Among the most interesting documents included among the writings of Hippocrates is the physician’s oath. While it may not have been formulated by the master, it undoubtedly represents the principles of his school. Thus early had Greek physicians formed themselves into a guild and pledged themselves to certain rules of conduct. These guilds were, however, not secret associations or fraternities and had no professional arcana different from those of the present day. The novitiate pledged himself to regard his teacher as equally dear with his own parents; to hold his sons in equal esteem with his own brothers; to teach them and his own sons the medical art without fee, if they desired to learn it; to keep aloof from whatever is detrimental to health; to give no deadly drug even when asked; to pass his life in purity and holiness; to abstain from any harmful act in whatsoever house he might enter for the benefit of the sick; to divulge no secrets connected with his professional practise, and to refuse to administer to any woman a drug that will produce abortion. It is evident from the oath here given in substance that the morals of the medical fraternity were, at least in theory, far in advance of those of the general public and of many well-known philosophers by profession.

SOIL FERTILITY.

By J. B. DANDENO,

MICHIGAN AGRICULTURAL COLLEGE.

PROBABLY the most important single problem which confronts the farmer to-day is that of the conservation of the fertility of the soil. Fertility may be defined as that condition of the soil which yields the maximum of that material which the plant is capable of using for the best development of those qualities which the farmer desires. Strange as it may seem, just wherein this fertility consists is not yet fully known. Some years ago it was well known, that is to say, it was thought, that all that could be said had been said about it. At the present time, the more thoughtful and cautious among those studying the question of plant growth from a scientific standpoint are by no means settled upon the point. They recognize that there is yet much to be cleared up in regard to it, especially from the physical and the bacteriological sides. The question may be examined from the *chemical*, *physical*, *bacteriological* and *ecological* standpoints.

Much has been done in the chemical laboratory—too much, in fact, judging by the results obtained. It was thought that a knowledge of the chemical composition of the soil was the key to the solution of the problem. But it has never been decided just what the chemical composition should be to produce the best results, for the simple reason that it is not known exactly what the requirements of the plants are. Nor does a chemical analysis of the plant itself answer the question. There are certain elements which are no doubt necessary for proper growth, but the analysis of the content of the plant and of the soil does not give a very complete notion of the proper conditions under which certain substances should exist when in the soil. The chemical analysis of soils and fertilizers, though not without considerable importance, is now being relegated to the background in comparison with the physical and the bacteriological conditions. The so-called perfect fertilizers, as sold on the market to the farmer, have been looked upon with some distrust, mainly because they have not produced the results in the production of crops which might be expected from the chemical standpoint. The farmer becomes skeptical and again and again sends samples to the chemist to see if the materials have the proper chemical constituents. The chemist finds it all right, and it *is* all right from his point of view, but to the farmer the results are still unsatisfactory. It is as much to the futile results of the chemical analyses of soils and

fertilizers as applied to the growing of crops as to any other single thing that farmers have been so hostile to 'scientific' farming and to scientific agricultural institutions.

The physical conditions of the soil in regard to fertility are as important perhaps to the farmer as all the others put together, because they are more directly under his control. Yet this has never been fully understood by the farmer, nor has it been developed with agricultural students as it should have been. *Air* and *moisture* are the two most important substances in the soil. The conservation of these and the bringing of them to the roots of the plants is, therefore, one of the chief problems. It is merely the management of these two substances, for they are always present, that the farmer should concern himself with. Timely and suitable cultivation, then, for the development of crops is of the highest importance. Indeed, manuring of soil resolves itself largely into a question of supplying moisture and placing soil in such a condition that the air and moisture are in the best situation for use by the plant. In fact, when a farmer plows under a crop of rye he does not add any material to the soil excepting what the plant obtained from the air, and this is *always* available from the air. The other substances contained in the rye are simply restored to the soil. There is no addition. The rye is, therefore, not a manure in the proper sense, but a means by which the farmer improves the physical conditions.

It is not difficult to see, therefore, that the artificial manures in powder form can not contribute to any very great extent to fertility, if fertility is so largely a physical question. There are conditions of soil, such as size, shape and arrangement of particles, which have to do directly with the air and the water content. The arrangement of the particles can be controlled largely by the farmer.

There is one other force called physical affinity, which is of the highest importance because it is largely through the interaction of this force among the various substances in the soil that plants are capable of extracting solids in solution from it. This physical affinity is exercised among the various soil constituents, each one exerting an influence over the others. Now, if some substance (not in the soil) be added to it, the whole equilibrium may be disturbed by the affinity this may have for the substances already there. A chemical analysis can not determine this. The soil yields up to chemical analysis all that it contains, no matter what the relationship may be among the constituents. To the plant, however, which depends upon a form of physical affinity for its soil food, all the soluble substances will probably not be given up. Therefore, it is a question of physics, as well as one of chemistry, which will determine soil fertility.

When the farmer summer-fallows a field he does not add anything directly by the way of a fertilizer to the field, yet it is much more fertile the year after the summer-fallowing has been done. One benefit of

this operation is the clearing the field of weeds, but, aside from this, the soil is much more productive and, it may be said, more fertile. What is done to the soil in the process of cultivation is to break up the lumps and allow the air to permeate freely, to retain the moisture by making the surface portions fine and porous, thus acting as a 'Campbell blanket,' to mix so thoroughly that the physical affinity of the soil substances becomes changed, the soil being renewed to a very large extent. In this way a farmer can control the fertility without adding any fertilizer. Similar to this is the case already mentioned where the farmer plows under a field of rye. He increases the fertility without adding any fertilizer.

Land should never be allowed to bake or become hard on the surface. If so, air is kept from the roots of the plants. Baking of the soil can be largely controlled by the farmer with certain crops. It occurs, more or less, after rain, depending upon the character of the soil. This crust should be broken up, and kept broken up, by cultivation. In hoeing weeds a man is fertilizing the soil. Weeds, therefore, may be of considerable indirect benefit.

The fable of the farmer dying when on the point of revealing great hidden treasure to his sons illustrates the point. When about to die he told his sons that immense treasure lay buried in the ground on the farm, but death came just before he was able to tell the exact spot. His sons then dug through every inch of soil, over and over again, with the greatest diligence, but did not find any such treasure as they expected to find. The result, however, of such thorough digging was great abundance in the crops. They really did unearth the treasure, but in a far different way from that which they expected.

The bacterial content plays also a very important rôle in the process. Comparatively little is known in regard to the interrelationship existing among these organisms, and of their relations with plants. The processes of nitrifying and denitrifying are in themselves important, but these are probably only an extremely small part of the bacteriological question. And chemical analysis of soils does not throw much light upon it. It is a more complicated problem than a mere chemical one.

Root-tubercles and their production, although a bacterial proposition, require, because of their importance, special mention. The organism which produces the tubercle is capable of extracting nitrogen from the air and rendering it available for the plant upon which the nodule is produced. And these nodules are capable of being produced on many plants of the 'bean' family, such as clover, alfalfa, peas, vetches and the like. The cultivation of such crops, therefore, is productive of additional fertility in nitrogen. The soil, of course, should contain the bacteria peculiar to the plant upon which they work. The soil may contain them already; if not, it should be inoculated. Each farmer,

however, should determine for himself whether his soil needs inoculation. The test is the formation of nodules on the roots. Nodules are more likely to occur on poor soil, especially if it be of a sandy character. If the roots of clover are found to possess nodules, then there is no need of inoculation for that form which grows upon clover. It is similarly true with peas, vetches, alfalfa and the like. The farmer can decide the matter for himself before he makes any outlay for material for inoculation purposes.

It should be said, however, that there is much experimental work yet to be done to show in how far such plants as soy beans enrich the ground for succeeding crops. Some contend that the results are disappointing, especially in the case of the soy bean which produces so large tubercles and in such quantity.

With respect to the ecological aspect of the question it may be said that the growing of mixed crops, cover crops, rotation of crops, and the problem of weeds enter largely into the subject. This involves the relationship existing among different species and the soil conditions. This is comparatively a new aspect of crop conditions, for very little has been done to establish any definite results, although for many years it has been suspected that one plant might exert some injurious or beneficial effects upon others in the same soil, apart from the physical conditions arising out of the relationship. It is quite commonly known that on the ground under trees certain plants will not thrive, for some reason or other, aside from the injury produced by the shading. The tree seems to produce an effect upon the soil injurious to that particular plant. Just how different species of plants react upon one another when growing in the same soil, whether in an injurious manner or not, and just how they affect the soil for a succeeding crop are questions full of promise.

It has recently been asserted that certain parasitic *Mucors* (molds) are capable of doing what the bacteria of the root-tubercles do for those leguminous plants upon which they work. And the suggestion has also been offered that some *Mycorrhizas* (root fungi) may serve the office of adding to the available nitrogen supply of the soil. And this may account for the immense growth of pine on sandy barren soil. The *Mycorrhizas* do serve the function of root hairs, and they may also take the place of the bacteria of the root-tubercles in supplying nitrogen to the host plant.

Soil fertility, then, is not so much a chemical as it is a physical bacteriological and ecological problem. So, whether the soil contain phosphorus, nitrogen, sulphur, potassium, calcium and other elements is not of so much importance as *how* it contains them, and what relationship they have to water, air, to one another, to the soil particles and to the bacterial content of the soil.

SOME OF THE LOCALITIES IN FRANCE AND ENGLAND
WHERE MONUMENTS OF THE LATE STONE AND
BRONZE AGES HAVE BEEN FOUND.

BY J. HOWARD WILSON,
COLUMBIA UNIVERSITY.

AS we pass from the earlier periods into the neolithic, the culture and modes of life of our ancestors become more varied and complex; the weapons, implements and ornaments are found in greater number and in almost universal geographical distribution and exhibit an ever increasing diversity of form and perfection of workmanship. All these characters are still more pronounced at the beginning of the bronze age, which is comparatively close to the first confines of the historic period. In the later prehistoric times, the developing culture and, in a measure, civilization, made such progress and became so diversified as to require their division and classification into different groups, each of which demands special study.

In the present brief paper, I have confined myself to a short account of the stone monuments of the late stone and bronze ages, which are found in many parts of the world, and furthermore have restricted it to some of the most famous groups in northern France and southern England.

There would seem to be no well-defined law in regard to the general distribution of the prehistoric stone monuments. They are found all over Europe and Asia, as well as in other parts of the world; at high altitudes above the sea in interior mountain districts, as well as in low lying lands so close to the sea as to be drenched with spray in storms. But the greatest known groups are found, curiously enough, within or near the region which has furnished the most numerous evidences of paleolithic man. This fact may be a mere coincidence and not possessed of any especial significance.

At Carnac, in Brittany, and in the neighboring region is the greatest group in the world of these stone monuments. In one field at Carnac, in eight or more parallel rows, are over 1,100 standing stones or menhirs, while two other groups near-by furnish similar numbers, besides a great number of dolmens with stone-circles and tumuli. On Wiltshire Downs there are said to be over 1,000 tumuli, which, although at first sight seem to be mere mounds of earth, are really megalithic monuments in their more complete form. On Salisbury

Plain is the perfect and well-known monument of Stonehenge, with over three hundred tumuli within a radius of three miles. A few miles further north is the great temple of Avebury, which Sir John Lubbock calls the greatest of all so-called Druidical monuments, and which he says, quoting from Aubrey, 'did as much exceed Stonehenge as a cathedral does a parish church.' Here, originally, were 650 great standing stones, although at present not more than 20 have been left in place, while near by, belonging to the great monument of Avebury.



AVEBURY CIRCLE, WILTSHIRE.

is Silbury Hill, 130 feet high and covering five and one half acres, the largest artificial mound in Europe.

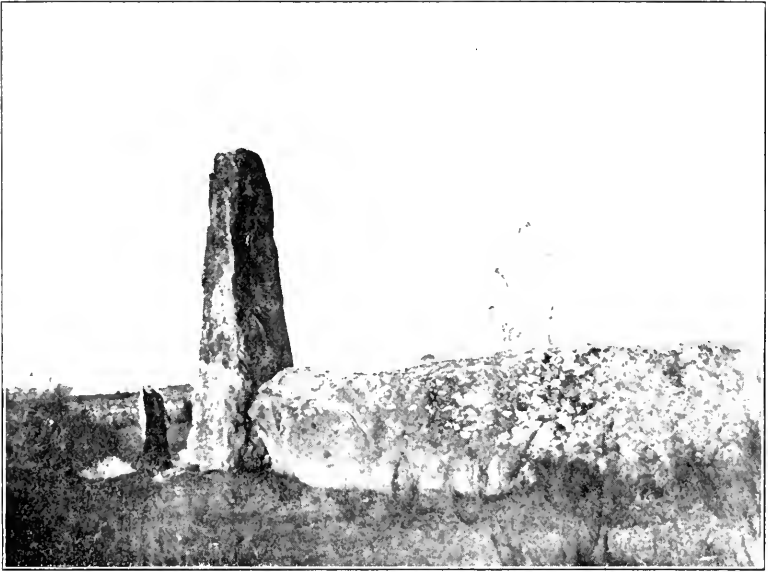
The monuments of Europe have been divided into nine classes, if we follow the classification given in Brittany.

1. Menhirs, meaning, in Breton, 'long stones,' single untrimmed stones placed upright.

2. Alignments, groups of menhirs placed in one or several lines.

3. Lechs, menhirs which have been trimmed, having generally engraved crosses upon their sides, and which are so comparatively recent as to be hardly worthy of consideration as compared with the other prehistoric monuments.

4. Cromlechs, meaning 'circle places,' groups of menhirs arranged to form circles; although in England this term is erroneously used to denote a dolmen or other stone monument.



MENHIRS, NEAR CARNAC, BRITTANY.



DEVIL'S DEN, NEAR AVEBURY, WILTSHIRE.

5. Dolmens, signifying 'table stones,' consisting of a number of menhirs called supports, placed close together to form a rectangle, open at one end and covered by one or more table stones.

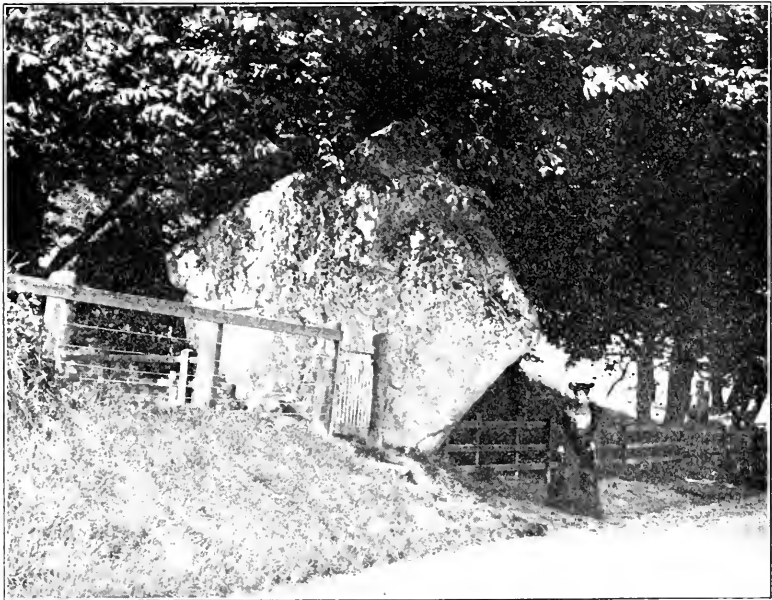
6. Covered passages, two lines of parallel menhirs or supports covered by table stones.

7. Stone cists, composed of flat stones forming small closed chambers in the nature of stone coffins.

8. Tumuli, artificial mounds of earth called in England 'barrows,' either oblong or round.

9. Galgals, artificial mounds formed of small stones.

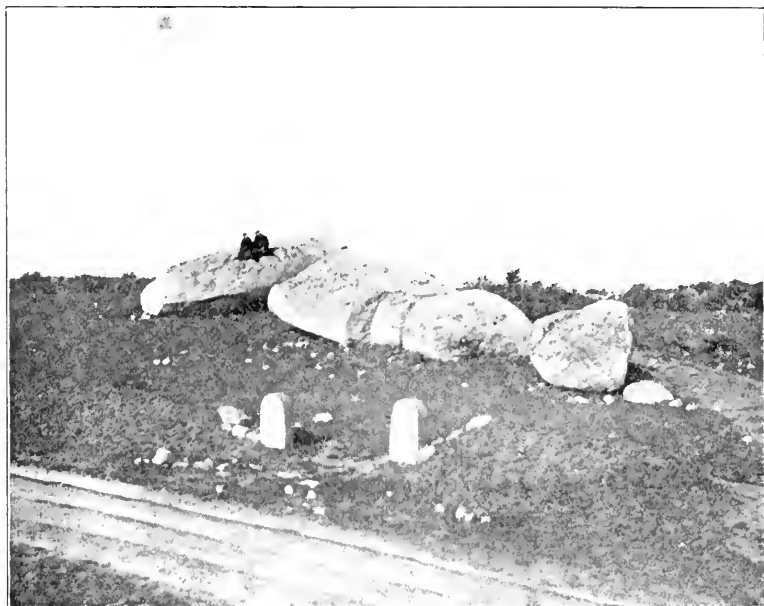
The single standing stone or menhir is probably the oldest form



MENHIR, AVEBURY CIRCLE, WILTSHIRE.

of all these monuments. Very rude peoples would soon naturally employ it for purposes of designation—to mark the grave of a chief or a spot become in some way sacred or important. Then a slab was placed across two or more uprights when an interment took place, and we have the beginning of the dolmen, which later developed into a more or less elaborate chamber, with or without vestibule or covered passage leading to it or auxiliary chambers connected with it; and finally the whole became covered with a mound of earth or small stones, and may have been surmounted by a menhir.

It has been said that the complete megalithic monument consisted of a stone chamber or dolmen covered with a mound, and the whole



THE GREAT MENHIR, LOCKMARIQUER, BRITTANY.

surmounted by a menhir. In Brittany always, and probably generally, if not always, elsewhere, the dolmen was covered with a mound of earth or small stones. Those dolmens which stand exposed have probably had the earth removed by natural or artificial agencies. In Brittany many of the dolmens show no trace of mounds, standing bare upon the surface of the ground; but it is known that the soil has been removed by the peasants to spread upon their fields, the soil in this part of France being scanty, and the mounds furnishing an available supply. Many of the dolmens and covered passages are still partly underground, the whole of the tumuli not having been removed.

The menhirs vary greatly in size, from a small stone, not over two feet high, to larger ones many times that dimension, and weighing many tons. The greatest of all menhirs is the 'Great Stone' or 'Grand Menhir' at Locmariaquer, in Brittany. It is no longer standing, and is broken into several pieces, but was 70 feet high and weighed 300 tons.

The lechs are considered to be comparatively recent, for all these stone monuments, even in the same region, do not belong to the same period, some dating as far back as the stone age, while others can claim no greater antiquity than the age of bronze or even than a still later time.

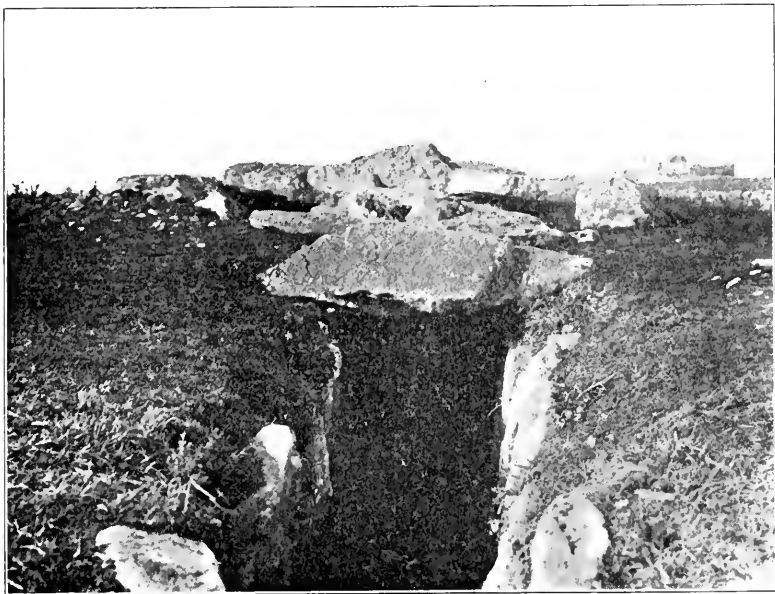
The dolmen may be a simple chamber or a number of connecting chambers, and may open directly or may be preceded by a gallery or covered passage of varying length, but it is always open at one end.

The covered passage or *allée couverte* may terminate in a small chamber, made by partitioning off the end of the passage by means of one or more menhirs or supports, so that there would seem to be no sharp line of distinction between the dolmen and the covered passage, each perhaps at times being a modification of the other.

The dolmen seems to be always sepulchral and, as the final resting place of the earthly remains of a chief or a line of important rulers, it must have been regarded as sacred and an object of veneration. At all events it was covered with an elaborate tumulus.

The stone cist appears to be, as a rule, of later age than the dolmen, but was likewise the receptacle of the remains of the dead and was covered with a tumulus or galgal. The great tumulus of Mont Saint Michel at Carnac, which in its eastern part seems to be composed of small stones and thus to be in the nature of a galgal, contains a number of dolmens and stone cists or cists-veu, as they are called in Brittany. A tunnel which has been driven near the base at the eastern end for the purpose of exploration has brought to view dolmens and stone cists with their contents of human bones, ashes, stone implements and ornaments, including some jadeite axes and a collar of white pearls.

The alignments seem to have more of a religious than a mortuary significance, and are associated with the cromlechs or stone circles. The great circular temple of Avebury in England had originally a double row of menhirs leading away from it on two opposite sides.



DOLMEN, AT LOCKMARIAQUER, BRITTANY.

But it is in Brittany, in the region about Carnac, that are found the greatest parallel rows of menhirs with their associated cromlechs. They have here a general east and west alignment. It seems probable that originally the alignments always terminated in a cromlech, or were connected or associated with one in some way, but at present often a trace only remains of the cromlech and even this may be lacking.

The field of Ménez contains 1,100 of these great stones arranged in 11 lines and terminating at their western extremity in a cromlech composed of 70 menhirs. In the field of Kermario are 982 menhirs in ten rows, the largest of the stones being about 20 feet high. The field of Kerlescan contains a rectangular cromlech or quadrilateral of



ALIGNMENTS NEAR CARNAC, BRITTANY.

39 menhirs, with 579 menhirs in 13 lines. At Erdeven, a few kilometers to the west, are the alignments of Kerzchro, composed of 1,129 menhirs in 10 rows. At right angles to these, and extending in a northerly direction, is a line of 23 menhirs, the largest being 18 feet high, which may possibly be the remnant of a great cromlech. Besides these great groups, near Carnac are numerous others of less importance either connected with these or occupying independent positions, while all about are scattered innumerable menhirs and dolmens, including some magnificent specimens, with occasional tumuli and other monuments.

Excavations and explorations made about the alignments and cromlechs have yielded practically nothing in the way of relics, save a few

fragments of stone implements and pottery and some Gallo-Roman objects, all of which have been probably lost or accidentally introduced into the soil near the monuments. These monuments then are apparently not tombs nor in any way sepulchral. There would appear to be little doubt that the alignments and cromlechs are a sort of temple, the alignments with the avenues between being comparable to the columns and the aisles of a cathedral, and the cromlech at the end to the altar or inner sanctuary.

At Avebury and Stonehenge the interments have been made in barrows near the cromlechs; within three miles of Stonehenge, as has been mentioned, are over three hundred of these barrows, which have



MENHIRS, AVEBURY CIRCLE, WILTSHIRE.

yielded interesting relics to the excavations and efforts of investigators. The cromlechs themselves, here as elsewhere, are evidently temples. There seems to be no trace of any alignments at Stonehenge, but in their place is the double circle, the inner composed of smaller stones being considered the original, and the outer and more striking, much more recent. Avebury had originally two double rows of menhirs leading to it from opposite sides, but few of these stones now remain. Avebury differs from Stonehenge and the cromlechs of Morbihan in several important particulars. It consists mainly of a great circular earthwork within which is a ditch or sort of dry moat, containing twenty-eight and one half acres. Inside the ditch was the principal



ENTRANCE, TABLE DES MARCHANDS, LOCKMARIAQUER, BRITTANY.

circle of great stones, while within the area enclosed were two small circles formed with a double row of smaller stones.

Occasionally the interior surface of a support in some dolmen or covered passage is found to be engraved with curious figures. Generally, they seem to be circles or some form of curved lines, and at times there is a figure representing the stone celt,* which was an object of veneration even after it ceased to be employed as a tool or weapon. Some of the best examples of these are in the famous dolmen on the island of Gavrinis at Locmariaquer.

The meaning of these curious circles and curves has never been explained. They are probably symbolical or the characters used to denote some definite idea among the people who made them, or may be simply decorative, although this latter interpretation I believe to be far less probable. Certain linguists have at times claimed to see in some of them modifications of hieroglyphics or letters of ancient languages. A controversy has arisen as to the nature of the instrument

* The figure of a celt is engraved on the under surface of the cap stone of the dolmen Table des Marshands.

employed to cut these characters into the faces of the hard rocks. Some archeologists claim that the work could not possibly have been done without the use of metal tools; others assert as positively, and apparently prove their case, that the engraving could have been done by means of stone engravers alone. A determination of this question would shed a certain amount of light upon the age of these monuments, especially as to the age of the particular ones bearing these characters, but this question is unimportant, their antiquity as a whole or as to type being determined in other ways.

Of course, many interesting legends have grown up in regard to these mysterious monuments of the past which are still believed in by



TABLE DES MARCHANDS, LOCKMARIAQUER, BRITTANY.

the superstitious peasants. In regard to a group of menhirs in the western part of Brittany near the coast, it is claimed that every one hundred years on St. Sylvester's Eve, the great stones rush down to the sea for a drink of the salt water, and while they are gone, one may find untold treasures of gold and precious stones in the hollows over which they stood. But woe to the over-covetous, who in greed for more delays too long, and is crushed by the great stones on their return. There is a legend also in regard to the origin of the marvelous alignments of Carnac. It seems that a saint was being hunted down by the pagans, and reaching the sea, could go no further. He turned and invoking his miraculous powers stretched forth his hand and turned them into stone.. Another version makes them Roman soldiers in line



DOLMEN, NEAR CARNAC, BRITTANY.

of battle, but why so many were needed to overcome one poor saint is not stated. Old customs and superstitions cling long to a rude uncultured people. They change slowly. While accepting the new ideas or religion, they do not give up the old. Both may flourish side by side.

Some of the stone monuments of Brittany were probably reared or constructed as late as the christian era. As late as the time of Gregory of Tours, the worship of stone monuments was still so prevalent as to call forth an edict of the church putting under a ban all who persisted in still adhering to it, while in some of the remote valleys of the Pyrenees, according to some of the best authorities, the worship of stone exists at the present day.

There seems to be considerable evidence that the people who built Stonehenge and Avebury and erected the menhirs and alignments of Brittany were sun-worshippers, and while a monolith or megalithic monument may have been regarded with veneration and worshipped itself, originally it was simply the symbol and representative of something greater. These customs would not die out easily among a rude clannish people even after the introduction of Christianity, and furthermore, we are all sun-worshippers more or less.

The age of these marvelous and mysterious monuments can not be told in years, but in a more general way. They are not all of the same age; some date as far back as the Neolithic period, many belong to the age of bronze, while others are as recent as the christian era. Since

some of these stones in Brittany were put in place, there has been a noticeable subsidence of the coast, so that now some are only revealed at low tide. On the island of ErLANIC in the Gulf of Morbihan is half of a cromlech; the other half with the whole of another circle tangent to the first is under water. But this subsidence of the land since these monuments were built would not necessarily indicate any great antiquity, for appreciable movements of the earth's crust, producing changes in level, have taken place in this region in comparatively recent times.

Most of the monuments of Brittany, with the exception of the lechs, which are known to be comparatively recent, seem to be of unhewn stone and many undoubtedly belong to some part of the Neolithic period, while others belong to the bronze. Stonehenge has been satisfactorily determined to belong to the bronze age, from its apparent association with the barrows which surround it. An examination of many of these barrows has revealed many bronze instruments and ornaments and determined them as belonging to that age. Avebury is probably much older, consisting entirely, besides the earthwork, of unhewn menhirs, while almost all the stones of Stonehenge are trimmed and squared, and the great outer circle is furnished with oblong, squared capping stones. And more than this, the capping stones dovetail into each other and are secured on their supports by means of hollows on their under surfaces fitting over bosses on the supports.



DOLMAN, NEAR CARNAC, BRITTANY.

Before closing this brief paper, it is interesting to note the engineering problem presented by the capping stones, both at Stonehenge and on the dolmens. How were they placed in position? They could hardly have been slid into position without overturning the supports. It would seem as if they must have been lowered from above or else that the supports were buried to their tops until the table stones were placed in position, and then dug out. The erection of the great menhirs presents a similar problem. Those who placed them in position may have resorted to the inclined plane, rolled them up and then tilted them over the vertical edge. The placing in position of these table stones, which often weigh many tons, as well as the erection of the great menhirs, certainly required a considerable amount of engineering skill, and we are here, as well as when confronted by the great feats of other ancient peoples, somewhat surprised at the early date at which it made its appearance. The tourist, scientist or archeologist, in viewing the great monuments in Wiltshire and in Morbihan, can hardly fail to be impressed by the magnitude of the works undertaken and completed in these prehistoric times, nor can the observer overlook their significance in regard to the lives and culture of the builders.

THE VALUE OF NON-EUCLIDEAN GEOMETRY.

BY PROFESSOR GEORGE BRUCE HALSTED,

KENYON COLLEGE, GAMBIER, OHIO.

Among conditions to a more profound understanding of even very elementary parts of the Euclidean geometry, the knowledge of the non-Euclidean geometry can not be dispensed with.—E. Study.

ELEMENTARY geometry has been the most stable part of all science. This was due to one book, of which Philip Kelland says:

It is certain, that from its completeness, uniformity and faultlessness, from its arrangement and progressive character, and from the universal adoption of the completest and best line of argument, Euclid's Elements stand pre-eminently at the head of all human productions. In no science, in no department of knowledge, has anything appeared like this work: for upwards of 2,000 years it has commanded the admiration of mankind, and that period has suggested little towards its improvement.

In all lands and languages, in all the world, there was but one geometry. For the abstractest philosophy, for the most utilitarian technology, geometry is of fundamental importance. For education it is the before and after, the oldest medium and the newest; older, more classic than the classics, as new as the automobile. The first of the sciences, it is ever the newest requisite for their ongo. Says H. J. S. Smith:

I often find the conviction forced upon me that the increase of mathematical knowledge is a necessary condition for the advancement of science, and, if so, a no less necessary condition for the improvement of mankind. I could not augur well for the enduring intellectual strength of any nation of men, whose education was not based on a solid foundation of mathematical learning, and whose scientific conceptions, or, in other words, whose notions of the world and of the things in it, were not braced and girt together with a strong framework of mathematical reasoning.

Of what startling interest then must it be that at length this century-plant has flowered, a new epoch has unfolded. How did this happen? Euclid deduced his geometry from just five axioms and five postulates. These were all very, very short and simple, except the last postulate, which was in such striking contrast to the others that not its truth, but the necessity of assuming or postulating it, was doubted from remotest antiquity. The great astronomer Ptolemæos (Ptolemy) wrote a treatise purporting to prove it, and hundreds after him spent their brains in like attempts. What vast effort has been wasted in this chimeric hope, says Poincaré, is truly unimaginable!

This most celebrated, most notorious of all postulates, Euclid's parallel-postulate, is not used for his first 28 propositions. When at length used, it is seen to be the inverse of a proposition already demonstrated, the seventeenth, as Proklos remarked, therefrom, according to Lambert, arguing its demonstrability. Moreover, its one and only use is in proving the inverse of another proposition already demonstrated, the twenty-seventh. No one had a doubt of the necessary external reality and exact applicability of the postulate. The Euclidean geometry was supposed to be the only possible form of space-science; that is, the space analyzed in Euclid's axioms and postulates was supposed to be the only non-contradictory sort of space. Even Gauss never doubted the actual reality of the parallel-postulate for our space, the space of our external world, according to Dr. Max Simon, who says in his 'Euclid,' 1901, p. 36:

Nur darf man nicht glauben, dass Gauss je an der thatsächlichen Richtigkeit des Satzes für unsern Raum gezweifelt habe, so wenig, wie an der der Dreidimensionalität des Raumes, obwohl er auch hier das logisch Hypothetische erkannte.

But could not this postulate be deduced from the other assumptions and the 28 propositions already proved by Euclid without it? Euclid had among these very propositions demonstrated things more axiomatic by far. His twentieth, 'Any two sides of a triangle are together greater than the third side,' the Sophists said, even donkeys knew. Yet, after he has finished his demonstration, that straight lines making with a transversal equal alternate angles are parallel, in order to prove the inverse, that parallels cut by a transversal make equal alternate angles, he brings in the unwieldy assumption thus translated by Williamson (Oxford, 1781):

11. And if a straight line meeting two straight lines makes those angles which are inward and upon the same side of it less than two right angles, the two straight lines being produced indefinitely will meet each other on the side where the angles are less than two right angles.

This ponderous assertion is neither so axiomatic nor so simple as the theorem it is used to prove. As Staeckel says:

It requires a certain courage to declare such a requirement, alongside the other exceedingly simple axioms and postulates.

Says Baden Powell in his 'History of Natural Philosophy,' p. 34:

The primary defect in the theory of parallel lines still remains.

This supposed defect an ever renewing stream of mathematicians tried in vain to remedy. Some of these merely exhibit their profound ignorance, like Ferdinand Hoefler, who in his 'Histoire des Mathématiques,' Paris, 1874, p. 176, says:

Certain defects with which Euclid is reproached may be explained by simple transpositions. Such is the case of the Postulatum V.

He then proceeds to misquote it as follows:

Si une droite, en coupant deux autres droites, fait les angles internes inégaux, ou moindres que deux angles droits, ces deux droites, prolongées à l'infini, se rencontreront du côté où les angles sont plus petits que deux droits; and continues,

It is certain that, placed after the definitions, this Postulatum is incomprehensible. But, placed after Proposition XXVI. of the first book, where the author demonstrates that 'if the interior angles together equal two right angles, the lines will not meet,' it acquires almost the evidence of an axiom.

The XXVI. is, of course, a mistake for XXVIII.

Other mathematicians have tried to turn the flank of the difficulty by substituting a new definition of parallels for Euclid's.

Eu. I., Def. 35, is: 'Parallel straight lines are such as are in the same plane, and which being produced ever so far both ways do not meet.'

On this Hobbs petulantly remarks:

How shall a man know that there be straight lines which shall never meet, though both ways infinitely produced?

The answer is simple: Read Eu. I., 27, where if the straight line be infinite, is proven that those making equal alternate angles nowhere meet.

Wolf, Boscovich and T. Simpson substitute for Euclid's the definition: 'Straight lines are parallel which preserve always the same distance from each other.' But this is begging the question, since it assumes the definition, 'two straight lines are parallel when there are two points in the one on the same side of the other from which the perpendiculars to it are equal,' and at the same time assumes the theorem, 'all perpendiculars from one of these lines to the other are equal.'

Just so the assumption that there are straights having the same direction is a *petitio principii*, since it assumes the definition of Varignon and Bézout, that 'parallel lines are those which make equal angles with a third line,' and at the same time assumes the theorem that 'straight lines which make equal angles with one given transversal make equal angles with all transversals.'

Other and more penetrating geometers have proposed substitutes for the parallel-postulate. Of these the simplest are Ludlam's: 'Two straight lines which cut one another can not *both* be parallel to the same straight line,' and W. Bolyai's 'Any three points are costraight or coneyelic.'

But the largest and most desperate class of attempts to remove this supposed blemish from geometry consists of those who strive to deduce the theory of parallels from reasonings about the nature of the straight line and plane angle, helped out by Euclid's nine other assumptions

and first twenty-eight propositions. Hundreds of geometers tried at this. All failed. That eminent man, Legendre, was continually trying at this, and continually failing at it, throughout his very long life.

Naturally, some very respectable mathematicians were deceived.

The acute logician, De Morgan, accepted and reproduced a wholly fallacious proof of Euclid's parallel postulate, recently republished as sound by the Open Court Publishing Company, Chicago, 1898. A like pseudo-proof published in *Crelle's Journal* (1834) trapped even our well-known Professor W. W. Johnson, head mathematician of the U. S. Naval Academy, who translated and published it in the *Analyst* (Vol. III., 1876, p. 103), saying:

This demonstration seems to have been generally overlooked by writers of geometrical text-books, though apparently exactly what was needed to put the theory upon a perfectly sound basis.

But a more recent, a veritably shocking, example is at hand. On April 29, 1901, a Mr. Israel Euclid Rabinovitch submitted to the Board of University Studies of the Johns Hopkins University, in conformity with the requirements for the degree of doctor of philosophy, a dissertation in which, after an introduction full of the most palpable blunders, he proceeds to persuade himself that he proves Euclid's parallel postulate by using the worn-out device of attacking it from space of three dimensions, a device already squeezed dry and discarded by the very creator of non-Euclidean geometry, John Bolyai. And his dissertation was accepted by the referees. And since then Dr. (J. H. U.) Israel Euclid Rabinovitch has written, March 25, 1904:

As to Poincaré's assertion about the impossibility to [sic] prove the Euclidean postulate, it is no more than a belief—though an enthusiastic one [sic]—never proved mathematically, and in its very nature incapable of mathematical proof.

Poincaré is undoubtedly a great mathematician, perhaps the greatest now living; but his assertion of his inmost conviction, no matter how strongly put, can not pass for mathematical truth, unless mathematically proved.

His conclusion—shared also by many another noted mathematician as well as by the founders of the non-Euclidean geometries—can only be based on the fact of the existence of these last geometries, self-consistent and perfectly logical. But this is a poor proof of the impossibility to [sic] establish the Euclidean postulate.

If space is regarded as a point-manifold, it is Euclidean, and the postulate can be proved as soon as we are allowed to look for its establishment in three-dimensional geometry.

The two-dimensional elliptic geometry described by Klein, Lindemann and Killing, according to my opinion, is an absurdity for a point-space in the ordinary sense of the term.

Poincaré says that all depends upon convention. But still he deduces from this the perfectly gratuitous conclusion that therefore the parallel-postulate can not be proved.

Alongside this modern instance, too pathetic for comment, we may, however, be allowed to quote what one of the two greatest living mathematicians, Poincaré, says in reviewing the work of the other, Hilbert's transcendently beautiful 'Grundlagen der Geometrie,' itself an outcome of non-Euclidean geometry:

What are the fundamental principles of geometry? What is its origin; its nature; its scope?

These are questions which have at all times engaged the attention of mathematicians and thinkers, but which took on an entirely new aspect, thanks to the ideas of Lobachevski and of Bolyai.

For a long time we attempted to demonstrate the proposition known as the *postulate of Euclid*; we constantly failed; we know now the reason for these failures.

Lobachevski succeeded in building a logical edifice as coherent as the geometry of Euclid, but in which the famous postulate is assumed false, and in which the sum of the angles of a triangle is always less than two right angles. Riemann devised another logical system, equally free from contradiction, in which the sum is, on the other hand, always greater than two right angles. These two geometries, that of Lobachevski and that of Riemann, are what are called the *non-Euclidean geometries*. The postulate of Euclid then can not be demonstrated; and this impossibility is as absolutely certain as any mathematical truth whatsoever.

It was the attainment of this very perception which in fact led to the creation of the non-Euclidean geometry. Says Lobachevski in the introduction to his 'New Elements of Geometry':

The futility of the efforts which have been made since Euclid's time during the lapse of two thousand years awoke in me the suspicion that the ideas employed might not contain the truth sought to be demonstrated. When finally I had convinced myself of the correctness of my supposition I wrote a paper on it [assuming the infinity of the straight].

It is easy to show that two straights making equal angles with a third never meet.

Euclid assumed inversely, that two straights unequally inclined to a third always meet.

To demonstrate this latter assumption, recourse has been had to many different procedures.

All these demonstrations, some ingenious, are without exception false, defective in their foundations and without the necessary rigor of deduction.

John Bolyai calls his immortal two dozen pages (the most extraordinary two dozen pages in the whole history of thought), 'The Science Absolute of Space, independent of the truth or falsity of Euclid's Axiom XI. (which can never be decided *a priori*).'

Later we read on the title page of W. Bolyai's 'Kurzer Grundriss': 'the question, *whether two straights cut by a third, if the sum of the interior angles does not equal two right angles, intersect or not?* no one on the earth can answer without assuming an axiom (as Euclid the eleventh)' [the parallel postulate].

With the ordinary continuity assumptions or the Archimedes postulate, it suffices to know the angle-sum in a single rectilinear triangle in order to determine whether space be Euclidean or non-Euclidean.

How peculiarly prophetic or mystic then that the clairvoyant inspiration of the genius of Dante, the voice of ten silent centuries, should have connected with the wisdom of Solomon and the special opportunity vouchsafed him by God a question whose answer would have established the case of Euclidean geometry seven hundred years before it was born, or that of non-Euclidean geometry three thousand years before its creation.

I. Kings 3 : 5 is :

In Gibeon the Lord appeared to Solomon in a dream by night: and God said, Ask what I shall give thee.

Then says Dante of his asking,

'Twas not to know the number in which are

Or if in semicircle can be made
Triangle so that it have no right angle.

O se del mezzo cerechio far si puote
Triangol sì, ch'un retto non avesse.

Par. C. XIII. 101-102.

How startling this! How strangely reinforced by the fact that in the fourth canto of the 'Divina Commedia,' with Cæsar greatest of the sons of men, Dante ranks, among exalted personages

. . . who slow their eyes around
Majestically moved, and in their port
Bore eminent authority:

Hippocrates of Chios, who found the quadrature of the lune (nearest that ever man came to the quadrature of the circle until finally John Bolyai squared it in non-Euclidean geometry and Lindemann proved no man could square it in Euclidean geometry); Euclid, the geometer, the elementist, preceptor, by his postulate, of the common universe, Euclidean space; and then Ptolemy, first of the long line of those who have tried by proof to answer the question Dante says Solomon might have asked God and did not, a question crucial as to whether Euclid or Bolyai owns the real world.

Anyhow, the shock currents to scientific somnolence and complacency breaking in to the entrenched thought camp from over the ramparts on the far frontiers almost simultaneously at Kazan on the Volga and at Maros-Vásárhely in far Erdély, started an ever-deepening movement to sift, to revise the foundations of geometry, then of all mathematics, then of all science, a movement of which the latest, as the most charming and weightiest, outcome is that pair of wonder-books, Poincaré's 'Science and Hypothesis' and 'The Value of Science.'

It was formerly customary to consider the assumption that space is a triply extended continuous number-manifold as a self-evident outcome of the continuity relations of space and the curves and surfaces in it. But since the rise of non-Euclidean geometry, it has come more and more to be seen that such presupposition about space is only admissible when one has already established and developed elementary geometry synthetically. Lobachevski stressed this in 1836 in his introduction to the 'New Elements,' where he says:

One must necessarily make the beginning with synthesis, in order, finally, after one has found the equations, therewith likewise to reach the limit beyond which now all goes over into the science of numbers.

For example, one demonstrates in geometry that two straights perpendicular to a third never meet; that the equality of triangles follows from that of certain of their parts.

In vain would one seek to treat analytically propositions of this species, even as all the theory of parallels. One would never succeed, just as one would not be able to do without synthesis for measuring plane rectilinear figures, or solids terminated by plane surfaces. It is incontestible that in the beginnings of geometry or mechanics, analysis can not serve as sole method.

One may compress the circle of synthesis; but it is impossible completely to suppress it.

From this, however, it follows that all investigations, such as those of Sophus Lie which start with the idea of number-manifold, involve a *petitio principii*, if interpreted directly as researches on the foundations of geometry. In the same way, the non-Euclidean geometry stops the old wrangle as to whether the axioms of geometry are *a priori* or empirical by showing that they are neither, but are conventions, disguised definitions, or unprovable assumptions pre-created by auto-active animal and human minds.

As Lambert insisted, for the space problem the mathematical treatment is in essence the treatment by logic. The start is from a system of axioms, assumptions. We postulate that between the elements of a system of entities certain relations shall hold, *e. g.*, two *points* determine a *straight*, three a *plane*. There is to be shown that these axioms are independent and not contradictory, presupposing pure logic and the applicability to the entities of an arithmetic founded by and made of pure logic. That the assumptions considered should be axioms of *geometry*, they must satisfy a further condition, which Hilbert formulates thus:

A system of assumptions is called a system of axioms of geometry if it gives the necessary and sufficient and independent conditions to which a system of things must be subjected in order that every property of these things should correspond to a geometric fact, and inversely; so that therefore in Hertz's sense these things should be a complete and simple picture of geometric reality.

The physiologic-psychologic investigation of the space problem must give the meaning of the words *geometric fact*, *geometric reality*.

It is the set of assumptions which makes the geometry what it is, which determines it. Thus, in my 'Rational Geometry,' one system of assumptions about the elements, points and straights on a plane, makes Euclidean planimetry. Another set makes Riemannian planimetry, in which when we picture it as in Euclidean space, we may call the straights straightests (great circles), and the plane sphere.

In the light of all this we see how the importance of non-Euclidean geometry for the teacher is still emphasized by the text-books of France, which have never recovered from Clairaut and Legendre. Even the latest and best French geometry, that of Hadamard, published under the editorship of Gaston Darboux, never presents nor consciously considers the question of its own foundations. It seems childishly unconscious of what is now requisite for any geometry pretending to be scientific or rigorous. This lack of foundation is allowable in a preliminary

course of intuitive geometry which does not attempt to be rigorously demonstrative, which emphasizes the sensuous rather than the rational. But in a serious work it is now no longer permissible to have nothing to start from. Wherever rigorous mathematics, there pure logic.

It may be a relief to many that the non-Euclidean geometry has shown the limitations to the arithmetization of mathematics. The opinion that only the concepts of analysis or arithmetic are susceptible of perfectly rigorous treatment Hilbert considers entirely erroneous.

On the contrary, he says, I think that wherever, from the side of the theory of knowledge, or in geometry, or from the theories of natural or physical science, mathematical ideas come up, the problem arises for mathematical science to investigate the principles underlying these ideas and so to establish them upon a simple and complete system of axioms, that the exactness of the new ideas and their applicability to deduction shall be in no respect inferior to those of the old arithmetical concepts.

The arithmetical symbols are written diagrams and the geometrical figures are graphic formulas.

The use of geometrical signs as a means of strict proof presupposes the exact knowledge and complete mastery of the axioms which underlie those figures; and in order that these geometrical figures may be incorporated in the general treasure of mathematical signs, there is necessary a rigorous axiomatic investigation of their conceptual content.

In other words, the world has outgrown Wentworth's geometry. More than this, as Frankland puts it, the possibility of explaining 'mass' (the fundamental property of matter) as a function of 'electric charge' is on the point of banishing both ordinary gross matter and also ether, since the principle of parsimony forbids needless hypothetical entities. Now the relation between the two opposite electricities so closely resembles that between Bolyaian and Riemannian space that, as Clifford adumbrated, we may expect to see matter, ether and electricity banished in favor of *space*, the various and changing geometries of which will be found adequate to account for all the phenomena of the material world.

Furthermore, these geometries of physical space will be found not to be 'continuous,' but to be the varied and changing 'tactical' arrangements of a *discrete*, a discontinuous manifold consisting of indivisible units. The notion of continuous extension, so long considered ultimate, will, by this simplification, be subsumed under the finally ultimate notion of juxtaposition, with which Lobachevski begins his great treatise 'Noviya nachala,' in whose very first article he says of it: "This simple idea derives from no other, and so is subject to no further explanation."

UNIVERSITY EDUCATION AND NATIONAL LIFE.*

BY SIR RICHARD C. JEBB, LITT. D., D.C.L., M.P.

EVERY country has educational problems of its own, intimately dependent on its social and economic conditions. The progressive study of education tends, indeed, towards a certain amount of general agreement on principles. But the crucial difficulties in framing and administering educational measures are very largely difficulties of detail; since an educational system, if it is to be workable, must be more or less accurately adjusted to all the complex circumstances of a given community. As one of those who are now visiting South Africa for the first time, I feel that what I bring with me from England is an interest in education, and some acquaintance with certain phases of it in the United Kingdom; but with regard to the inner nature of the educational questions which are now before this country, I am here to learn from those who can speak with knowledge. In this respect the British Association is doing for me very much what a famous bequest does for those young men whom it sends to Oxford; I am, in fact, a sort of Rhodes scholar from the other end—not subject, happily, to an age limit—who will find here a delightful and instructive opportunity of enlarging his outlook on the world, and more particularly on the field of education.

As usage prescribes that the work of this section, as of others, should be opened by an address from the chair, I have ventured to take a subject suggested by one of the most striking phenomena of our time—the growing importance of that part which universities seem destined to play in the life of nations.

Among the developments of British intellectual life which marked the Victorian age, none was more remarkable, and none is more important to-day, than the rapid extension of a demand for university education, and the great increase in the number of institutions which supply it. In the year 1832 Oxford and Cambridge were the only universities south of the Tweed, and their position was then far from satisfactory. Their range of studies was too narrow; their social operation was too limited. Then, by successive reforms, the quality of their teaching was improved, and its scope greatly enlarged; their doors were opened

* Address by the president to the Educational Science Section of the British Association for the Advancement of Science, South Africa, 1905.

to classes of the community against which they had formerly been closed. But meanwhile the growing desire for higher education—a result of the gradual improvement in elementary and secondary training—was creating new institutions of various kinds. The earliest of these arose while access to Oxford and Cambridge was still restricted. The University of Durham was established in 1833. In 1836 the University of London, as an examining and degree-giving body, received its first charter. A series of important colleges, giving education of a university type, arose in the greater towns of England and Wales. The next step was the formation of federal universities. The Victoria University, in which the Colleges of Manchester, Liverpool and Leeds were associated, received its charter in 1880. The Colleges of Aberystwyth, Bangor and Cardiff were federated in the University of Wales, which dates from 1893. The latest development has been the institution of the great urban universities. The foundation of the University of Birmingham hastened an event which other causes had already prepared. The federal Victoria University has been replaced by three independent universities, those of Manchester, Liverpool and Leeds. Lastly, a charter has recently been granted to the University of Sheffield. Then the University of London has been reconstituted; it is no longer only an examining board; it is also a teaching university, comprising a number of recognized schools in and around London. Thus in England and Wales there are now no fewer than ten teaching universities. Among the newer institutions there are some varieties of type. But, so far as the new universities in great cities are concerned, it may be said that they are predominantly scientific, and also that they devote special attention to the needs of practical life, professional, industrial and commercial; while at the same time they desire to maintain a high standard of general education. It may be observed that in some points these universities have taken hints from the four ancient universities of Scotland—which themselves have lately undergone a process of temperate reform. The Scottish universities are accessible to every class of the community; and the success with which they have helped to mold the intellectual life of a people traditionally zealous for education renders their example instructive for the younger institutions. With reference to the provision made by the newer universities for studies bearing on practical life, it should be remarked that much has been done in the same direction by the two older universities also. At Cambridge, for example, degrees can be taken in economics and associated branches of political science; in mechanism and applied mechanics, and in agricultural sciences. It certainly can not now be said that the old universities neglect studies which are of direct utility, though they rightly insist that the basis and method of such studies shall be liberal.

In looking back on the general course of this whole movement in England, we find that it has been steady, smooth and fairly rapid. It has not been due to any spasmodic impulse or artificial propaganda, but has been the result of natural forces operating throughout the nation. Universities, and the training which they give, have come to count for more in our national life as a whole. It should be noted in passing that the missionary movement known as university extension did not arise in the first instance from spontaneous academic action, but was a response to public appeals from without. It had its origin in memorials addressed to the University of Cambridge, in 1872, by various public bodies; and it was in compliance with those memorials that, in the winter of 1873, the first courses of extension lectures were organized in the Midlands. Another fact of vital significance in the movement is that it has included ample provision for the higher education of women.

With reference to the present position and prospects of the higher education in South Africa, I tried, before leaving England, to acquaint myself with at least the outlines of the general situation; but it is only with great diffidence that I shall offer a few observations bearing on some of the broader aspects of the question. I trust to be heard with indulgence by those from whom I shall hope to learn more. At any rate, I can truly say that the question seems to me one of the deepest interest and of the gravest importance. Indeed, it does not require much insight or imagination to apprehend the greatness of the issues that are involved.

In the first place, it would be correct, if I am not mistaken, to say that in South Africa at large there is a genuine and a keen desire for efficient education of the highest type. A sound liberal education is desired for all who can profit by it, whatever their future callings are to be. But the practical and immediate need for the organizing of the highest teaching is felt, I believe, more particularly in regard to three great professions—the profession of engineering, in all its branches; the profession of agriculture (including forestry); and the profession of education itself, on which the intellectual future of South Africa must so largely and directly depend. That the interest in the higher instruction is so real must be regarded as the best tribute to the efforts of those able and devoted men who, in various parts of this land, have labored with dauntless perseverance for the improvement of primary and secondary education. Unstinted gratitude is due also to the University of the Cape of Good Hope. It is acknowledged on all hands that the university, as the chief guardian of learning in South Africa, has done admirable work in maintaining a high standard of general education. Certainly it can not be regarded as any disparagement of that work if, as seems to be the case, a widespread desire exists that

South Africa should possess an institution, or institutions, of university rank, which, besides examining, should also teach. That is a natural progress, which is illustrated by the recent reconstitution of the London University itself. I am not qualified, nor should I desire, to discuss the various difficulties of detail which surround the question of a teaching university. That question is, for South Africa, an eminently practical one; and doubtless it will be solved, possibly at no distant time, by those who are most competent to deal with it. I will only venture to say a few words on some of the more general aspects of the matter.

The primary needs of daily life in a new country make demands for certain forms of higher training—demands which may be unable to wait for the development of anything so complex and costly as a teaching university. It is necessary to provide a training for men who shall be able to supervise the building of houses, the making of roads, bridges and railways, and to direct skilled labor in various useful arts and handicrafts. The first step in such a provision is to establish technical schools and institutes. Germany is, I suppose, the country where the educational possibilities of the technical school are realized in the amplest measure. In Germany the results of the highest education are systematically brought to bear on all the greater industries. But this highest education is not given only in completely equipped universities which confer degrees. It is largely given in the institutions known as technical high schools. In these schools teaching of a university standard is given, by professors of university rank, in subjects such as architecture, various branches of engineering, chemistry and general technical science. There are, I think, some ten or eleven of these technical high schools in Germany. In these institutions the teaching of the special art or science, on its theoretical side, is carried, I believe, to a point as high as could be attained in a university; while on the practical side it is carried beyond the point which in a university would usually be possible. In England we have nothing, I believe, which properly corresponds to the German technical high school; but we may expect to see some of the functions of such a school included among the functions of the new universities in our great industrial and commercial towns.

Now technical schools or institutes, which do not reach the level of a German technical high school, may, nevertheless, be so planned as to be capable of being further developed as parts of a great teaching university. And the point which I now wish to note is this—that the higher education given in a technical institute, which is only such, will not be quite the same as that given in the corresponding department of a teaching university. University education, as such, when it is efficient, has certain characteristics which differentiate it from the train-

ing of a specialist, however high the level of the teaching in the special subject may be. Here, however, I pause for a moment to guard against a possible misconception. I am not suggesting that the specialist training given in a technical institute, though limited, is not an excellent thing in itself; or that, in certain conditions and circumstances, it is not desirable to have such a training, attested by a diploma or certificate, instead of aiming at a university standard and a university degree. Universities themselves recognize this fact. They reserve their degrees for those who have had a university training; but they also grant diplomas for proficiency in certain special branches of knowledge. Cambridge, for instance, gives a diploma in the science and practise of agriculture; and the examinations for the diploma are open to persons who are not members of the university.

But the university training, whatever its subject, ought to give something which the purely specialist training does not give. What do we understand by a university education? What are its distinctive characteristics? The word *universitas*, as you know, is merely a general term for a corporation, specially applied in the middle ages to a body of persons associated for purposes of study, who, by becoming a corporation, acquired certain immunities and privileges. Though a particular university might be strongest in a particular faculty, as Bologna was in law and Paris in theology, yet it is a traditional attribute of such a body that several different branches of higher study shall be represented in it. It is among the distinctive advantages of a university that it brings together in one place students—by whom I mean teachers as well as learners—of various subjects. By doing this the university tends to produce a general breadth of intellectual interests and sympathies; it enables the specialist to acquire some sense of the relations between his own pursuit and other pursuits; he is helped to perceive the largeness of knowledge. But, besides bringing together students of various subjects, it is the business of a university to see that each subject shall be studied in such a manner as to afford some general discipline of the mental faculties. In his book on ‘The Idea of a University’ Newman says:

This process of training, by which the intellect, instead of being formed or sacrificed to some particular or accidental purpose, some specific trade or profession, or study or science, is disciplined for its own sake, for the perception of its own proper object, and for its own highest culture, is called liberal education; and though there is no one in whom it is carried as far as is conceivable, or whose intellect would be a pattern of what intellects should be made, yet there is scarcely any one but may gain an idea of what real training is, and at least look towards it, and make its true scope and result, not something else, his standard of excellence; and numbers there are who may submit themselves to it and secure it to themselves in good measure. And to set forth the right standard, and to train according to it, and to help forward all students

towards it according to their various capacities, this I conceive to be the business of a university

It may be granted that the function of a university, as Newman here describes it, is not always realized; universities, like other human institutions, have their failures. But his words truly express the aim and tendency of the best university teaching. It belongs to the spirit of such teaching that it should nourish and sustain ideals; and a university can do nothing better for its sons than that; a vision of the ideal can guard monotony of work from becoming monotony of life. But there is yet another element of university training which must not be left out of account; it is, indeed, among the most vital of all. I mean that informal education which young men give to each other. Many of us, probably, in looking back on our undergraduate days, could say that the society of our contemporaries was not the least powerful of the educational influences which we experienced. The social life of the colleges at Oxford and Cambridge is a most essential part of the training received there. In considering the questions of the higher education in South Africa it is well to remember that the social intercourse of young students, under conditions such as a great residential university might provide, is an instrument of education which nothing else can replace. And it might be added that such social intercourse is also an excellent thing for the teachers.

The highest education, when it bears its proper fruit, gives not knowledge only, but mental culture. A man may be learned, and yet deficient in culture: that fact is implied by the word 'pedantry.' "Culture," said Huxley, "certainly means something quite different from learning or technical skill. It implies the possession of an ideal, and the habit of critically estimating the value of things by a theoretic standard." "It is the love of knowledge," says Henry Sidgwick, "the ardor of scientific curiosity, driving us continually to absorb new facts and ideas, to make them our own, and fit them into the living and growing system of our thought; and the trained faculty of doing this, the alert and supple intelligence exercised and continually developed in doing this—it is in these that culture essentially lies." And if this is what culture really means, evidently it can not be regarded as something superfine—as an intellectual luxury suited only for people who can lead lives of elegant leisure. Education consists in organizing the resources of the human being; it seeks to give him powers which shall fit him for his social and physical world. One mark of an uneducated person is that he is embarrassed by any situation to which he is not accustomed. The educated person is able to deal with circumstances in which he has never been placed before; he is so, because he has acquired general conceptions; his imagination, his judgment, his powers of intelligent sympathy, have been developed. The mental culture

which includes such attributes is of inestimable value in the practical work of life, and especially in work of a pioneer kind. It is precisely in a country which presents new problems, where novel difficulties of all sorts have to be faced, where social and political questions assume complex forms for which experience furnishes no exact parallel, it is precisely there that the largest and best gifts which the higher education can confer are most urgently demanded.

But how is culture, as distinct from mere knowledge, to be attained? The question arises as soon as we turn from the machinery of the higher education to consider its essence, and the general aims which it has in view. Culture can not be secured by planning courses of study, nor can it be adequately tested by the most ingenious system of examinations. But it would be generally allowed that a university training, if it is really successful, ought to result in giving culture, over and above such knowledge as the student may acquire in his particular branch or branches of study. We all know what Matthew Arnold did, a generation ago, to interpret and diffuse in England his conception of culture. The charm, the humor and also the earnestness of the essays in which he pleaded that cause render them permanently attractive in themselves, while at the same time they have the historical interest of marking a phase in the progress of English thought and feeling about education. For, indeed, whatever may be the criticisms to which Arnold's treatment of the subject is open in detail, he truly indicated a great national defect; and by leading a multitude of educated persons to realize it, he helped to prepare the way for better things. Dealing with England as it was in the sixties, he complained that the bulk of the well-to-do classes were devoid of mental culture—crude in their perceptions, insensible to beauty, and complacently impenetrable to ideas. If, during the last thirty or forty years, there has been a marked improvement, the popular influence of Matthew Arnold's writings may fairly be numbered among the contributory causes, though other and much more potent causes have also been at work. When we examine Arnold's own conception of culture, as expressed in successive essays, we find that it goes through a process of evolution. At first he means by 'culture' a knowledge and love of the best literature, ancient and modern, and the influence on mind and manners which flows thence. Then his conception of culture becomes enlarged; it is now no longer solely or mainly esthetic, but also intellectual; it includes receptivity of new ideas; it is even the passion for 'seeing things as they really are.' But there is yet a further development. True culture, in his final view, is not only esthetic and intellectual; it is also moral and spiritual; its aim is, in his phrase, 'the harmonious expansion of all the powers which made the beauty and worth of human nature.' But whether the scope which Arnold, at a

particular moment, assigned to culture was narrower or wider, the instrument of culture with which he was chiefly concerned was always literature. Culture requires us, he said, to know ourselves and the world; and, as a means to this end, we must 'know the best that has been thought and said in the world.' By literature, then—as he once said in reply to Huxley—he did not mean merely *belles lettres*; he included the books which record the great results of science. But he insisted mainly on the best poetry and the highest eloquence. In comparing science and literature as general instruments of education, Arnold observed that the power of intellect and knowledge is not the only one that goes to the building up of human life; there is also the power of conduct and the power of beauty. Literature, he said, serves to bring knowledge into relation with our sense for conduct and our sense for beauty. The greater and more fruitful is the progress of science, the greater is the need for humane letters, to establish and maintain a harmony between the new knowledge and those profound, unchanging instincts of our nature.

It is not surprising that, in the last third of the nineteenth century, Arnold's fascinating advocacy of literature, as the paramount agency of culture, should have incurred some criticism from the standpoint of science and of philosophy. The general drift of this criticism was that the claim which he made for literature, though just in many respects, was carried too far; and also that his conception of intellectual culture was inadequate. As a representative of such criticism, I would take the eminent philosopher whose own definition of culture has already been cited, Henry Sidgwick: for no one, I think, could put more incisively the particular point with which we are here concerned. "Matthew Arnold's method of seeking truth," says Sidgwick, "is a survival from a prescientific age. He is a man of letters pure and simple; and often seems quite serenely unconscious of the intellectual limitations of his type." The critic proceeds to enumerate some things which, as he affirms, are 'quite alien to the habitual thought of a mere man of letters.' They are such as these: "How the crude matter of common experience is reduced to the order and system which constitutes it an object of scientific knowledge; how the precisest possible conceptions are applied in the exact apprehension and analysis of facts, and how by facts thus established and analyzed the conceptions in their turn are gradually rectified; how the laws of nature are ascertained by the combined processes of induction and deduction, provisional assumption and careful verification; how a general hypothesis is used to guide inquiry, and, after due comparison with ascertained particulars, becomes an accepted theory; and how a theory, receiving further confirmation, takes its place finally as an organic part of a vast, living, ever-growing system of knowledge." Sidgwick's conclusion is as fol-

lows: "Intellectual culture, at the end of the nineteenth century, must include as its most essential element a scientific habit of mind; and a scientific habit of mind can only be acquired by the methodical study of some part at least of what the human race has come scientifically to know."

There is nothing in that statement to which exception need be taken by the firmest believer in the value of literary education. The more serious and methodical studies of literature demand, in some measure, a scientific habit of mind, in the largest sense of that expression; such a habit is necessary, for instance, in the study of history, in the scientific study of language and in the 'higher criticism.' Nor, again, does any one question that the studies of the natural sciences are instruments of intellectual culture of the highest order. The powers of observation and of reasoning are thereby disciplined in manifold ways; and the scientific habit of mind so formed is in itself an education. To define and describe the modes in which that discipline operates on the mind is a task for the man of science; it could not, of course, be attempted by any one whose own training has been wholly literary. But there is one fact which may be noted by any intelligent observer. Many of our most eminent teachers of science, and more especially of science in its technical applications, insist on a demand which, in the provinces of science, is analogous to a demand made in the province of literary study by those who wish such study to be a true instrument of culture. As the latter desire that literature should be a means of educating the student's intelligence and sympathies, so that teachers of science, whether pure or applied, insist on the necessity of cultivating the scientific imagination, of developing a power of initiative in the learner, and of drawing out his inventive faculties. They urge that, in the interests of the technical industries themselves, the great need is for a training which shall be more than technical—which shall be thoroughly scientific. Wherever scientific and technical education attains its highest forms in institutions of university rank, the aim is not merely to form skilled craftsmen, but to produce men who can contribute to the advance of their respective sciences and arts, men who can originate and invent. There is a vast world-competition in scientific progress, on which industrial and commercial progress must ultimately depend; and it is of national importance for every country that it should have men who are not merely expert in things already known, but who can take their places in the forefront of the onward march.

But meanwhile the claims of literary culture, as part of the general higher education, must not be neglected or undervalued. It may be that, in the prescientific age, those claims were occasionally stated in a somewhat exaggerated or one-sided manner. But it remains as true as ever that literary studies form an indispensable element of a really

liberal education. And the educational value of good literature is all the greater in our day, because the progress of knowledge more and more enforces early specialization. Good literature tends to preserve the breadth and variety of intellectual interests. It also tends to cultivate the sympathies; it exerts a humanizing influence by the clear and beautiful expression of noble thoughts and sentiments; by the contemplation of great actions and great characters; by following the varied development of human life, not only as an evolution governed by certain laws, but also as a drama full of interests which intimately concern us. Moreover, as has well been said, if literature be viewed as one of the fine arts, it is found to be the most altruistic of them all, since it can educate a sensibility for other forms of beauty besides its own. The genius of a Ruskin can quicken our feeling for masterpieces of architecture, sculpture and painting. Even a very limited study of literature, if it be only of the right quality, may provide permanent springs of refreshment for those whose principal studies and occupations are other than literary. We may recall here some weighty words written by one of the very greatest of modern men of science. "If I had to live my life again," said Charles Darwin, "I would have made it a rule to read some poetry and listen to some music at least once every week. . . . The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature." The same lesson is enforced by John Stuart Mill, in that remarkable passage of his 'Autobiography' where he describes how, while still a youth, he became aware of a serious defect, a great lacuna, in that severe intellectual training which, for him, had commenced in childhood. It was a training from which the influences of imaginative literature had been rigidly excluded. He turned to that literature for mental relief, and found what he wanted in the poetry of Wordsworth. "I had now learned by experience"—this is his comment—"that the passive susceptibilities needed to be cultivated as well as the active capacities, and required to be nourished and enriched as well as guided." Nor is it merely to the happiness and mental well-being of the individual that literature can minister. By rendering his intelligence more flexible, by deepening his humanity, by increasing his power of comprehending others, by fostering worthy ideals, it will add something to his capacity for cooperating with his fellows in every station of life and in every phase of action; it will make him a better citizen, and not only a more sympathetic, but also a more efficient member of society.

One of the urgent problems of the higher education in our day is how to secure an adequate measure of literary culture to those students whose primary concern is with scientific and technical pursuits. Some of the younger English universities, which give degrees in science, con-

tribute to this purpose by providing certain options in the science curriculum; that is, a given number of scientific subjects being prescribed for study with a view to the degree of B.Sc., the candidate is allowed to substitute for one of these a subject taken from the arts curriculum, such, for instance, as the theory and practise of education. This is the case in the University of Wales and in the University of Birmingham; and there are indications, I believe, that this example will be followed elsewhere. Considering how hard and sustained is the work exacted from students of science, pure or applied, it seems important that the subjects from which they are to derive their literary culture should be presented to them, not in a dry-as-dust fashion, not chiefly as subjects of examination, but rather as sources of recreation and changes of mental activity. From this point of view, for British students of science the best literature of the English language offers unequalled advantages. It may be mentioned that the board of education in London is giving particular attention to the place which English literature should hold in the examination of students at the training colleges, and has under consideration carefully planned courses of study, in which portions of the best English writers of prose and of verse are prescribed to be read in connection with corresponding periods of English history, it being understood that the study of the literature shall be directed, not to philological or grammatical detail, but to the substance and meaning of the books, and to the leading characteristics of each writer's style. If, on the other hand, the student is to derive his literary culture, wholly or in part, from a foreign literature, ancient or modern, then it will be most desirable that, before leaving school, he should have surmounted the initial difficulties of grammar, and should have learned to read the foreign language with tolerable ease.

When we look at this problem—how to combine the scientific and the literary elements of culture—in the light of existing or prospective conditions in South Africa, it appears natural to suppose that, in a teaching university, the faculty of education would be that with which literary studies would be more particularly connected. And if students of practical sciences, such as engineering and agriculture, were brought together at the same center where the faculty of education had its seat, then it should not be difficult, without unduly trenching on the time demanded by scientific or technical studies, to provide such students with facilities for some measure of good literary training.

A further subject is necessarily suggested by that with which we have been dealing—I mean the relation of university to secondary education; but on that I can only touch very briefly. Before university education can be widely efficient, it is indispensable that secondary education should be fairly well developed and organized. Secondary education should be intelligent—liberal in spirit—not too much tram-

meled by the somewhat mechanical uniformity apt to result from working for external examinations, but sufficiently elastic to allow for different aptitudes in the pupils, and to afford scope for the free initiative of able teachers. It is a gain for the continuity of education when a school-leaving examination can be accepted as giving admission to the university. Such an examination must be conducted under the authority of the university; but there is much to be said in favor of the view that, under proper safeguards, the school-teachers should have a part in the examination; always provided that the ultimate control, and the decision in all cases of doubt, shall rest with the university. A system of school-leaving examinations for this country was earnestly advocated, I believe, by Mr. P. A. Barnett, who has achieved such excellent work for the cause of education in Natal. To discuss the advantages or difficulties of such a proposal, as they at present affect South Africa, would demand knowledge which I do not possess; and I must content myself with the expression of a hope that in days to come—perhaps in a not distant future—it may be found practicable to form such a link between the highest education and the grade next below it.

But the limit of time proper for a chairman's address has now almost been reached. I thank you sincerely for the kindness and patience with which you have heard me. In conclusion, I would only say how entirely I share a conviction which has been expressed by one to whose ability, to whose generous enthusiasm and unflagging efforts the cause of education in this country owes an incalculable debt—I refer to Mr. E. B. Sargant. Like him, I believe that the progress of education in all its grades, from the lowest to the highest, is the agency which, more surely than any other, will conduce to the prosperity and the unity of South Africa. For all workers in that great cause it must be an inspiring thought that they are engaged in promoting the most fundamental and the most far-reaching of national interests. They are endeavoring to secure that the men and women to whom the future of this country belongs shall be equal to their responsibilities and worthy of their inheritance. In that endeavor the sympathies which they carry with them are world-wide. As we come to see, more and more clearly, that the highest education is not only a national but an imperial concern, there is a growing desire for interchange of counsels and for active cooperation between the educational institutions of the colonies and those of the mother country. The development of education in South Africa will command keen attention, and will be followed by earnest good wishes, not only in England, but throughout the British dominions. One of the ideas which are bound up with the history and the traditions of our English public schools and universities is the idea of efficient work for the state. Those institutions have been largely

molded, from generation to generation, by the aim of ensuring a supply of men qualified to bear a worthy part, either in the government of the nation, or in professional activities which are indispensable to the national welfare. In our own time, and more especially within the last thirty years, one particular aspect of that idea is illustrated by the closer connections which have been formed between the universities and the higher branches of the civil service. The conception of work for the commonweal is in its turn inseparable from loyalty to those ideals of character and conduct by which English life and public policy have been built up. It is by the long and gradual training which such ideals have given that our race has been fitted to grapple with responsibilities which have inevitably grown, both in extent and in complexity, far beyond anything of which our forefathers could have dreamed. That training tends also to national self-knowledge; it makes for a sober estimate of our national qualities and defects; it quickens a national sense of duty to our neighbor. The munificence of a far-sighted statesman has provided that selected youths, whose homes are in this land, and whose life-work may be here, shall go for a while to England, shall breathe the intellectual and social atmosphere of a great English university, and shall learn to judge for themselves of the sources from which the best English traditions have flowed. That is excellent. But it is also most desirable that those traditions should pass as living forces into the higher teaching of South Africa itself, and that their spirit should animate educational institutions whose special forms have been molded by local requirements. That, indeed, has been, and is, the fervent wish of men whose labors for South African education have already borne abundant fruit, and are destined to bear yet larger fruit in the future. May those labors prosper, and may that wish be fulfilled! The sooner will come the day when the inhabitants of this country, this country of vast and still indefinite possibilities, will be able to feel, in a sense higher and deeper than citizens of the Roman Empire could conceive, *Cuncti gens una sumus* ('We are all one people'). If the work which lies before us, in this section of the British Association, should result in contributing anything towards the promotion of those great objects, by helping to elucidate the conditions of further progress, our deliberations will not have been held in vain.

THE CATTLE PROBLEM OF ARCHIMEDES.

BY PROFESSOR MANSFIELD MERRIMAN,

LEHIGH UNIVERSITY.

THE sleepy town of Wolfenbüttel in northern Germany is the proud possessor of a library containing about 240,000 books and 10,000 manuscripts, many of the latter being Greek and Latin writings of interest and value. Lessing, the poet and philosopher, was appointed its librarian in 1769, and a few years later he published translations of some of the unique manuscripts with commentaries thereon. One of these was a Greek poem of forty-four lines which states an arithmetical problem that has since attracted much attention on account of the difficulty of its solution and the enormous numbers required to fulfil its conditions. The name of Archimedes appears in the title of the poem, it being said that he sent it in a letter to Eratosthenes, the Cyrean, to be investigated by the mathematicians of Alexandria. Opinions differ as to the truth of this statement, and it may well be doubted if Archimedes was the real author, particularly as no mention of the problem has been found in the writings of the Greek mathematicians.

The following statement of the cattle problem has been abridged from the German translations published by Nesselmann in 1842, and by Krumbiegel in 1880:

Compute, O friend, the number of the cattle of the sun which once grazed upon the plains of Sicily, divided according to color into four herds, one milk-white, one black, one dappled and one yellow. The number of bulls is greater than the number of cows, and the relations between them are as follows:

White bulls = $(\frac{1}{2} + \frac{1}{3})$ black bulls + yellow bulls,
 Black bulls = $(\frac{1}{4} + \frac{1}{5})$ dappled bulls + yellow bulls,
 Dappled bulls = $(\frac{1}{6} + \frac{1}{7})$ white bulls + yellow bulls,
 White cows = $(\frac{1}{8} + \frac{1}{9})$ black herd,
 Black cows = $(\frac{1}{10} + \frac{1}{11})$ dappled herd,
 Dappled cows = $(\frac{1}{12} + \frac{1}{13})$ yellow herd,
 Yellow cows = $(\frac{1}{14} + \frac{1}{15})$ white herd.

If thou canst give, O friend, the number of each kind of bulls and cows, thou art no novice in numbers, yet can not be regarded as of high skill. Consider, however, the following additional relations between the bulls of the sun:

White bulls + black bulls = a square number,
 Dappled bulls + yellow bulls = a triangular number.

If thou hast computed these also, O friend, and found the total number of cattle, then exult as a conqueror, for thou hast proved thyself most skilled in numbers.

The Wolfenbüttel manuscript has an appendix, also in Greek, giving numbers in answer to the problem, the total number of cattle being stated as 4,031,126,560, but the results satisfy only the first seven conditions. Lessing also gives results computed by Leiste, a clergyman of Wolfenbüttel, whose solution satisfies these seven conditions and likewise the eighth one. In 1821 J. and K. L. Struve published a critical and mathematical discussion, which was followed in 1828 by another from G. Hermann. The latter makes the interesting remark that Gauss had arrived at a complete solution: but, if so, no further information regarding it has been obtained. Many other attempts at solution were made, but the large numbers required to satisfy the nine conditions discouraged many investigators. Some critics thought that the original problem of Archimedes included only the first seven conditions and that the two others had been added by a later writer. It is, of course, clearly seen that the exercise as stated includes two problems, the first to find integral numbers that satisfy the first seven conditions, and the second to find integral numbers that satisfy all the nine conditions. As the poem says, the first problem may be solved by those of moderate proficiency in numbers, while the second can only be done by those of the highest skill.

The first problem is an easy one for a boy in the high school. Let W, B, D, Y represent the number of white, black, dappled and yellow bulls and let w, b, d, y represent the number of white, black, dappled and yellow cows. The seven conditions then give the seven equations:

$$W = \frac{5}{3} B + Y, \quad (1)$$

$$B = \frac{9}{20} D + Y, \quad (2)$$

$$D = \frac{13}{42} W + Y, \quad (3)$$

$$w = \frac{7}{12} (B + b), \quad (4)$$

$$b = \frac{9}{20} (D + d), \quad (5)$$

$$d = \frac{1}{30} (Y + y), \quad (6)$$

$$y = \frac{13}{42} (W + w), \quad (7)$$

and these contain eight unknown quantities. The problem, therefore, is of the kind called indeterminate, for many sets of numbers may be found to satisfy the seven equations. That set having the smallest numbers is the one required, for any other set may be found by multiplying these numbers by the same integer. If B and W are eliminated from equations (1), (2), (3), there will be found the single equation $891 D = 1,580 Y$, and hence $Y = 891$ and $D = 1,580$ are the smallest integral numbers satisfying it; from these are found $B = 1,602$ and $W = 2,226$. These values, before insertion in equations (4) to (7), are to be multiplied by a factor m , the value of which is later to be determined, so that the number of cows in each herd shall be an integer. Proceeding with the elimination, the values of w, b, d, y are deduced in terms of m , and it is then seen that 4,657 is the least value of m which will make the results integers. It is thus easily found that

$$\begin{aligned} B &= 7,460,514, \\ W &= 10,366,482, \\ D &= 7,358,060, \\ Y &= 4,149,387, \end{aligned}$$

$$\begin{aligned} b &= 4,893,246, \\ w &= 7,206,360, \\ d &= 3,515,820, \\ y &= 5,439,213, \end{aligned}$$

are the least numbers satisfying the conditions of the first problem. The total number of cattle is 50,389,082, not too great to graze upon the island Sicily, the area of which is about 7,000,000 acres. If the above numbers are multiplied by 80 they give the results stated in the appendix to the Wolfenbüttel manuscript.

The second or complete problem includes the determination of numbers which satisfy not only equations (1) to (7), but also

$$W + B = \text{a square number}, \quad (8)$$

$$D + Y = \text{a triangular number}, \quad (9)$$

and this is to be done by finding an integer N to multiply into each of the results of the first problem. Since $W + B$ is 17,826,996 and $D + Y$ is 11,507,447, these equations become

$$17,826,996 N = \text{a square number},$$

$$11,507,447 N = \text{a triangular number}.$$

A number N that will satisfy one of these conditions can be found without difficulty, but to determine one that will satisfy both is a task requiring an enormous amount of labor and patience. In fact, this required number N has never been completely computed.

It has been claimed by some critics that the ninth condition should be rejected altogether, for they asserted that there is no evidence that Archimedes or the Greek mathematicians had the idea of a triangular number. On this hypothesis the solution is easy. Since $W + B$ is $17,826,966 N$ or $4 \times 4,456,749 N$, and since 4,456,749 contains no number that is a perfect square, it is plain that N must be 4,456,749. Accordingly, each of the numbers found in the first solution must be multiplied by 4,456,749 in order to satisfy equations (1) to (8) inclusive; the number $W + B$ is then 79,450,446,596,004, which is a perfect square, but the number $D + Y$ is 51,285,802,909,803, which is not a triangular number. This solution is identical with that of Leiste as published by Lessing in 1773.

For the benefit of those who are neither novices nor of high skill in numbers, it is now time to explain what is meant by a triangular number. The number 10 is triangular because ten dots can be arranged in rows in the form of a triangle, there being one dot in the first row, two in the second, three in the third and four in the fourth. The next higher triangular number is 15 and the next 21, and in general $\frac{1}{2} n(n+1)$ is a triangular number whenever n is an integer, n being the number of rows parallel to one side of the triangle. The proof that 51,285,802,909,803 is not a triangular number consists in

equating it to $\frac{1}{2}n(n+1)$ and computing the value of n by the solution of the quadratic equation; this value of n is found to be not an integer.

Some mathematicians who desired to solve the cattle problem have claimed that $W+B$ is not required to be a perfect square, because the statement of the eighth condition in the Greek manuscript does not use the term square number, but mentions 'a square figure.' Since the length of a bovine animal is greater than its breadth, it was maintained by Wurm, about 1830, that $W+B$ is required to be a rectangular number, that is, a number having two factors. On this hypothesis he made a solution which gave the total number of cattle as 5,916,837,175,686, and the number of white and black bulls as 2,093,299,351,328, which has the factors $704,538 \times 2,971,166$, as well as many others, while the number of dappled and yellow bulls is 1,351,238,949,081, which is a triangular number, so that these bulls could be arranged in a triangle with 3,287,843 rows.

The consensus of opinion regarding the eighth and ninth conditions is expressed, however, in the statement of the problem as given above, namely, that the terms 'square figure' and 'triangular figure' should be understood to mean square number and triangular number. Since 51,285,802,909,803 is the number of dappled and yellow bulls which results from a solution that satisfies conditions (1) to (8) inclusive, it is plain that the ninth condition may be expressed by

$$51,285,802,909,803, x^2 = \frac{1}{2}n(n+1),$$

in which x and n are to be integers. When x^2 has been found, each of the numbers of the first solution is to be multiplied by $4,456.749 x^2$, in order to give the number of bulls and cows in each herd, satisfying the nine imposed conditions.

These numbers were readily seen to be so great that the island of Sicily could not contain all the cattle, as the problem seems to demand. This requirement, however, was understood to be only figurative, and mathematicians agreed that the numbers, though very large, could be found, but that no useful purpose would be attained by computing them. Thus the question rested until 1880, when Amthor undertook to determine how many figures were required to express one of the numbers. His lengthy investigation demonstrates that 206,545 figures are needed to express the total number of cattle. He further computed that 766 are the first three figures of this number, so that $766 \times 10^{206,542}$ is the approximate number of cattle. This is an enormous number, and it is easy to show that a sphere having the diameter of the milky way, across which light takes ten thousand years to travel, could contain only a part of this great number of animals, even if the size of each is that of the smallest bacterium.

It would be thought that, after this investigation by Amthor, the question of solving the cattle problem would have been finally dropped, but such was not the case. The certainty that numbers could be found satisfying all nine conditions existed, and until they had been actually computed the challenge of the author of the problem still remained open. The way to solve it was well understood from the theory of indeterminate analysis. Let the preceding equation be multiplied by 8 and unity added to each member, and let $2n + 1$ be called y ; then it reduces to

$$y^2 - 410,286,423,278,424 x^2 = 1$$

which is of the form $y^2 - Ax^2 = 1$, and it is known that when A is an integer there can always be found integral values of y and x which satisfy the equation. The method of obtaining such values of x and y can not well be explained here, but such a method was devised many years ago by Pell and by Fermat, and it is well known to those skilled in higher arithmetic. For example, take the simple case where $A = 19$, or $y^2 - 19x^2 = 1$, then the smallest integral values of y and x which satisfy this equation may be found to be 170 and 39, so that the square of 170 minus 19 times the square of 39 equals unity.

In 1889 A. H. Bell, a surveyor and civil engineer of Hillsboro, Illinois, began the work of solution. He formed the Hillsboro Mathematical Club, consisting of Edmund Fish, George H. Richards and himself, and nearly four years were spent on the work. They computed thirty of the left-hand figures and twelve of the right-hand figures of the value of x^2 without finding the intermediate ones. This value is

$$x^2 = 34,555,906,354,559.370 \dots\dots\dots 252,058,980,100$$

in which the dots indicate fifteen computed figures which it is here unnecessary to give and 206,487 uncomputed ones; the total number of figures in this number is 206,531. The final step is to multiply each of the numbers of the first solution by 4,456,749 and by this value of x^2 , and thus are obtained

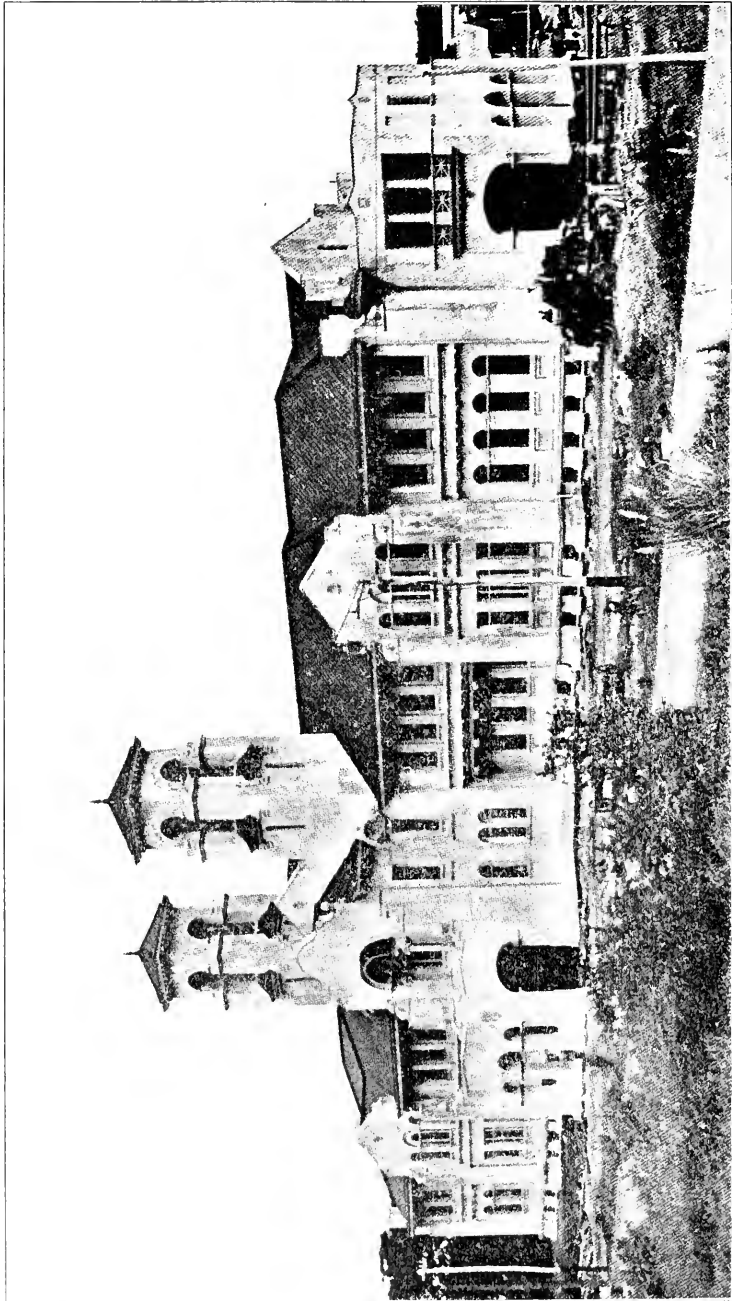
White bulls	=	1,596,510	.....	341,800
Black bulls	=	1,148,971	.....	178,600
Dappled bulls	=	1,133,192	.....	894,000
Yellow bulls	=	639,034	.....	026,300
White cows	=	1,109,829	.....	564,000
Black cows	=	735,594	.....	645,400
Dappled cows	=	541,460	.....	318,000
Yellow cows	=	837,676	.....	113,700
Total cattle		7,760,271	.....	081,800

in which the dots represent 206,532 figures, the total number of figures in each line being either 206,545 or 206,544. In each of these lines there are omitted twenty-four figures at the left-end and six at the

right-end which were computed by the Hillsboro Mathematical Club.

This solution is published in the *American Mathematical Magazine* for May, 1895, where Bell remarks that each of these enormous numbers is 'one half mile long.' A clearer idea of its length may be obtained from considering the space it would take to print it. Each page of this MONTHLY contains 45 lines and in each line about 50 figures may be set, so that one page would permit a number of about 2,250 figures to be printed. To print a number containing 206,545 figures there would be required 92 pages, and to print the nine numbers indicated above a volume of about 830 large octavo pages in this size of page and type would be needed.

It is known that Archimedes speculated regarding large numbers, for his book called *Arenarius* is devoted to showing that a number may be written that will express the number of grains of sand in a sphere of the size of the earth. It can not be proved that Archimedes was, or was not, the author of the cattle problem, but, as Amthor remarks, the enormous numbers required in its solution render it worthy of his genius and proper to bear his name. Its closing challenge still remains open, for the complete solution has not yet been made. Moreover, it is practically impossible that the long numbers can ever be computed, since the investigations of Bell show that this would require the work of a thousand men for thousand years. The little prairie town of Hillsboro may, however, well exult as a conqueror, for its mathematical club has made the most complete of all solutions of the cattle problem and has proved itself to be highly skilled in numbers.



BUILDING OF THE BUREAU OF GOVERNMENT LABORATORIES, MANILA.

THE PROGRESS OF SCIENCE.

*SCIENTIFIC WORK IN THE
PHILIPPINE ISLANDS.*

THE civil government of the Philippine Islands has been prompt in recognizing the importance of scientific work. The commission established in 1901 a Bureau of Government Laboratories and authorized the preparation of plans for a suitable building for the installation of biological and chemical laboratories. The commission was fortunate in securing as superintendent Dr. Paul C. Freer, professor of chemistry in the University of Michigan, under whose able direction the work has been organized and a building erected.

The illustration shows the building, which was designed with the assistance of the chief of the Insular Bureau of Architecture, Mr. E. K. Bourne, and is of pleasing and suitable architecture. In laboratory construction a low building has many advantages, and in the Philippine Islands the danger from earthquakes must be taken into consideration. In a tropical country coolness and ventilation are of great importance. Corridors, ten feet wide, run the entire length of the building, and as these are open at both ends a breeze usually passes through them. The laboratories are comparatively small rooms opening from the corridors. The building is divided into two symmetrical parts, the east half being used for biological and the west half for chemical work, with a library in the center. The power house has been placed in the rear, and in it is a serum laboratory. In addition to heat and electric power there are gas generators, compressed air, vacuum pumps and a refrigerating machine. The separate laboratories are provided with

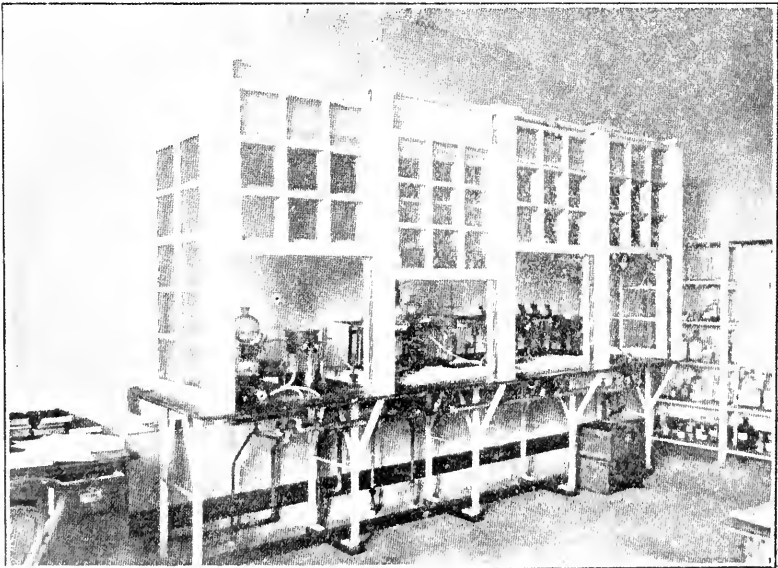
these conveniences for research and are well equipped with apparatus. The collection includes fifteen microscopes of the best Zeiss pattern, five Schanze microtomes and two Minot microtomes, incubators, balances, electrical furnaces and the like. The equipment is of special importance, as it takes at least seven months to procure new supplies from Europe or America. The library contains some 12,000 volumes and seventy sets of publications, and these again are essential where there is no access to large libraries.

The work done in the laboratories appears to be of much scientific value, twenty-two publications having been issued by members of the staff. It is, however, naturally difficult to secure scientific workers in distant and tropical regions unless they are attracted by the special problems that can only be solved there. The director of the laboratories hopes that facilities may be given similar, for example, to those at the Naples station, which will attract scientific workers to the islands. He also thinks it possible that the laboratories may be supported by gifts from those who are interested in the development of the islands or in the special problems that can only there be undertaken.

In addition to the scientific work undertaken by the Philippine government, the president of the United States has recommended that a scientific survey of the Islands be undertaken at the expense of the federal government. At his request the National Academy of Sciences appointed a committee to report on the desirability of instituting scientific explorations of the Islands, and this report was transmitted to the last congress



LIBRARY, SHOWING ONE OF THE READING TABLES.



ONE OF THE LARGER HOODS IN THE CHEMICAL LABORATORY.

by the president, with the recommendation that provision be made for the appointment of a board of surveys to superintend national surveys and explorations in the islands. This board would consist of representatives of the Coast and Geodetic Survey, the Geological Survey, the Biological Survey, the Division of Botany, the Forest Service, the Bureau of Fisheries and the Bureau of American Ethnology. The president urges that while these surveys would be beneficial to the inhabitants of the Philippine Islands, they should be undertaken as a national work valuable for the people of this country and of the world. It is to be hoped that congress will find time to take up this measure at the approaching session.

THE RUMFORD FUND.

THE American Academy of Arts and Sciences has published a pamphlet regarding the Rumford Fund administered by it which contains some facts of general scientific interest. Benjamin Thompson, who was created a count by Prince Maximilian of Bavaria and who chose to be called Count Rumford after a New Hampshire town from which the family of his wife had come, was born in Massachusetts in 1753 and died in France in 1814. He founded the Royal Institution of Great Britain in 1799, and by a bequest established the Rumford professorship for the application of science to the useful arts at Harvard University. In 1796 he gave to

the Royal Society of Great Britain and to the American Academy of Arts and Sciences of Boston the sum of \$5,000, the income of which in each case was to be given once every second year to the author of the most important discovery or useful improvement made during the preceding two years in heat or in light. The premium was to take the form of medals. An illustration of the medal awarded by the American Academy is here reproduced.

The Royal Society made the first award from the fund of Count Rumford himself in 1802; and every second year since, with the exception of several years, the medal has been awarded. The list of those on whom the premium has been conferred by the Royal Society is an illustrious series of men of science closing with Professor Ernest Rutherford, of McGill University, on whom it was conferred in 1904. The Royal Society was not limited in regard to the nationality of those on whom the premium could be conferred, but the American Academy by the terms of the gift could only confer it on authors on the continent of America or the American Islands. It appears that for many years there was no claimant whose merit was such in the opinion of the academy as to justify the award, and the fund accumulated to the amount of \$20,000, when in 1831 application was made to the Supreme Court of Massachusetts for relief. It was ordered that in addition to the



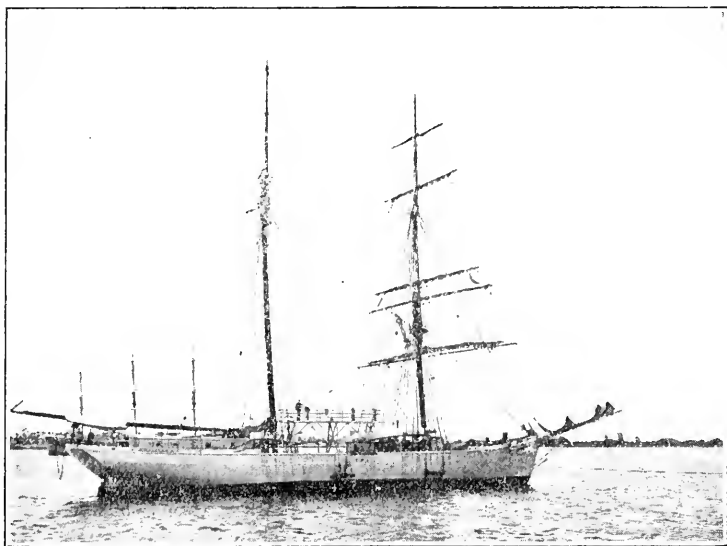
THE RUMFORD MEDAL OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

medals of the value of \$300 which might be awarded every second year, the residue of the income could be used for the purchase of books and apparatus, for publications or for assisting investigation.

The first award of the Rumford premium of the Academy was made in 1839 to Robert Hare, of Philadelphia, for his oxyhydrogen-blowpipe, and the second was awarded in 1862 to John Ericsson for his caloric engine. Since that time the award has been made with tolerable regularity, the last

'Thermo-electric Force of Metals and Alloys'; Harry W. Morse, 'Fluorescence'; John Trowbridge, 'Electric Double Refraction of Light'; Edwin H. Hall, 'Thermal and Thermo-electric Properties of Iron and Other Metals.'

The Rumford fund now amounts to nearly \$60,000, and is administered by a standing committee of the American Academy. Applications for aid in the furtherance of research on light and heat may be made to the chairman of the committee, Professor Charles R. Cross, in care of the American Acad-



THE *Galilee* IN SAN DIEGO HARBOR.

awards having been made in 1902 to Professor George E. Hale for the spectroheliograph and in 1904 to Professor E. F. Nichols for his researches on radiation. The surplus income of the Rumford fund was at first awarded chiefly to the Harvard College Observatory and to other departments of Harvard University. The awards this year have been for researches as follows: Professor D. B. Brace, whose untimely death occurred this month, 'Double Refraction in Gases in an Electrical Field'; Charles B. Thwing,

of Arts and Sciences, Boston, Mass.

THE MAGNETIC SURVEY OF THE NORTH PACIFIC OCEAN.

THE CARNEGIE INSTITUTION of Washington has made an appropriation of \$20,000 to cover the expenses for the current year of a Magnetic Survey of the North Pacific Ocean, to be made by its Department of Terrestrial Magnetism of which Dr. L. A. Bauer is the director. For this purpose a wood-built, non-metallic sailing vessel of

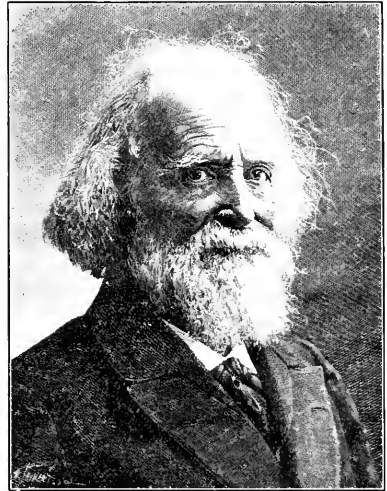
about 600 tons displacement, *The Galilee*, has been chartered at San Francisco. The scientific personnel at present consists of Mr. J. F. Pratt, commander; Dr. J. Hobart Egbert, surgeon and magnetic observer; Mr. J. P. Ault, magnetic observer, and Mr. P. C. Whitney, magnetic observer and watch officer. The sailing master is Captain J. T. Hayes.

Trial trips were made early in August under the direction of Dr. Bauer, and the ship set sail on September 1 for the Hawaiian Islands. After its return, it will depart early in 1906 for a more lengthy cruise, embracing nearly the entire circuit of the North Pacific Ocean. The total length of the course marked out is about 70,000 knots. It is not supposed that great irregularity in the distribution of the earth's magnetism will be found over the deep waters of the Pacific, but distortions are likely to occur along the coast and in the neighborhood of islands. Thus, as Dr. Bauer has pointed out, with the aid of the results of the detailed magnetic survey of the United States and Alaska, opportunity will be afforded of studying the effect of the configuration of land and water on the distribution of the magnetic forces. The first circuit, passing as it does along the American and Asiatic coasts, will yield especially interesting results in this respect. Along the Aleutian Islands marked local disturbances will probably be disclosed, as reports are received frequently from mariners in this region regarding the unsatisfactory behavior of the compass.

ELISÉE RECLUS.

M. ELISÉE RECLUS, who died near Bruges, on July 4, in his seventy-sixth year, was an eminent geographer and an interesting personality. He was the son of a protestant pastor, one of a family of twelve children, several of whom have become eminent. The revolutionary spirit which he showed

all through his life may have been responsible for his geographical work, for it was after he was expelled from France in 1851 that he spent six years in continuous travel. Reclus returned to Paris in 1857 and wrote numerous geographical articles and books, including the volumes that have been translated into English under the title 'The Earth.' During the siege of Paris, he took the side of the com-



ELISÉE RECLUS.

munists, though among them he was conservative. He was, however, again banished from France, and did not return until the general amnesty of 1879. In Switzerland he began his great 'Nouvelle géographique universelle,' the nineteen volumes of which were completed in 1894. He left at the time of his death an unpublished work in four volumes treating history as influenced by geographical conditions. During the later years of his life he was a professor in the Université libre of Brussels. We reproduce here a portrait from *La Nature*. Reclus is said to have been a man of the most intense human sympathy, always ready to sacrifice himself for his communistic and anarchistic convictions. Yet he found time to accomplish a vast

amount of work, noteworthy for its attractive style as well as for its scientific accuracy.

SCIENTIFIC ITEMS.

WE regret to record the death of Professor De Witt Bristol Brace, head of the Department of Physics of the University of Nebraska, and of Baron Ferdinand von Richthofen, professor of geography in the University of Berlin.

DR. W J MCGEE, U. S. Commissioner of the International Archeological and Ethnological Commission, lately chief of the department of anthropology and ethnology of the St. Louis Exposition and ethnologist in charge of the Bureau of American Ethnology, has been appointed managing director of the St. Louis Public Museum.—H. Foster Bain, Ph.D. (Chicago), geologist of the U. S. Geological Survey and formerly assistant state geologist of Iowa, has been appointed state geologist of Illinois.—Dr. Melvill Dewey has resigned the directorship of the New York State Library and of the Home Education Department. It is expected that a statement may be made later in regard to the causes of Dr. Dewey's resignation and the future of the library school which he has conducted.

MR. JOHN D. ROCKEFELLER has now

paid to the General Education Board the \$10,000,000 in accordance with the announcement made last June. The income, it will be remembered, will be distributed to promote a comprehensive system of higher education in the United States, and it is assumed, though perhaps not correctly, that the larger part will be given to the denominational colleges. The secretary of the board is the Rev. Dr. Wallace Butterick, 54 William Street, New York City.—By the will of the late General Isaac J. Wistar, the Wistar Institute of Anatomy and Biology of the University of Pennsylvania, founded by him, will receive the residue of his estate, thought to amount to about \$400,000.

MESSRS. HOUGHTON, MIFFLIN & Co. announce that they will publish in eight volumes the Proceedings of the International Congress of Arts and Science, held at St. Louis, in September, 1904. The volumes, ranging from 500 to 800 pages, have the following titles: 1. 'Philosophy and Mathematics'; 2. 'Politics, Law and Religion'; 3. 'Language, Literature and Art'; 4. 'Inorganic Science'; 5. 'Biology and Psychology'; 6. 'Medicine and Technology'; 7. 'Social Sciences'; 8. 'Education and Religion.'

THE POPULAR SCIENCE MONTHLY.

DECEMBER, 1905.

FRESH-WATER SPRINGS IN THE OCEAN.

BY PROFESSOR C. H. HITCHCOCK,
DARTMOUTH COLLEGE.

THE ancient Greeks tell of a river of the Peloponnesus called Alpheus, rising in Mt. Stymphalus, flowing through Arcadia and Elis, and then making its way beneath the Mediterranean as far as Sicily, where it united with the fountain Arethusa near Syracuse. It was the love of a swain for a nymph which led to this movement, and this emotion seems to have been able to prevent the commingling of the two kinds of water where ordinarily a mixture would result. What has been narrated in fable seems to be true to-day in the existence of boiling fresh-water springs rising up persistently in the briny deep off certain shores in the Hawaiian and West India islands and elsewhere. So little is known about them that I venture to present a few facts that have fallen under my observation, in the hope that this slight contribution to hydrology may interest others and lead to important results.

The suggestion of this conclusion came from the combination of facts ascertained in different parts of the world. First of all was a study of artesian wells upon the island of Oahu.* This island has an area of about 600 square miles, an irregular four-sided figure with an extreme diametral line of 46 miles. Figure 1 represents Oahu and a few of its more general topographical features. The land rises to two mountainous ranges about 13 miles apart, parallel to each other. The Kaala or Waianae Mountains, 21 miles long, lie on the southwest side, with a culmination of 4,030 feet. The Koolau Mountains on the northeast side culminate in Konahuinui, 3,105 feet high, and a length of 37 miles; and the two parts are known as Koolauloa and Koolaupoko.

* 'Geology of Oahu,' *Bulletin Geol. Soc. America*, Vol. XI., p. 25.

The lowland between rises gradually to a watershed 888 feet above the sea. Each range represents an elongated dome composed of basaltic layers gently inclined outwards in every direction (quaqueversal). The Kaala dome originated first in igneous ejections outpouring at the bottom of the ocean; they were constantly renewed, and finally emerged above the waters. It was then exposed to the erosive influences of the rains brought by the trade-winds. The streams excavated cañons in the basalt upon both sides of the island, eating away more of the rock in certain portions than in others. After a

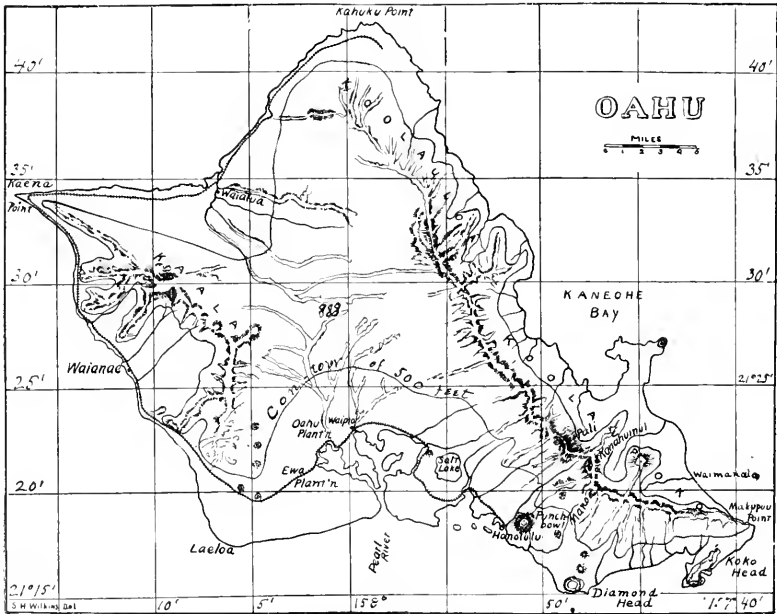


FIG. 1. MAP OF OAHU.

long period a similar but longer island developed upon the eastern side, becoming the Koolau range, with more marked erosion upon the windward side, and very little upon the northern half of the leeward side. The Koolau lava poured itself out profusely, and covered up some of the earlier formed cañons upon the Kaala range.

The character of the erosion is shown in Figure 2 upon the Waianae side of the Kaala range. The cañon has been enlarged to an alcove and the precipitous side—called a *Pali* by the Hawaiians—presents a curious scalloped surface, or what might almost be called the ribs of the mountain side. Precisely similar waves appear upon the pali at the eastern side of the Koolau range. The most interesting point is at a wind-gap, 1,205 feet above the sea, the only place in the whole range where a road has been cut through from Honolulu by way of Nuuanu Valley to Kaneohe Bay. Up this valley for about eight miles about a hundred years ago King Kamehameha drove an army of his enemies,

who were crowded forward so furiously that they were precipitated down this pali of a thousand feet, where their bones could be seen till quite recently. This pali is one of the most interesting sights visited by modern tourists.

The Pliocene Tertiary.

These are quite extensive plains near the sea level composed partly of sediments derived from the decay of the basalts and other igneous products, and partly of calcareous marine deposits. Without attempting precision of delimitation, our map presents an approximate contour line of 500 feet altitude, which may represent the upper border of the terrane, which is clearly proved by its fossils to belong to the Pliocene



FIG. 2. EROSION ON THE WAIANAË SIDE OF KAALA.

Tertiary.* This band has a very variable width, dependent upon the amount of subaerial erosion, being the most extensive in valleys like those of Waianae and Waimanalo and in the more open area between the two mountain ranges. It is upon these plains that several large sugar plantations have been installed, for whose benefit numerous artesian wells have been sunk. In the southern part of Oahu there is a continuous belt of cane-fields eighteen miles in length, and averaging two in breadth to the west of the city of Honolulu. Others are near Waianae and Waialua.

The sugar plantations were at first located upon other islands of the group, as on Kauai, Hawaii and Maui, where plenty of streams of water afford plentiful supplies for moistening the soil, or to trans-

* W. H. Dall, *Bulletin Geol. Soc. America*, Vol. XI., p. 57.

port the cane from the uplands to the mills in flumes. Oahu was neglected because it is comparatively arid. Near Hilo, upon Hawaii, the rainfall amounts to 175 inches annually; in East Maui to 230 inches annually; while about Honolulu it varies from 24 to 38 inches; at Ewa and vicinity from 16 to 40 inches, and is quite variable by years, and insufficient for the growth of the cane. At first, attempts were made to supply water by irrigation. Like other cities, Honolulu receives much water from mountain streams brought by pipes for household and manufacturing purposes, as well as for the flowage of extensive tracts of rice land. The great need of water led to suggestions of an artesian supply. In 1879 James Campbell sank the first artesian well upon the island, near the Pearl River lagoon. Water commenced to flow from the depth of 240 feet, and the auger penetrated 33 feet more. The next one was sunk the following year at the mouth of Manoa Valley, where the discharge proved to be abundant from the depth of 298 feet. In the same year Judge McCully obtained a still greater supply from the depth of 418 feet. This last well was within the city limits, where it was easily seen by the public, who thoroughly appreciated its value. Many other persons followed the example of these pioneers, till now there are 195 wells upon the five leading plantations, yielding daily 287 million of gallons, and there are many more within the city limits of Honolulu.*

The Artesian Conditions.

Oahu presents two series of diversified sheets of rock dipping gently toward the sea from high central points; but the material is volcanic. In the early days successful artesian wells had been sunk through sedimentary strata, whence it was inferred that it would be useless to attempt borings in the so-called unstratified rocks. Many were dissuaded from such attempts by that consideration, yet any geologist would quickly observe the resemblance between these volcanic sheets and a nearly horizontal stratification. Nowhere is the succession of varied igneous layers better seen than on Kauai. This land is to be compared with either one of the Oahu or Maui domes; so that these latter islands may be termed *doublets*. The highest land on Kauai is at its center, Mt. Waialeale, over 5,000 feet in altitude. So far as is known no scientific explorer has yet penetrated this central point which is also commonly obscured by clouds. On the flanks of this central elevation are extensive plains gently inclined seaward and reminding one of a sedimentary fan, covered by a fertile soil. Streams have cut through these plains, displaying perhaps 200 feet thickness of alternating volcanic clays, earths or laterites and hard basalts. The diversity of the sheets is such as to give the conditions necessary for the de-

* Since this statement was made the number of wells and the consequent yield have considerably increased.

velopment of underground currents, but these are all clearly of volcanic origin, and here and there may be seen the remnants of the secondary craters whence came the ejections.

Oahu resembles Kauai in the dispersal of friable material in layers alternating with hard basalts, and adds marine accumulations to the igneous. The meteorological conditions explain the source and spread of the waters. Rain is profusely abundant on the highlands. The trade-winds, laden with moisture, drop their burdens on coming in contact with the land surfaces. The maximum rainfall is at the altitude of about 1,200 feet. The preponderance of the discharge, being upon the windward side, determines the place of the most copious streams and the more effective erosion. Hence the domes have been worn away unequally. One side may be entirely removed, and the other be scarcely affected at the surface. If the ridge is narrow at the altitude of greatest precipitation both sides will be extensively worn down. This is well shown on the Koolau upland, where the southeast end has been greatly denuded upon both sides from Mokapu point to the pali, while to the north, at a greater height, the cañons are less conspicuous on the west side.

The laying bare of the interior of the dome allows the water to sink into the pervious layers, and to flow beneath the surface towards Kaala and the southwest. Only the needful alternation of pervious and impervious strata is necessary to give rise to the subterraneous streams which will send water to the surface when pierced by the artesian wells.

The borings upon Oahu prove the alternation of basalt, clay, earth and limestone to the depth of several hundred feet. The principal water-bearing stratum is a very porous basalt, from 300 to 400 feet below the sea level by the shore. It has a hard, impervious cover, sufficiently tight to prevent the passage of water through it. The following general statements concerning the artesian conditions seem to be well established:

1. The presence of a porous water-bearing stratum beneath an impervious cover.
2. Water is reached usually at the depth of from 300 to 500 feet.
3. The water flows freely without pumping only in a narrow belt of territory adjacent to the coast line, where the surface is but slightly elevated; which is 42 feet at Honolulu, 32 feet at Ewa and 26 feet at Kahuku, at the northeast angle of the island. Wells sunk in higher ground show the water rising to the level indicated. Thus at the height of 100 feet the water will rise to the level of 42 feet at Honolulu, above which it will discharge only by the application of a pump.
4. For convenience in obtaining a proper supply several wells are sunk adjacent to each other. Naturally, as development takes place, the number of the wells increases. Thus the Ewa plantation had at first six ten-inch wells about thirty feet apart connected to a single pump,

which lifted the water about sixty feet. Later the wells are a foot in diameter in groups of ten for each pump. The water is forced through steel pipes twenty-four and thirty inches in diameter to a maximum elevation of four hundred feet. From various points ditches are dug which carry the water to every field of the plantation. The photograph, Figure 3, shows one of these pumping stations where there are twenty wells, each a foot in diameter. Though the pumps act without cessation, the water never fails; 5,000 acres of land are irrigated from these wells. The water here rises to the height of 22 feet above sea level.

5. These wells at Ewa are found to be slightly affected by the brine

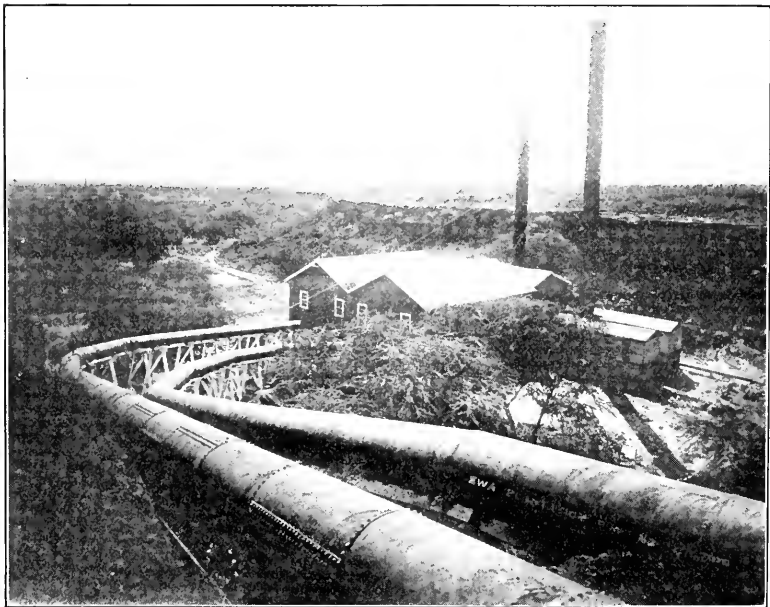


FIG. 3. EWA PLANTATION PUMPING STATION.

of the sea. The natural waters of the island contain .0073 per cent. of salt according to Dr. Walter Maxwell;* Pacific water holds 2.921 per cent. of the same. One hundred grains to the gallon of water represents 0.14 per cent. The analyst of the Ewa company found that the chlorine present (sodium chloride) was more abundant in the wells nearest the ocean. At station No. 1 the chlorine amounted to 17.61 grains in a gallon. At stations Nos. 2 and 3, farther inland, the chlorine had diminished to 8.18 and 11.97 grains to the gallon. By experiment at several localities it has been found that the salinity increases when the pumping becomes excessive. At Ewa it is stated that vegetation is not at all affected when the number of grains per

* 'Lavas and Soils of the Hawaiian Islands,' 1898.

gallon is less than sixty. At Molokai, where the salinity is greater, it is stated that the cane is not affected unless the number of grains per gallon exceeds one hundred.

From all the facts available, the conclusion seems warranted that the underground waters descend to the seas from the highlands and remain free from admixture till the pressure of the ocean exceeds that of the descending stream, when a commingling of the two liquids results. When the ocean pressure becomes greater, because of excessive pumping, the brine will increase in amount. In a small island the ocean water will force itself inland quite conspicuously. Molokai illustrates this proposition. Our information is derived from a report of Waldemar Lindgren in the Water Supply and Irrigation Papers No. 77. The springs there are of three classes, of which only the first calls for consideration here, (1) those very near the shore, (2) those breaking forth up to the height of 2,000 feet, (3) running streams still higher.

Shallow wells near the shore show the following degrees of salinity or number of grains per gallon, 238, 403, 150, 126, 109, 86, 102, 86; of deeper wells the first gave 86 grains at the surface and became ocean water at 50 feet. The second became ocean water at 125 feet. At Naiwa there are 90 grains of salinity at 70 feet. At Kalamaula several deep wells gave 102 and 104 grains and pure ocean water. The American Sugar Company sank several deep wells at Kaunakakai, of which the first five had 150 grains per gallon; others ranged from 270 to 485 grains. The Risdon wells yielded 70 to 79 grains per gallon. Better results appeared in nine wells sunk at Kawela, many of them showing less than 50 grains of salinity. The fresh water is contaminated up to four or five feet above the sea level. None of the underground streams can be more than eight miles in length, and many do not exceed three. It is also probable that no impervious layer protects the underground water as in Oahu.

6. There are springs of fresh water near the sea-shore in Oahu which may correspond to the artesian fountains. One is the famous Kamehameha Bath near Punahou, a second is near the railroad station at Honolulu, and a third gladdens the thirsty soul at Waiialua near the Haleiwa Hotel. Another is at Niu, west of Koko Head. It would seem that the underground water finds its way to the surface through some crevice, after the usual manner of springs, and that it is powerful enough to prevent the commingling of the ocean water with it.

The theory of the subterranean stream from the summits to sea level has been further tested practically by the driving of tunnels to reach the water near its source. Thus derived the water is free from any possible saline contamination, and being delivered by means of a ditch sloping downwards, the expense of sinking artesian wells and the subsequent pumping is saved. In this way a copious daily flow has

been obtained from the Waianae side of Kaala, utilized to run a dynamo, besides irrigating several plantations. On Maui near Lahaina, a six-million-gallon daily flow is derived from the altitude of 2,600 feet through a tunnel of the same length. There are no springs nor other signs of underground water along the route. It must be permanent, as the flow has been constant for the past two years. Other examples could be cited.

Springs in the Ocean.

7. After so many introductory statements it is possible now to postulate the central idea of this paper: springs of fresh water arise in the midst of the ocean at some distance from the shore. The facts are not numerous, but are stated upon the best authority. Professor Joseph Le Conte, in his 'Geology,'* says that fresh-water springs arise in the ocean in the Hawaiian Islands. In reply to my inquiry as to details, he wrote that he had not preserved the memoranda relating to these phenomena, and that they had escaped his memory. No one can doubt the correctness of the statement in view of the existence of the proved underground waters. Powerful streams discharge millions of gallons of water through the artificial openings very near the sea-shore. If not intercepted, they must continue a considerable distance out to sea, and hence must well up to the surface amid saline billows.

Inquiry about these springs during the past summer in the territory of Hawaii has resulted in the discovery of several upon Oahu, there is one off Diamond Head; a second off Waialae. At the east end of Maui, in Hana, there was a fortress named Kaimuke, occupied by soldiers in the ancient times. As it was almost an island communication with the mainland was not feasible in the time of a siege, and for the lack of water it could not have been held except for the presence of submarine springs. The natives would dive down to collect water in their calabashes, which supplied all the wants of the garrison. Other springs were known in the harbor of Hana, and at low tide at Lahaina. Upon Hawadi I found there were fresh-water springs off Kawadahae and Punaluu. Further inquiry would doubtless discover many other examples.

Underground Waters in Florida.

A later residence of a few weeks in Florida proved that the characteristic fluvial phenomena cited above were even better developed there than in Hawaii. If there is anything peculiar about drinking-water one discovers it very soon, as was the case in Florida. The first feature to be noted along the eastern coast of Florida is the presence of hundreds of driven and artesian wells. Every cottage of importance derives its water for culinary and irrigating purposes from them.

* 'Elements of Geology,' p. 74.

In the Water Supply and Irrigation Papers, No. 102, Mr. M. L. Fuller, of the U. S. Geological Survey, has brought together all sorts of information about the natural and artificial sources of water of Florida, as well as of the whole eastern United States. Mr. Fuller has kindly answered my inquiries about these fresh-water springs in the ocean, stating important facts supplementary to this Water Supply Paper.

The peninsula of Florida is underlaid by Tertiary deposits of all ages, the older portions lying along the central axis, and are flanked upon both sides by the Oligocene, Miocene and Pliocene. Artesian wells are successfully operated upon both the Atlantic and Gulf coasts. The strata dip gently from the central axis towards both shores, and where there is the proper diversity of hard, soft, pervious and impervious strata the water comes to the surface without pumping. A few statements about the better known wells partly derived from original observations and partly taken from Mr. Fuller's report will be pertinent. At Jacksonville the visitors to the subtropical exposition in 1888 saw water flowing in a stream from a well several hundred feet deep, supplying the various needs of the management. Flowing wells have since then been sunk to the depths of 616, 708, 740, 800, 850, 3,000 and 5,000 feet.

At St. Augustine a well 1,500 feet deep furnishes the East Coast Hotel system with plenty of water, including a spacious swimming tank. It has a temperature of 70° F., so that bathing in it is agreeable in the coldest weather.

At Ormond there are numerous wells at comparatively shallow depths, the deepest one reaching 200 feet. At Daytona, close by, there are 400 wells from 100 to 220 feet deep. There are many others at nearly every town along the coast. At Palm Beach, close to the seashore, a well 1,200 feet deep is quite saline.

On the west coast the wells in the more northern section yield water by pumping. In Manatee County and at Fort Myers the fluid discharges in the normal way from depths exceeding 400 feet. One on the premises of T. A. Edison, the distinguished inventor, yields most abundantly from the 350-foot level, and will discharge from the height of twenty feet.

Most of these waters are characterized by the presence of sulphur, besides being warm. Chemical analyses show the presence of the following compounds: calcium sulphate, sodium chloride, sodium carbonate, calcium and magnesium carbonates, and occasionally potassium chloride and sulphate. Commonly these ingredients are so abundant as to make the water disagreeable to the taste, and when used for bathing the tubs are easily soiled, and cleansed with difficulty. When used for the table it is found expedient to allow the water to stand for

several hours before using, so that the sulphur may be volatilized and the temperature reduced.

Florida is a well watered country. Lakes, streams and springs are extremely numerous. The underlying limestone is full of caverns containing water. Every one knows about the Silver Spring in Marion County. It starts as a full-grown river from a spring 25 to 30 feet deep, perfectly clear, with an outlet 60 feet wide, 10 to 14 feet deep. It is the Oclawaha River, navigable for steamers from its very source. The water is probably the rainfall of the region filtering through miles of sand, with a temperature of 72° and perceptibly calcareous to the taste.

The water in the lakes is purer than that from the springs, probably because on exposure the compounds break up, and the gases, sulphur and hydrogen, carbonic acid, oxygen and nitrogen (common air) are eliminated. The Everglades and Lake Okeechobee illustrate this fact. The steamers plying down the Kissimmee River, across Okeechobee and down the Caloosahatchee River to Fort Myers obtain their drinking-water from far out in the lake, because nowhere else can it be found so palatable, or so well fitted for use in the boilers of the steamers.

The source of the sulphuretted hydrogen must be the various sulphates decomposed by the action upon them of organic matter. The mineral compounds arise naturally from the solubility of the various salts, either from the original strata or from their dissemination through the soil.

Fresh-water Springs in the Ocean.

Many of these underground streams proved to exist by the artesian bore-holes are of great volume, and hence must pass to some distance under the ocean. This fact is further corroborated by the small degree of salinity even in the deeper wells. Statements made by residents claim the existence of fresh-water springs miles away from the land opposite St. Augustine, Matanzas and Ormond. The first of these is also mentioned by T. C. Mendenhall, formerly superintendent of the United States Coast Survey, in a letter to J. W. Gregory, in charge of Artesian Well Investigations, Department of Agriculture.

Mr. M. L. Fuller furnishes me with the following additional localities. Dr. Mendenhall mentions the reported occurrence of fresh-water springs off the mouth of the Mississippi River. In 'The Island of Cuba,' by Lieutenant A. S. Rowan and M. M. Ramsey (Henry Holt & Co., 1896), page 18, it is stated that the water is often forced by hydrostatic pressure to the surface far out at sea. Elisée Réclus remarked that 'in the Jardines (east of the Isle of Pinos), so named from the verdure-clad islets strewn like gardens amid the blue waters, springs of fresh water bubble up from the deep, flowing probably in subterranean galleries from the mainland.'

Mr. Fuller also adds the following quotation from a paper by

himself upon the 'Hydrology of Cuba,' in the Water Supply Paper No. 110, page 93: the springs "issue at all altitudes, from the higher portions of the hills down to the lowland border, or even at sea level. . . . Not all the water comes to the surface as springs, but some passes outward and emerges from the sea bottom along the coast, where in many instances the fresh water can be seen bubbling up through the salt water. Such springs occur in Havana Harbor and at many other points. The fresh water which surges as copious springs on some of the keys is probably of the same origin, coming from the mainland through subterranean passages in the limestone."

These may be an illustration of the derivation of fresh water from the mainland upon the island of Nashawena in Buzzards Bay Massachusetts. This is a large island midway between New Bedford and Marthas Vineyard, upon which it is proposed to erect a new state prison as well as a leprosarium. Near the center of the island and very high up is Menaud Pond, a splendid body of pure fresh water, capable of furnishing an ample supply to the new institutions. There is no perceptible inlet or outlet; the supply seems to be derived from springs, such as may be conceived to originate upon the mainland, to pass beneath the bay and to rise to the surface at the summit of Nashawena. Except for the accidental presence of land here this stream would have risen to the surface in the midst of salt water. People familiar with the shallows over the region between Long Island and the Great Banks of Newfoundland speak of an 'underground river' extending from Labrador to Block Island having many outlets similar to the supposed one at Menaud Pond. Our theory of a connection with the mainland through Tertiary strata is a better one.

Conclusions.

The foregoing facts warrant us in believing in the existence of fresh-water springs bubbling up through the brine of the ocean. They are known to exist among the Hawaiian and West India islands and off the coast of Florida. The necessary conditions seem to be those which will permit the existence of underground streams flowing towards the sea; such as will render the boring of artesian wells successful. Evidently there must be strata—whether of the later fossiliferous rocks or igneous sheets—dipping gently seawards; and the springs can not appear very far away from the coast. We should, therefore, look for these phenomena adjacent to islands and all coasts bordered by Tertiary and basaltic rocks. They may be seen off nearly the entire eastern coast of the United States—from Cape Cod to the Rio Grande. Possibly also fresh water may be able to accumulate beneath the submarine belt of Tertiary between Nantucket and the Great Banks of Newfoundland. It is conceivable that they might be utilized for the supply of steamships in places where the local supply is either defective or unwholesome.

ECONOMY IN IRRIGATION.

BY DR. VOLNEY M. SPALDING,

DESERT BOTANICAL LABORATORY, TUCSON, ARIZ.

THE annual reports of the Reclamation Service of the United States and current numbers of *Forestry and Irrigation* embody, as is well known, a large amount of information of great general interest and at the same time of vital concern to that half of the country lying west of the Missouri River. What chiefly impresses the casual reader is the fact that a body of trained engineers, under government employ, in Arizona, California, Colorado, North and South Dakota, Idaho, Kansas, Montana, Nevada, Oklahoma, Oregon, Utah, Washington and Wyoming, are engaged in the great work of opening arid America to cultivation, and that irrigation is the chief agency by which this is being accomplished. Topographic parties are engaged in mapping and in sinking test pits, careful surveys have been made, land and water relations in different states have been thoroughly studied, and methods of raising, storing and distributing water are being worked out, both theoretically and practically, on a scale and in a manner new to the world. With a sympathetic popular interest awakened, the favorable attitude of the general government, and the high character and attainments of the experts who are engaged in solving the problems involved, the Reclamation Service has made noteworthy progress in a work that for scientific interest combined with economic importance is perhaps second to none ever attempted by any government.

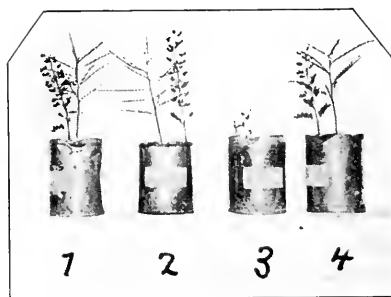
As is natural in a region where water is the one great essential, and of which it would seem that there can never be enough, the first thought apparently in all cases has been directed towards securing a sufficient and permanent supply, while economy of use has not, thus far, been embodied in any satisfactory general system. Years ago Professor Hilgard, of the California Agricultural Experiment Station, urged the necessity of more perfect utilization of irrigation water by putting it where it would do the most good, close to the stem of the plant or trunk of the tree, and letting it soak downward so as to form a moist path for the roots to follow to the greatest possible depth.* More recently Dr. Elwood Mead, chief of irrigation and drainage investigations, U. S. Department of Agriculture, has given measurements showing the great loss by seepage and evaporation from irrigation canals, and has discussed methods by which the water-supply might be more economically utilized. After giving tables which show in a striking manner

* California Expt. Sta. Bul. 121. 1898.

the extent of losses by methods still in vogue, the author concludes: "A comparison of the duties secured . . . leads to the belief that it will be possible through improved methods to double the average duty now obtained, so that the quantity now required for one acre will serve to irrigate two. If this can be accomplished it will relieve the scarcity under many canals, put an end to many controversies growing out of such scarcity, lessen the expense per acre for water and immensely increase the productive and taxable resources of the arid states."*

In various parts of the old world, where much valuable land has been reclaimed by irrigation, water is distributed in such a way as to secure the best practicable results. At Biskra, Algeria, for example, where the famous Deglet Noor date is grown and the supply of water is limited, an excavation is made around the base of each tree, and this is filled with water, thus greatly lessening the loss that would otherwise result from evaporation.† At Bassorah, on the river separating Persia from Arabia, the extensive date plantations are watered by means of a system of canals which are flooded with each high tide, dams of mud being built with the hollow trunks of palms run through them, which permit the water forced into the canals by the rising tide to flow away slowly. Thus, by taking advantage of favorable natural conditions, an ideal system of combined irrigation and drainage is effected at a minimum of expense.‡

In close agreement with the estimates of Dr. Mead, observations of the writer have shown that plants supplied with water below the surface of the ground have made a vigorous growth on a little more than one half the quantity of water that would be required if applied at the surface. To report a single rather striking case—the plants shown in the accompanying figure are photographs of seedlings of palo verde (*Parkinsonia*, two species) which, with some other desert plants, were under investigation. They are here shown as they appeared August 10, after being supplied with measured quantities of water since June 12. During this period numbers 1 and 2 each received 71 ounces of water, while numbers 3 and 4 each received but 39 ounces, or 55 per cent. as much as 1 and 2. Numbers 1 and 3



SEEDLINGS OF PALO VERDE Number 3 had as much water as number 4, but it was not economically applied.

* U. S. Dept. Agr. Office of Expt. Stations, Bul. 86. 1900.

† Swingle, W. T., 'The Date Palm and its Utilization in the Southwestern States,' U. S. Dept. Agr. Bureau of Plant Industry, Bul. 53. 1904.

‡ Fairechild, D. G., 'Persian Gulf Dates and their Introduction into the United States,' U. S. Dept. Agr. Bureau of Plant Industry, Bul. 54. 1903.

received at the surface all the water given them, while 2 and 4 were subirrigated by means of a three-fourth-inch glass tube which extended some three inches vertically into the soil.

These plants started all alike, and in every other respect except water-supply had an even chance, so that the difference in their development, as seen two months after the seeds were sown, is highly instructive. The thing which at once strikes the eye is the hopeless condition of the plants numbered 3, which, having had a meager supply of water, applied wholly at surface, had been left behind in the race at an early day and were now drying up. The plants numbered 4 had received exactly the same amount of water, but it was placed, by the simple method of subirrigation already described, where it would be utilized with a minimum loss by evaporation.

A comparison of numbers 1 and 2 indicates that there is no virtue in subirrigation, in itself considered. It is merely a means of preventing waste. Both of these had received a large quantity of water, the former at the surface, and the latter by way of subirrigation. As far as this experiment goes, then, it appears that aside from alkaline or other conditions requiring special treatment, which it is not the purpose of this article to discuss, water may be applied indifferently at or below the surface, if there is only enough of it. It is simply a matter of supplying the roots of the plant with all the water it requires. But if it only needs about half as much when applied in the simple way that has been described, the fact is of sufficient importance to engage the attention of horticulturists from Colorado to California. It is true that reports on the results of subirrigation, thus far, have not been encouraging in all respects, and the application of such methods on a large scale would necessarily involve a rather large initial outlay; but when one considers the great expense involved in preparing for the irrigation of an orange grove, say, in southern California, and the continual outlay of time, labor and money required by the present wasteful methods of applying water, it may well be asked whether some simple method of subirrigation may not be developed which, when once the practical difficulties have been overcome, will prove in the end more economical as regards cash outlay, and at the same time make it possible for the available water to do double duty.

It is to be borne in mind that with very few apparent exceptions, such, for example, as the areas bordering upon the lower Colorado, the arid states and territories are nowhere possessed of an unlimited water-supply; in most cases there is a fixed limit, beyond which no amount of 'development' will produce more water. If, then, by economical methods, a given quantity of water—all that can be depended upon for a certain area—can be made to irrigate satisfactorily twice as many acres as by wasteful methods, he who shows how this can best be done, and inaugurates the doing of it, will deserve well of his country.

MINING AND USE OF METALS BY THE ANCIENT EGYPTIANS.*

BY PROFESSOR R. D. GEORGE,
UNIVERSITY OF COLORADO.

THE use of metals by the ancients antedates authentic history. So far as the discoveries of the archeologist have shown, the metals first used by mankind were those which occur native, such as gold, silver and copper. These three possess qualities which would appeal to the primitive workman. They are all bright and beautiful when polished, they are all malleable and easily shaped with the hammer, they respond readily to the graving tool and are highly resistant to fire. The ancient Egyptians knew, and used, gold, copper, silver, iron, lead and tin, and the alloys, bronze, brass, electron and solder. The fact that brass was used has led some Egyptologists to believe that zinc was known, but the unalloyed metal has not been found, nor do the inscriptions contain any reference to it. The majority of writers, therefore, hold that the brass was produced by mixing some ore of zinc, possibly calamine, with copper ores in the smelting furnace. The oxide of manganese is supposed to have been an article of commerce between the Bedouins of the Sinai peninsula and the ancient Egyptians.

'Nub,' the Egyptian word for gold, is found in the oldest inscriptions, and at Beni-Hassan, a series of pictures dating back to the twelfth dynasty, 2130-1930 B.C., illustrate the whole process of making gold ornaments. Centuries before this, the Nubians had mined gold in the mountainous, desert regions between the Nile and the Red Sea, and it has been suggested that the name Nubia is derived from the name of the metal. The Egyptian kings of the twelfth dynasty invaded Nubia and finally annexed that part of the territory containing the gold mines, and built and garrisoned a wall which should mark the boundary between the two peoples. The mines were vigorously operated by the new owners, and the quantity of gold in the land of the

* The materials for this article have been drawn from many sources, and it would be impossible to give specific references, as a single sentence may contain facts taken from several writers. The principal works consulted are: Birch (ed.), 'Records of the Past'; Brugsch-Bey, 'Egypt under the Pharaohs'; Mahaffy, 'Empire of the Ptolemies'; Maspero-Sayce, 'Dawn of Civilization'; Rawlinson, 'Ancient Egypt'; Perrot and Chipiez, 'History of Ancient Egyptian Art'; Winckler, 'The Tell-el-Amarna Letters'; Adams, 'Egypt Past and Present'; Von Meyer, 'History of Chemistry'; Erman, 'Life in Ancient Egypt'; Chas. J. Alford, *Eng. and Min. Jour.*, Vol. 73; Professor Petrie in *Harper's* for July, 1888.

Pharaohs increased rapidly. At the opening of the New Empire, about 1530 B.C., the lavish use of this metal by the kings indicates the wonderful productiveness of the mines. Much gold is believed to have been brought into Egypt from Ethiopia and the eastern shores of the Red Sea, and gold dust (?) from the Soudan.

Within the last few years the ancient workings of many gold mines have been discovered in eastern and southern Egypt and in Nubia. The mining region of Egypt proper was the mountainous belt bordering the Red Sea from the Gulf of Suez to the southern part of the country, where it connected with the mining area of the Nubian Desert farther inland, and with that of Nubia proper. Charles J. Alford* describes the northern part of this region as follows: "The larger mountain masses are usually formed of a hornblende granite. Surrounding these, in lower ranges, and covering very extensive areas, is a rather fine-grained gray granite, passing in places into a gneiss, and that into mica schist, traversed by dikes and intrusions of greenstone, felsite, porphyry, and a very fine grained, white, elvan granite. It is in these rocks that most of the auriferous quartz veins were found to occur, and the more the granite was cut up by the intrusive rocks, the more frequent and more promising the quartz veins appeared to be."

In this region a number of mining sites were found which consisted of groups of round and square huts built of rough stone. Some of these villages are surrounded by walls. The old sand-filled workings follow the veins and ore-shoots, but with few exceptions the working faces and the bottoms of the shafts have not been uncovered by recent explorations. Near Um Rus on the Red Sea, there is an ancient camp of large size. A large number of quartz veins outcrop in a gray granite which is much cut by dikes of greenstone, porphyry and felsite. Nearly all the veins were worked in ancient times, and in places some of the rich ore-shoots have been completely worked out, while the leaner ore has been allowed to remain. The veins vary in thickness from one to over three feet, and all carry free-milling gold in varying amounts. The quartz is white to gray in color, and in places carries a little pyrite. The ore seems to have been reduced to a coarse powder by means of stone rolling pins on elliptical rubbing stones. It was then transferred to a circular mill consisting of an upper and a lower stone.†

At one of the camps in the south, there is the ruin of a building 260 feet by 190 feet, which is supposed by some to have been the mill in which the gold was separated from the ore. At the old workings near Coptos, Lat. 26° N., may be seen the ruins of over 1,300 stone huts once occupied by the miners. Very extensive workings found still farther to the south are probably the mines for which the kings of the twelfth dynasty sacrificed the lives of many thousand men, and

* *Eng. and Min. Jour.*, Vol. 73, p. 103.

† See illustration. *Eng. and Min. Jour.*, Vol. 73, p. 104.

from which the largest supply of Egyptian gold was derived. They are located in an almost inaccessible mountain group surrounded on all sides by a waterless desert. Here may be seen tunnels and shafts penetrating the mountains to unknown depths. Three hundred stone huts shelter three hundred mills used in pulverizing the ore, immense cisterns once caught the scanty water supply from the higher slopes, and near them stand the sloping stone tables on which the pulverized ore was washed. Records show that these mines were worked with but little interruption for twenty centuries by the Egyptians, and we have no means of knowing how long they were worked by the Nubians before them.

Inscriptions near the mines recount the difficulties of the journey by which the region was reached, and, judging by the loss of life on the way and the distress suffered by those who reached the goal, the 'Forty-niner' and the Klondiker could not tell of greater hardships. The miners were largely prisoners of war and criminals. The Greek writer, Diodorus (III. 11.), describes the operation of the mines in the time of the Ptolemies, and the terrible sufferings of the laborers under their brutal taskmasters.

The oldest charts or maps of any kind in existence are two papyri showing the topography of the country, and the position of the workings, mills, miners' houses and other buildings connected with some of these ancient mines. One of these maps was made in the reign of Ramses II., the second king of the nineteenth dynasty, which began about 1320 B.C. The locality mapped is in the Bechen Mountain, east of Coptos. The other, better preserved, but having lost the name, shows the position of four short ranges or rows of mountains with the valleys between them; the position of the mines, high on the slopes of one of the peaks; the workmen's houses; the water-tanks, the place where the gold washing was done, the areas of cultivated ground; a temple site and other details. Some of the mountains are colored red, and across them are written the words: 'These are the mountains where the gold is washed; they are also of this red color.' Von Meyer* says that in the time of Ramses II. the Nubian mines yielded \$625,000,000 worth of gold annually. (The world's production of gold for 1903 was valued at approximately \$327,000,000.) The kings of the eighteenth dynasty also received gold in considerable quantity from the Soudan and from the eastern shores of the Red Sea.

In all the Egyptian and Nubian mines the ore was in the form of native gold in a quartz gangue. Some of the veins are of large size and are considerably branched. The vein matter was fractured and loosened by building fires over it. The blocks were then dug out by the miners, possibly with iron tools; and old men, women and children carried the ore to the crushers. The earliest form of mill

* 'History of Chemistry.'

consisted of a small stone mortar with a stone pestle. But there was a development in milling methods, and the next consisted of a block of rock, with a slight depression in the top for the ore, which was pulverized by means of a heavy rubbing stone. A still later development, possibly belonging to the time of the Ptolemies, 330–322 B.C., was a mill somewhat like the *arastra* which may still be seen in California and Mexico. It consisted of a block of rock several feet in diameter and circular in outline, in the top of which was a shallow depression to receive the ore. The pestle consisted of a large spherical or cylindrical block of the same kind of rock. The finely broken ore was placed in the depression, and the movable block was rolled around over it until it was reduced to the desired fineness. The mill was essentially a huge shallow stone mortar in which the pestle was rolled by slaves.

The powdered ore from the mortars was sprinkled upon the tops of sloping stone tables over which water was kept running. By this means the lighter rock powder was carried away and the gold remained behind. The supply of water was secured by the construction of large cisterns or reservoirs on the slopes of the mountain. In the upper ends of the tables there were tanks for the immediate supply, and the operator dipped the water out and poured it over the sloping surface. When a quantity of gold had accumulated on the table it was removed, dried and placed in a covered clay crucible and heated for five days in a charcoal fire blown constantly by a rude bellows, or by mouth blowpipes. No fluxes were used in the earliest times, but it was not long before these primitive metallurgists learnt the use of lead and common desert salts in refining their gold. Diodorus Siculus—second century B.C.—mentions the use of lead by the Egyptians in the refining of gold, but it is believed that it had been in use many centuries before his time.

Pictures and sculptures of very early date show the refiners of gold (and silver) sitting before the fire with blowpipes of very large size, but otherwise not unlike those in use at the present time. The main part of the pipe was probably of wood, but a metal tip concentrated and directed the current of air. Others show the workman blowing the fire with a bellows consisting of two leather bags furnished with metal nozzles. The bellows was distended by pulling a cord attached to the upper side of the bag. When at work, the operator stood with one foot on each bag and held the cords in his hands. Then by a swaying movement he threw his weight first on one foot and then on the other and at the same time pulled the cord attached to the bag from which the pressure was removed, raising its upper wall and causing it to take in air and become distended. The pressure of the foot forced the air through the nozzle of the bellows into the fire. When a large amount of metal was to be worked, an open fire of charcoal was used and a

bellows was placed on each side. For smaller amounts, the fire was placed in an earthen bowl and the blowpipe was used to fan the flame.

Goldsmiths. The goldsmith was held in higher esteem than any other craftsman. This regard was probably due, in part, to the fact that he prepared the images of the gods, the finer decorations for the temples, and the jewels and vessels for the royal household. The guild was under the direct control of the king, and was thoroughly organized by his command into goldsmiths, chief goldsmiths and superintendents of goldsmiths. The trade passed from father to son in a sort of family trade union. Plato says that in Egypt every particular trade and manufacture was carried on by its own craftsmen, and none changed from one trade to another or carried on several. As early as the twelfth dynasty, 2130 B.C., the Egyptian goldsmiths had attained a high degree of skill in their work; and the wonderful jewels found on the mummy of queen A'hhotep and in the tomb of Kha-em-uas, son of Ramses II., for elegance of design, delicate engraving and beautiful inlaying are not excelled at the present time. That some of this work could have been done without the aid of a lens, is considered impossible. A type of cloisonne work, the outlining of figures and the tracing of designs in delicate gold and silver wire to be filled in with precious stones or other metal, was a remarkable feature of the goldsmith's art. (The Chinese cloisonne work differs in that the filling is largely with enamel and porcelain, and is hardened in place by burning.) Gold plating was practised in very early times, and some of this work manifests a skill not to be scorned by the best workers of the twentieth century. The gold leaf was undoubtedly made with the hammer, and its uniform thickness speaks well for the skill of the goldsmith. Inlaid work with settings of precious stones and enamels was common. Gold was extensively used to overlay models in wood and other material in sculpture and architecture.

The tools used were of the simplest kind, probably including only the blowpipe, tongs, forceps, hammer and graving tools. A very large part of the work was done by softening the gold in the fire and pressing it into shape with forceps and tongs. The casting of gold was much practised in the latter part of the Middle Empire, about 1600 B.C.

In the inscriptions of the New Empire, various kinds or grades of gold are mentioned, as: 'mountain gold,' 'good gold,' 'gold of twice' (refining?), 'gold of thrice,' 'gold of the weight,' 'good gold of Katm, that is, of the Semitic countries. The 'gold-brick' and the tender-foot are not peculiar to the present day. In one of the Tell-el-Amarna letters, written during the eighteenth dynasty, 1600-1400 B.C., the king of Babylon accuses Amenophis III. (or IV.) of Egypt of sending him a mass of base metal for gold. He says: 'The twenty minas of gold (you sent me) contained, when melted down, only five minas of pure gold.' In a letter from Mitani to the same monarch, the writer says:

'The gold you sent was very little and alloyed,' and in a later letter he says: 'A testing of a delivery of gold, undertaken before the whole royal court, has revealed the fact that what was sent was not gold at all.'

The chief uses of the metal among the ancient Egyptians were for ornament and decoration, and, to a limited extent, as a measure of value, but this use was probably not common except when very large sums had to be paid over. For use as money, it was fashioned into broad, centrally perforated discs or rings about five inches in diameter, but of one standard thickness or weight, and all payments necessitated the use of the balance. Among the commoner articles made of gold were articles of personal adornment—diadems, necklaces, armlets, bracelets, finger rings, earrings and various kinds of jewels. Domestic utensils, except those for the royal household, were seldom made of gold. Vases and other decorative vessels, images of the deities, statuettes of the kings and other royal personages, and images of the sacred animals were commonly made of hammered or cast gold. It was extensively used for temple and altar decorations, particularly during the New Empire, after the conquest of Nubia and Syria in the eighteenth dynasty. The Syrian goldsmiths were superior craftsmen, and much of their work found its way into the temples of Egypt. The decoration of the temples was an act of the most worthy piety, and it was the duty of the king's convoyers of gold from the mines to make an offering of gold in the temples.

When wrought into jewels and chains, it was used by the ruler as a means of bestowing rank and favor upon his worthy officials and court favorites. A victorious general was called into the king's presence, and 'before all the people, in the sight of the whole country,' the 'decoration of the gold' was conferred. The king commanded the royal treasurer to place about the neck and body of the honored servant a certain number of gold chains, and to present him with jewels and gifts, frequently of symbolic character. These might be in the form of bees, lions, bracelets, necklets, hatchets, vessels for ointment and ornament, all worked from the finest gold. The persons receiving this honor were afterwards known as 'the creatures of the gold.'

There is good reason to believe that the Egyptians used unalloyed copper in their arts and manufactures for centuries before they discovered that the addition of a little tin would greatly increase its hardness, make it more responsive to heat, and greatly widen its field of usefulness. But within the period covered by authentic history, copper alone seems to have had a much more limited use than bronze, and the archeologist finds that objects made of copper are not very numerous among the relics of any period of Egyptian history. It is held by some that the name used in the inscriptions for bronze sometimes refers to copper.

Possibly on account of the great abundance and long use of copper, very little definite information has been preserved regarding the process of extracting it from its ores, the making of the alloys (bronze and brass) or the methods of manufacturing copper and bronze objects. The goldsmith has received a great deal of attention from the sculptor and the painter, but the more practical and more indispensable worker in bronze has been almost wholly neglected. It is said that the only known picture illustrating the working of bronze is that of a man making knives. Even in the copper mines, the inscriptions rarely refer to copper as a product. Malachite, regarded by the Egyptians as one of the choicest of precious stones, and turquoise are spoken of as though they were the objects sought.

There was very little copper mined in Egypt, though it is said that native copper was found there (von Meyer). The great source of the metal was the Sinai peninsula. While most of these deposits were exhausted in ancient times, one at Wadi Nasb has been worked in recent years. To supplement the supply from these mines copper was imported. In one of the Tell-el-Amarna letters, written by the ruler of Cyprus to Amenophis III. (or IV.) in the fifteenth century B.C., the writer says: "I can only send this time 500 talents (?) of copper, for the plague prevails in my country, and for this reason no despatch of silver could take place." In another letter he says: "I am sending you 100 talents of copper."

When the Egyptians wanted gold they invaded Nubia and took possession of the mines. When they wanted copper they drove back the nomadic tribes of Sinai and built fortresses to defend themselves while they secured the metal which played such an important part in their national life. The most important mines were those of Wadi Maghara which had been worked by the natives, and from which they are said to have brought oxides of copper to the Nile delta. It is probable that the Egyptians made several unsuccessful attempts to get possession of the mines at a very early date. But it was not until the time of Zosiri, possibly in the third dynasty, that they succeeded temporarily in holding the region. Whether the conquerors followed up their victory and worked the mines in uncertain, but it is known that they were vigorously operated by King Snofru of the fourth dynasty, not later than 2830 B.C., and according to several authorities, much earlier. Other mines opened later, were the Wadi Nasb, the Sarbut elchadim and mount 'At'eka. Of these, the Sarbut elchadim were opened by Amen-eh-hat II., of the twelfth dynasty, about 2130-1930 B.C. All these mines, except those of 'At'eka, are in the mountains on the west side of the peninsula. The exact position of the 'At'eka mines is not known, but they were near the Gulf of Akaba on the east side of the peninsula, and so situated that the product was brought to Egypt both by sea and by land. They were opened by Ramses III., the second king

of the twentieth dynasty, which, according to Erman, lasted from 1180–1050 B.C. The western Sinai copper and turquoise mining region is separated from the Suez Gulf by a narrow plain and one range of hills. Pharaoh's men called it the country of grottoes, in allusion to the many pits and tunnels made by the Bedouin miners who preceded them. It is known that in very early times copper ore of some kind was mined not far from the gold mines of the southern desert region, but the workings indicate that no great amount of metal was produced from this locality.

The country rock of the west side of the peninsula is a soft, friable, yellow sandstone, probably cut by porphyry dikes,* and the method of laying out the mines was not unlike that used in coal mining at the present time. Tunnels or entries were driven and rooms were worked out on each side, leaving pillars of rock to support the roof.

On a peak at the junction of the Wadi Genneh and the Wadi Maghara, the traveler finds a low wall enclosing a group of over 200 stone huts—some round and some rectangular—in which the miners of many generations lived. With the exception of the houses of the overseers, which have two rooms, the dwellings consist of a single room, on one side of which a stone bunk or bench may have served for table and bed. The walls of the houses are made of the sandstone from the mines, and are laid up without mortar. The door is a very narrow opening in one of the walls. The roofs were made of wicker work covered with clay. The village was garrisoned to protect the miners from the native tribes, and a temple was erected for the worship of 'Hathor, the lady of the malachite country.' Below the village, an artificial lake or reservoir was formed by damming the valley, and the shellfish of the lake were used as food, along with dates, oil, milk and a coarse bread, with occasionally a fowl or some other meat. Occasionally the king sent a supply train into the camp, and an inscription says that one of these consisted of: corn, 16 oxen, 30 geese, fresh vegetables, live poultry and other things.

The tools found in the village were all of flint, and included knives, scrapers, hammers, saws, arrow heads and spear points. Stone tools with wooden handles were found in the mines, but it is probable that these were used in making the inscriptions which cover the walls, and that the mining was done with bronze tools. The mine laborers were principally criminals and prisoners of war, but an inscription records the fact that one of the kings sent out an army officer and 734 soldiers to work the mines. There seems to have been but little interruption in the operation of the mines from the latter part of the third dynasty until the end of the sixth (from about 2830 to possibly 2400 B.C.). From this time until the twelfth dynasty (2130 B.C.) but little work was done, but in this dynasty Egypt was on the crest of one of

* See Dana, under 'Turquoise.'

those great waves of prosperity which marked the nation's history. These and other mines were worked with great energy, and the national coffers were filled. The goldsmiths and bronze workers of this time have left behind them some of the most elaborate and beautiful specimens of their art. From the twelfth until the twentieth dynasty there were periods of great mining activity separated by others in which but little was done. The eighteenth dynasty (1530 to 1320) was a period of great mineral production, but during the twentieth (1180-1050 B.C., Erman, or 1280-1100 B.C., Rawlinson) most of the mines were almost exhausted. Major Macdonald, a Scotchman, built a house just below the village and worked one of the mines for turquoise some time within the nineteenth century. Monuments still stand at the Sarbut mines, recording the names of a long list of mine managers appointed by the various Pharaohs. When large quantities of copper or turquoise were wanted, the king would send out 1,000 or 2,000 additional miners, metallurgists and laborers to expedite matters.

The inscriptions show that the strike is not a new institution. A company of Egyptian prospectors used this means of bringing the managers to terms. The method employed by the manager to get his men to continue work is one which has not been tried in America. The men were called together to discuss matters, and they agreed to work if the manager would insure them the favor and protection of Hathor, the goddess of the region. The terms were complied with, and the men went to work.

The ruins of ancient refining works are found near the west Sinai mines, but from the very meager description found it is impossible to get any idea of the method of treating the ores. The fuel used was charcoal and wood. The ores mentioned in connection with these mines include malachite, the oxides of copper, native copper and a blue precious stone, which may refer to turquoise or to azurite. As the malachite was considered a precious stone, only the inferior part of this mineral would be used as ore. Whichever one of these ores predominated, the metallurgical process would be a rather simple one, but the copper produced was of a high degree of purity. The following quotation from Brugsch-Bey makes it clear that the ore of 'At'eka was smelted at the mines: "The metal shining like gold and in the form of bricks, was brought from the smelting-houses in those parts and laden on ships."

At certain periods in Egyptian history, as, for example, early in the new Empire (2130 B.C.), copper seems to have been recognized as the standard of value, and accounts were reckoned in uten of copper. These coins, if such they may be called, were made of very exact weight (about 91 grams), and were in the form of a spiral. Some of the blue and green pigments used by the artists and painters contain copper salts.

Bronze, the alloy of copper and tin was the Egyptian's tool-steel, his cast and wrought iron—in short, all that iron and steel are to the American. Just when he discovered the effect of tin on copper there is no means of knowing, but certain it is that many centuries have passed since he came into the possession of the secret.

The presence of flint tools only, in the deserted mining camp in Wadi Maghara can not be used as an argument that bronze and iron tools were not then in use, for they are mentioned in inscriptions, pictured in paintings and sculptures and are found in tombs belonging to a period many centuries before the abandonment of the mines. In the time of Herodotus the Egyptians used both stone and metal cutting instruments. The use of bronze is mentioned in inscriptions antedating the Great Pyramids. Of the work of the first three dynasties, Rawlinson says: 'A metallurgy of no small merit must have formed and hardened the implements whereby materials such as those employed by the Egyptian builders and sculptors were worked with ease and freedom.'

Possibly the oldest piece of cast bronze whose age has been established is a knob from the scepter of Papi, a Pharaoh of the sixth dynasty (about 2500 B.C.). This and other bronzes of very great antiquity are in the British Museum. The Posno collection in the Louvre contains two statues which are believed by Perrot and Chapiez to date from the close of the Old Empire or the beginning of the Middle Empire (about 2300–2000 B.C.), but Erman says they are 'archaistic works of the twenty-sixth dynasty (about 650–525 B.C.). They are light, hollow and cast in one piece. The eyes and eyebrows were made of precious stones inlaid in the bronze. The technical skill and workmanship displayed are said to be extraordinary. A hollow cast statue of Ramses II., of excellent design and skilful workmanship, dates from about 1300 B.C.

In the inscriptions, several kinds of bronze are spoken of again and again, as, for example, 'bronze,' 'bronze in the combination of six' and 'black bronze.' These varieties contain the constituent metals in different proportions. A very common bronze, used for a variety of purposes, contains copper 85 per cent., tin 15 per cent.; another common bronze has the composition: copper 88 per cent., tin 12 per cent. A bronze used for weapons and cutting instruments is found by analysis to contain copper 94 per cent., tin 5.9 per cent. and iron .1 per cent. Without the iron, this would be the softest of the three, but the iron probably compensates for the lower percentage of tin. It is evident that the use to which the alloy was to be put determined the proportion in which the metals should be combined. This fact supports the belief that from very early times the metal workers used metallic tin in the manufacture of bronze, and, therefore, that they were familiar with the separation of tin from its ores. Bronze weapons of the composition mentioned above, were so skilfully tempered that, after the lapse of

many centuries, their elasticity is almost equal to that of the best steel.

The working of bronze was one of the more honorable branches of industry, and must have furnished labor for a large number of men. Of the various subdivisions of this industry, that of the armorer was held in highest esteem. Reference has already been made to the lack of data concerning the metallurgy of copper and of bronze. But the finished products show that furnaces and smelting pots of large size must have been used in preparing the molten alloy for the molds. The bronze work of different periods shows varying degrees of skill, and it is difficult to say at what time the bronze workers attained the greatest excellence in their art. Both cast and hammered bronze work is found, which in grace of outline and perfection of finish has rarely, if ever been surpassed. The more elaborately finished work includes chasing, inlaying with precious stones, gold and silver, designs in gold and silver wire inlaid with other bronzes, enamels and precious stones. The method of inlaying with gold and silver consisted in making a groove in the bronze, laying the gold on and hammering it into place.

It would be almost impossible to enumerate the uses to which bronze was put. Some of the more important are: weapons and armor; farm implements (in part), artisans' tools, household utensils; boat and chariot building; architectural hardware, such as nails, bolts, hinges, locks; statuary, images, decorative objects and articles for personal adornment.

Iron. Iron never found wide favor in ancient Egypt, but there are abundant evidences that it was used side by side with bronze for tools of various kinds. There is no reason to believe that it was ever commonly used for decorative purposes, either in architecture or otherwise. The finding of iron bracelets proves that it was occasionally used for personal adornment. Even its use for tools seems to have been much more limited than that of bronze.

It has been suggested that the scarcity of iron objects may be accounted for, in part at least, by the readiness with which iron is destroyed by oxidation, especially in a soil so rich in nitrates as that of Egypt. It is also significant that the Asiatic neighbors of the Egyptians—the Hebrews, the Canaanites, the Chaldeans, the Babylonians and other contemporaneous peoples were familiar with the uses of iron.

Lepsius believes that this metal was used in Egypt as early as 3000 B.C., that it served primarily for hard instruments, and was prepared in smelting furnaces. The Great Pyramid was built by Khufu (Cheops), of the fourth dynasty, and not later than 2800 B.C. Herodotus says that iron tools were used in the construction of the great Pyramids, though others find reason to believe that the tools used were of tempered bronze. The question is of little importance in view of the fact that a band of iron was found in an inner joint of the Pyramid of Cheops, where the ancient architect placed it.

Thebes and Memphis are so ancient that history has preserved no record of their founding. Yet in the tombs of these long-decayed cities are found tools and other articles of iron, some of which may be seen among the treasures of the New York Historical Society. An ancient inscription at Harnak tells us that Thothmes I., who reigned in the eighteenth dynasty (probably 1500 B.C.), received from his chiefs and vassal kings, 'bars of wrought metal and vessels of copper and of bronze and of iron,' and from near Memphis he received lead, iron, wine and wrought metal. Iron was so highly prized that it was considered a desirable article of plunder, and the soldiers of this same monarch, on their return from fighting Chadasha, brought 'iron of the mountains, 40 cubes.' An iron sickle was found beneath one of the sphynxes at Harnak, but it may have been placed there not more than 600 years B.C. When the great obelisk that now stands in Central Park, New York, was taken from its original position on the banks of the Nile, a piece of very pure iron was found beneath it. 'Pieces of iron tools have been found at various places, bedded in masonry of very ancient date' (E). In the twenty-fifth dynasty iron was used for the door frames of the temple of Ptah. Very few of the iron relics found are well enough preserved to show the character of the workmanship, but they do show that the art of tempering iron was known at a very early date.

The known sources of Egyptian iron include the desert region of the south between the Nile and the Red Sea, and the Sinai peninsula. At Hamami in the desert there are the workings of an ancient iron mine from which hematite was taken, but no evidences of smelting have been reported from this locality. The mines of the Sinai region must have been an important source of this metal as well as of copper. In 1873 ruins of extensive iron works of great antiquity, but of undoubted Egyptian origin, were discovered near the Wells of Moses, and it is possible that ancient Arabia learned the metallurgy of iron from the Egyptians. There is also reason to believe that iron was imported from Chaldea, Phoenicia, Babylonia and Assyria.

Of the metallurgical processes used in the treatment of iron ores little is known. Oxides or ochers of iron were used for the yellow, brown and red pigments so commonly used in Egyptian art. Some of the iron articles found are tools of various kinds, weapons, bracelets, keys, wire, door-frames, fish-hooks, etc.

The inscriptions make but few, if any, references to tin, and comparatively few articles made of that metal have been found. For these reasons, it is held by some writers that the ancient peoples, the Egyptians included, did not understand the separation of the metal from its ores. But the fact that plates of pure tin have been found in considerable number in the tombs is an answer to those who hold this view. These plates were shaped and used to cover the incision made in the

right side of the corpse to remove the viscera preparatory to embalming. They were engraved with the symbolic eye-emblem of the sun-god Shu. But the principal use of tin was in the manufacture of the two alloys, bronze and solder, of which the former was many times the more important. Solder, the alloy of lead and tin, was very much used in the metal-worker's craft. The sources from which the Egyptians drew their supply of tin are not known. It is believed by some that the Phoenicians brought it from Spain and later from the shores of Britain. It has also been suggested that it may have been brought from the East Indies by very indirect channels of trade. Whatever may have been the source of supply, tin was used in large quantities by the ancient Egyptians.

Silver. Silver and gold were the precious metals of Egypt. In very early times silver was the rarer and more precious. This is probably due to the fact that it was not produced in Egypt or the neighboring countries. In later times when commerce developed and the products of all the earth began to come to the ports of the Nile and the Red Sea the two metals changed places in respect to value. The greater rarity of silver in the earlier dynasties is shown by its very limited use, as well as by the fact that in the old inscriptions it always stands before gold. Gold was lavished on the mummies and on the tomb decorations of the wealthy, but silver was seldom used in this way. In the temple decorations silver played but a small part, and in the ceremonies by which rank and title were bestowed upon faithful officers and court favorites, silver is rarely mentioned. The gifts to the king rarely include it, though copper and bronze are generally mentioned.

But about the time of the eighteenth dynasty the Phoenicians and Syrians brought much silver from Cilicia, and the island of Cyprus sent this metal to Egypt, as is shown by the Tell-el-Amarna letters. From this time the use of silver is much more common for many purposes than that of gold. King Ramses III. records the fact that during his reign of thirty-one years he gave to the temples, among other gifts: 1,015 kg. of gold, 2,994 kg. of silver, 940 kg. of black bronze and 13,060 kg. of bronze. Its use, likewise, in the arts became much more common, both alone and in the alloy *usm* or electron.

In the nineteenth dynasty, Ramses II. and Khita-sir, king of the Hittites, made a treaty for mutual protection and support. A silver tablet has been found on which is engraved the whole text of the treaty, and it is almost as wordy as similar documents of the present day.

The work of the silversmith was similar to that of the goldsmith, and vases of the Middle Empire (2130-1530) show more than average elegance of design and delicacy of workmanship, but the very elaborate work often found on objects of gold is rarely seen on those of silver. It is a remarkable fact that gilded silver is found.

Objects made of silver include jewels and other articles of personal adornment, plates for the adornment of mummies; statuettes of the gods and figures of the sacred animals; vases, and rings used for money. The central treasury was known as 'the house of silver of the treasury,' but the reason for the name is not apparent, unless at some time silver formed the principal money of the nation.

Electron, Egyptian 'usm.' This was an alloy of silver, gold and usually copper in small amount. The proportions were about 150 silver, 100 gold and 5 copper. Though not beautiful, it ranked with the precious metals, and was used chiefly for personal adornment and for vases, but occasionally it found a place in the more costly temple decorations. In the restoration of the temple of Ptah, in the twenty-fifth dynasty, the doors were made of electron (*usm*). Von Meyer states that this alloy was regarded as an individual metal, and that probably no means of separating the two metals was known. Lepsius, on the other hand, thinks that it was made by combining the metals by weight in much the same way as copper and tin were used in making bronze. Erman* says that from the 'Great Harris Papyrus' it appears that in weighing *usm* 1,278 uten of gold, 1,891 uten of silver and 67 uten of copper were employed. It is probable that this alloy was not used until after the change in the relative values of silver and gold mentioned above.

Lead. Of the metals known to the Egyptians, lead seems to have been the least used. Very few, if any, leaden objects have been found, and the only ways in which the metal is known to have been used are in the making of solder and in glazing pottery. The white pigment used on the mummy wrappings has been spoken of as white lead, but other writers state positively that no white lead has been found on the mummies or about the tombs. In very early times lead was mined in the desert region not far from the gold mines, and inscriptions state that it was received as tribute from foreign peoples.

* Foot-note, p. 461.

ANAXIMANDER, EARLIEST PRECURSOR OF DARWIN.

BY DR. CHARLES R. EASTMAN,

HARVARD UNIVERSITY.

AS has been aptly remarked by Huxley, 'There is no snare in which the feet of a modern student of ancient lore are more easily entangled, than that which is spread by the similarity of the language of antiquity to modern modes of expression.' The great exponent of evolution observes further in the same connection that he does 'not pretend to interpret the obscurist of Greek philosophers'; all that he wishes to point out is that 'the words, in the sense accepted by competent interpreters, fit modern ideas singularly well.'*

The force of these remarks becomes manifest when one inquires into the rightfulness of regarding Anaximander, the Milesian, companion or pupil of Thales ('*sodalis Thaletis*,' Cicero calls him) in the sixth century before our era, as the first who foreshadowed modern ideas of evolution. It may be of some profit for us to consider briefly the manner in which his doctrines have been interpreted by naturalists, and thereafter to examine into the original sources, which have preserved for us the skeleton of his system, and can alone enlighten us in regard to his conception of nature. An inquiry of this kind will not be without value in case it merely serves to bring home and emphasize the fact of historical continuity of ideas which are commonly considered as modern.

It is a matter of no little moment, when we stop to realize it, that conceptions of organic evolution, and also of a heliocentric cosmogony, assumed shape in the mind of man, however vaguely or imperfectly, in periods of remote antiquity, and have exercised a determining influence on human thought ever since. Natural laws become invested with new and more profound interest on finding that they have seldom been discovered offhand, revealed, as it were, by a single flash of genius; but by the progressive development of ideas, extending sometimes throughout centuries, and leading from dim, far-distant adumbrations up to our present understanding of the truth. There comes to us, also, through the tracing of ideas back to their sources, an increased sense of our indebtedness to the princely legacy of Greek thought. It has been justly said by one of Huxley's distinguished pupils, that 'even amidst our present wealth of facts, the impassable boundaries of human thought seem to confine us to unconscious revivals of Greek con-

* Huxley, T. H., 'Evolution and Ethics,' in his 'Collected Essays,' Vol. IX., p. 69 (London, 1894).

ceptions. There are many observers, but few who can strike out into the absolutely virgin soil of novel suggestion.*

Early christian theology reveals very clearly the impress of Greek philosophy, and natural science may be said to have been dominated by it. In so far as the theory of evolution is concerned, history shows beyond all doubt that it took its rise among Ionian philosophers, declined with the decay of Greek science, was kept alive by Greek influence in theology, and, after gathering increased momentum, became revealed in fuller grandeur to Lamarck and Darwin. Yet scholars are by no means agreed concerning the extent to which either the central theory, or its subordinate propositions, such as the law of the survival of the fittest, were developed amongst the Greeks. Many important scientific discoveries were actually anticipated by this ingenious people, though they seem to have felt their way rather by intuition than by inductive reasoning combined with the observational method. It is the belief of conservative writers that the Greeks anticipated the evolution idea by suggestion, or by a series of happy conjectures, though indeed they carried it well into the suggestive stage; nor does it seem possible to maintain a more superlative estimate than this.

The question as to who was the first evolutionist has been answered in various ways.† Professor Osborn, in the work above quoted, holds to the belief that it is not Anaximander, but Empedocles of Agrigentum, who 'may justly be called the father of the evolution idea.' Huxley pays a general tribute to the sages of Miletus by calling them 'pronounced evolutionists'; but it is Heraclitus, the corypheus of the Physicists, of whom he avers that 'no better expressions of the essence of the modern doctrine of Evolution can be found than are presented by some of his pithy aphorisms and metaphors.' Haeckel, on the other hand, apostrophizes Anaximander as 'the prophet of Kant and Laplace in cosmogony, and of Lamarck and Darwin in biology.' Another distinguished German critic, Schleiermacher, venerates Anaximander as 'the father of speculative natural science'; and a not unlike sentiment has been voiced by Lyell.

The causes of this singular lack of unanimity are not difficult to trace; they have one and all to do with the original sources. In the first place we must note the different interpretations of the meager yet priceless materials that have come down to us, all derived in the last resort from the 'Opinions' of Theophrastus, a work long since obliterated by the hand of time. Secondly, we must pay due heed to

* Osborn, H. F., 'From the Greeks to Darwin,' p. 10 (New York, 1894).

† Out of a mythical and legendary past far antedating the Homeric poems, if we would believe certain French writers, it is possible to reconstruct the earliest archetype of Darwin. Those who, as the author of 'Modern Mythology' would say, 'care to go in for these things a little,' will do well to consult the following: Houssey, F., 'Nouvelles recherches sur la faune et la flore des vases peints de l'époque mycénienne.' *Revue Archéol.*, Vol. XXX. (1897), p. 81 ff.—Coupin, H., 'Le poulpe et la croix gammée.' *La Nature*, May 20, 1905, p. 396.

the pitfalls Huxley has warned us against in the opening words of this article. Whoever seeks to understand ancient systems of philosophy must not be misled by 'the similarity of the language of antiquity to modern ideas of expression,' into supposing that the world presented itself to the classic mind under the same aspects, and that problems of nature and of life possessed for it the same significance, as in our day. Our contemplation of the universe has become modified by the sum-total of all the new ideas that have entered into the world during the last two thousand years, and if mental processes have not grown in the meantime more subtle, they have at least a vastly more complex *organum* to work upon. Speculations during the olden time were cast in a different psychic mold than with us; conceptions rested upon a different basis of fact; even the simplest words were used in a different significance. As M. Brochard sagely observes: 'C'est une erreur manifeste que de vouloir retrouver à tout prix chez les anciens nos propres solutions; mais c'est une aussi, est plus répandue encore, de s'imaginer que les questions à résoudre se posaient pour eux exactement comme pour nous.' What we understand now-a-days by the terms matter, motion, space, ether, soul and so on, is not what the corresponding words denoted in the past ages. Nomenclature, with halting gait, is invariably left behind by the onward march of ideas.

Disparity of modern estimates arises in still larger measure from another cause; from the attempted reconstruction of ancient systems of philosophy out of a handful of mutilated excerpts and traditions. Such attempts are almost certainly foredoomed, since the arbitrary nature of ideas precludes the application of a principle of 'correlation of parts,' by means of which the trained expert is enabled to restore missing features from a few characteristic fragments. Efficient as may be the workings of this principle in comparative anatomy, we must not be beguiled by the allurements of Renanism into transporting it, as some have endeavored to do, from the realm of morphological facts into the realm of ideas. We may be permitted to hazard shrewd guesses here and there, basing them upon the influence of *milieu* and previous suggestion, or upon contemporary analogy, in the endeavor to revive relics of intellectual progress that 'abode their little hour or two and went their way'; but beyond this we can not go.*

* For suggestions of contrary nature one may compare the following from Huit's 'Philosophie de la nature chez les anciens' (Paris, 1901): "Tel penseur de l'antiquité a eu son temps de célébrité: nous n'avons de son système qu'une connaissance rudimentaire et tronquée: à l'imagination et au raisonnement de le reconstruire. De l'œuvre antique rien ou presque rien n'a survécu; qu'à cela ne tienne: sur ces vagues indications, avec autant de hardiesse, mais moins de sûreté que Cuvier dans ses restitutions paléontologiques, l'esprit créera à nouveau ce qu'une autre pensée avait enfanté" (p. 208).

For an illustration of the manner in which suggestions of this nature have been carried out, we may refer to the attempted resuscitation of the doctrines of Empedocles by J. Bidez, the success of which is viewed by Professor Lortzing

Believing, as we think rightly, that Anaximander should be regarded as the earliest precursor of Darwin, it will be profitable for us at this point to examine the small collection of fragments which have survived, and which constitute the authentic sources of information in respect to his ideas of organic evolution. Notwithstanding these fragments are but five in number, they have not hitherto been searched out and brought together under one head in English form. Those desirous of consulting the original texts will find them collated in the indispensable works of Hermann Diels,* Ritter and Preller,† Fairbanks,‡ Mullach and others.

ORIGINAL SOURCES RELATING TO THE EVOLUTIONARY DOCTRINES OF
ANAXIMANDER.

PSEUDO-PLUT. *Stromat.* 2 (Dox. 579).—Further he [Anaximander] declares that in the beginning man must have been born from animals of a different species. His reason is that, whereas other animals quickly find food for themselves, man alone requires long rearing. And it is evident that had he been originally such as he now is, he could never have survived. §

HIPPOLYT. *Philosoph.*, I., 6 (Dox. 660).—Primitive animals were derived from moisture evaporated by the sun. In the beginning man was of very different form than at present, and resembled a fish.

ÆTIUS *Plac.*, V., 19, 4 (Dox. 430).—Anaximander taught that the first animals were begotten in the water, and were covered with prickly integuments; on attaining sufficient age, they emerged upon the land, and, their coverings having burst, they soon changed their manner of life.

PLUT. *Symp.*, VIII., 8, 4 (Diels, *Fragm. d. Vor-Sokrat.*, p. 20).—Wherefore they (the Syrians) reverence the fish as of the same origin and the same family as man, holding a more reasonable philosophy than that of Anaximander. For he declares, not that fishes and men were generated at the same time, but that at first men were engendered in the form of fishes; and that growing up as sharks§ do till they were able to nourish themselves, they then came forth on dry ground.

CENSORIN. *Dies Natal.*, 4, 7.—Anaximander of Miletus believed that either fish, or animals very like fish, sprang from heated earth and water, and that

in following wise: "Der Verfasser geht in seinen Kombinationen oft zu weit: er sucht aus dem dürftigen Material zu viel herauszupressen und lässt in der Ausfüllung der Lücken der Ueberlieferung seiner Phantasie allzusehr die Zügel schiessen" (*Jahresbe. Class. Altertumsw.*, Vol. CXVI., p. 33, 1903).

Moreover, as Dr. Alfred Gudeman has warned us in his interesting essay on 'Literary Frauds among the Greeks' ('Class. Stud. in honour of Henry Drisler,' 1894), much that appertains to the early doxographers is tainted with the suspicion of unguineness, or of later interpolation.

* 'Doxographi Græci' (Berlin, 1879). Idem, 'Fragmente der Vorsokratiker, Griechisch und Deutsch' (Berlin, 1903).

† 'Historia Philosophiæ Græcæ,' 8th ed. (Gotha, 1898).

‡ 'The First Philosophers of Greece' (London, 1898).

§ An interesting commentary on the argument here presented, which is recognized as extremely important for the general theory of evolution, is to be found in N. M. Butler's essay: 'Anaximander on the Prolongation of Infancy in Man' ('Class. Stud. in honour of Henry Drisler,' New York, 1894).

§ The reading of *γαλειοί* in place of *παλαιοί* is conjectural, but approved, nevertheless, by the best editors.

human fetuses grew in these animals to a state of puberty, so that when at length they burst, men and women capable of nourishing themselves proceeded from them.

It will be observed that the first four passages stand in substantial agreement with one another, as might be expected from having all been derived from a single source. This work of Theophrastus contained, no doubt, an accurate transcript of the doctrines of Anaximander, since in one instance his very words appear to have been quoted; and as the works of the latter are known to have been in the hands of Apollodorus, there is every reason to suppose that Theophrastus wrote with them lying open before him. When we come to Censorinus, however, we meet with such an absurd and strikingly different version as to leave little doubt that it rests upon a faulty translation of the Greek texts; yet we shall see presently that the majority of modern writers regard this as a faithful rendering of the Milesian's views.

As early as 1819, Heinrich Ritter, to whom we owe the first satisfactory collation of pre-Socratic texts, interpreted Anaximander as having taught that 'after the first imperfect and short-lived creatures had been engendered in slime, an advance took place from the lower to the higher grades of life, until at length man was formed.' Cuvier, whose accuracy and erudition have seldom been called in question, went so far as to attribute to our philosopher the belief that men had been first fish, then reptiles, then mammals, and lastly what they now are. 'This system,' he further remarks, 'we find reproduced in times very near to our own, and even in the nineteenth century.' More conservative is the estimate of Sir Charles Lyell, who while admitting that our philosopher 'made at least some slight approach, twenty-five centuries before our time, to the modern doctrine of evolution,' yet denies that he anticipated the Lamarckian theory of progressive development.*

Edward Zeller, than whom is no more competent authority, speaks in following wise of Anaximander's evolutionary ideas: "The animals, also, he thought, originated from primitive slime, under the influence of the sun's heat; and as the idea of a gradual succession of animal species corresponding with the periods of geological formation was naturally beyond his reach, he assumed that the land animals, including man, had been at first fishes, and afterwards, when they were able to develop themselves under their new shape, had come on shore and thrown off their scales."† Professor Osborn gives practically the same résumé as Zeller, adding, however, that we find in these fragments the 'dim notion of survival or persistence throughout decidedly trying circumstances, which was greatly developed later by Empedocles.' He is unwilling to grant that Anaximander attempted to account for the origin of other land animals, or had any notion of the development of higher from lower organisms, except in the case of man.

* 'Principles of Geology,' Vol. I., Chap. II.

† 'History of Greek Philosophy,' Vol. I., p. 255 (London, 1881).

Theodore Gomperz, in his work on 'Greek Thinkers,' suggests several influences which may have given definiteness to Anaximander's speculations. For instance, the theory that the first animals were generated in sea-slime is traceable as far back as the Homeric poems, in which water and earth were supposed to be the elements of all organic bodies; and this presumption, the author remarks, 'may have been strengthened by the wealth of all kinds of life contained in the sea, not to mention the discovery of the remains of prehistoric marine monsters.*' As for the casting by primeval animals of their bristly integuments, the same writer observes: "It is likely enough that the analogous change sustained by some insect larvæ may have led him to this hypothesis. We can hardly doubt that he traced the forefathers of the terrestrial fauna from the descendants of these marine animals, thus obtaining a first vague glimpse of the modern theory of evolution." Another ingenious suggestion is that Anaximander, in seeking to explain the origin of human species, drew his analogy from the shark, which 'was popularly believed to swallow her young when they crept out of their capsules, to vomit them forth and swallow them again, and go on repeating the process till the young animal was strong enough to support an independent existence.'

Comment upon the various estimates here brought together appears unnecessary. It is enough that they all present Anaximander to us as a keen and deeply contemplative student of nature, who arrived at a dim adumbration of great truths. Evolutionist or not, as one will, the fact remains that his teachings contain germs of suggestion having high potentiality, which developed in the fulness of time into definite conceptions of organic, and even universal evolution. It is worth while for us to know that hints occur, in that far-off period, of theories of the survival of the fittest, of adaptation to environment, even of evolution as an explanation of the origin of all forms of life. That they remained only hints was inevitable without a knowledge of the essential facts of paleontology. Yet, after all is said, we must grant it was no small thing for Ionic genius to have given the first impulse to lines of thought which have profoundly influenced all departments of human understanding. Nor is it a small thing to realize that our questionings of nature, and indeed our very conceptions of life, re-echo at this day in surprisingly similar manner the questionings and conceptions that occupied the Hellenic mind more than twenty-five centuries ago. As intellectual pioneers, we owe them reverence for having first blazed the way along which all modern thought has followed.

* Numbers of such discoveries are mentioned in pagan literature, some of the remains being interpreted as 'bones of giants,' others as belonging to 'sea monsters.' As late as the second century of our era, Pausanias, who seems to have had a veritable passion for natural curiosities of all sorts, records having seen huge bones in various parts of Greece. Near Megalopolis, where he observed some of them, remains of mammoths and other large extinct animals have been found plentifully in modern times.

THE PHILOSOPHY OF FRIEDRICH NIETZSCHE.

BY PROFESSOR FRANK THILLY,
PRINCETON UNIVERSITY.

EVERY once in a while in the history of human thought a man arises who protests against the mass of tradition in custom, law, morality, science, philosophy and religion, and asserts his own individuality. In the presence of the accumulated acquisitions of human minds and human hands, he experiences a feeling of restraint and dependence, he finds his thought and action tied down on every side by the traditional theories and rules of past generations; the weight of ages rests as an incubus upon his soul and he longs for the free and untrammelled use of his head and heart and hands. Unable any longer to bear the burden of the past upon his shoulders, he casts it off, he declares his independence, he asserts his individuality. He wipes the slate clean, and begins to write upon it new thoughts, new values, new ideals, or at least what seem to him to be new thoughts, values and ideals.

Our present age is the historical age *par excellence*. It studies the past and shows us how the present has grown out of this past. It regards everything as the product of evolution, it tells us that we are what we are because our ancestors were what they were, that we do what we do because they did what they did; it traces the development of the thinker, the poet, the statesman, of law, morality, religion, art, literature and science; it justifies our conceptions and institutions on the ground that they have grown from simple beginnings and will develop in their own good time into more and more complex and perfect forms. The individual is the child of the past, in him our grandfathers are speaking to the present, in him their ideals and values are asserting themselves; they are the laws of the present, he is their mouthpiece. Against these conceptions and values a man of our time, Friedrich Nietzsche, has uttered his everlasting No. "Man alone," he says, "finds himself so hard to bear. That is because he carries so many strange things upon his shoulders. Like the camel he kneels down and allows a heavy load to be placed on his back. Particularly, the strong, burden-bearing man, in whom reverence dwells: too many heavy strange words and values he loads upon his back—and now life seems to him a desert." He breaks the old tables of values and demands that new ones be set up in their stead. He is not content with studying the conditions that gave rise to the ideals which we now

uphold; indeed, he regards the historic sense as the cause of the weakness of our times. We must cease feeling that we are *epigoni*. It is the function of the philosopher, in his opinion, to create new values, new ideals, a new civilization. "The real philosophers," he declares, "are commanders and legislators; they say: Thus shall it be; they alone determine the whither and wherefore of man; with creative hands they touch the future—their knowing is creation, their creation is legislation, their will for truth is—will for power." "Blessed it must seem to you to press your hands upon thousands of years as upon wax," says Zarathustra (in Nietzsche's book: 'Thus spake Zarathustra').

What our estimate of the world, of life and of our civilization will be must depend, of course, upon our values, upon our standards, upon our ideal, upon what we really prize. Hence, in order to understand our philosopher and his iconoclasm, we must understand his fundamental proposition, his basal thought, his ideal, the standard with which he approaches things. We shall then be prepared to understand why he objected so strenuously to our times, why he waged such a relentless war against his contemporaries, and earned for himself the title of a *Kämpfer gegen seine Zeit*. I shall not here attempt to trace the development of his ideas and to show how he gradually grew into them. Nor shall I attempt to point out the contradictions in his thoughts or even offer a criticism of them. It will be sufficient for my purpose to find the *motif* of his philosophy, to discover the fundamental principle upon which his thinking rests, and to show how his thoroughgoing opposition to the things around him more or less logically followed from it.

Schopenhauer teaches that the will is the fundamental principle of life. This will to be, this will to live, is a blind striving, a constant struggle for existence, a battle against death which we are bound to lose at last. "The life of most men is a weary yearning and torture, a dreamy tottering through the four ages toward death, with a series of trivial thoughts as an accompaniment. They are like a clock-work which is wound up and goes without knowing why; and every time a man is conceived and born, the clock of human life is wound up anew in order to grind out the same old hackneyed tune which it has played so many countless times before, measure for measure, beat for beat, with insignificant variations." It follows from the very nature of the human will that life should be full of pain and misery. And because it is full of pain, says Schopenhauer, it is bad, it is an evil, and not to be is better than to be. It also follows from the nature of the will that it is selfish and base. Men are knaves or fools or both. The end and aim of the average man's existence is to keep himself alive, and he will do anything he can to eke out his petty life. He is a cruel, unjust and cowardly egoist, whom fear makes honest and vanity sociable. And the only way to succeed in this world is to be

as grasping and dishonest as the rest. Because the will is a selfish will, it is bad, and life is an evil, a curse. In order to be good the will must negate itself, it must give up its selfish strivings. When we feel the sufferings of others, when we pity them, when we see ourselves in them, when we feel that we and they are one, then we are able to negate our selfish desires, we are delivered from the will to live, we are saved, we are at rest. The struggle ceases, we have denied ourselves, we have renounced the world, we are free, our selfish will is dead. Pity or love or sympathy, therefore, is the cause of this negation of will, and hence pity is the fundamental principle of all morality. Sympathy or pity is good because it leads to the negation of the will. The ideal is renunciation, ascetic self-denial; sympathy is the true moral motive, the sole source and standard of morality.

Nietzsche accepts the fundamental thought of Schopenhauer that the will is the principle of existence, but he draws wholly different consequences from this view. Yes, the real fact of our life is the fact of our will. The reality directly known to us is the world of our desires, the world of our instincts, the world of our will. Every living being desires life and desires it extravagantly; its instincts all aim at power and self-assertion. Life is essentially a striving for a surplus of power; all striving is nothing but a striving for power; the will for power is the root of all life and action. And this will for power, for more power, this intense, overflowing, bubbling, healthy, exuberant instinct is good: *Alles Gute ist Instinkt*. Everything that makes for life in this sense is good, everything that makes for power, that helps to realize this goal, is good. "What is good? Everything that heightens the feeling of power in man, the will for power, power itself. What is bad? Everything that springs from weakness. What is happiness? The feeling that power is growing, that a resistance is overcome; *not* contentment, but more power, *not* peace as such, but war, *not* virtue, but efficiency (virtue in the Renaissance style, moraline-free virtue)." "I say yes to everything that makes life more beautiful, more intense, more worthy of being lived. If illusion and error develop life, I say yes to them. If hardness, cruelty, strategy, disregard of others, love of struggle, can increase the vitality of man, I say yes to evil and sin. If I believe that suffering helps to educate the human race, I say yes to suffering. If science and morality diminish vitality, I say no to them."

Life is good, the desire for power is good, yes power is the greatest good. If that is so, then the stronger, the intenser, the fuller this will or desire or instinct for power, the better it is. The ideal will, therefore, always be powerful men, a higher, stronger type of men, the *overmen*. "Mankind should constantly endeavor to produce great individuals—this and nothing else is our mission." The great men, the great personalities, the men of force and power, the few, are the ideal

men, they alone are worth while; the little men, the weaklings, the many, the all-too-many, the mediocre, the half-and-half, the commonplace, every-day people, all these are worthless. "A time will come," says Nietzsche, "in which we shall no longer consider the masses, but again the individuals, who form a kind of bridge over the seething stream of becoming. These individuals are not continuers of a process; they live timeless-contemporaneous lives; thanks to history which allows such cooperation, they live as the republic of geniuses of whom Schopenhauer once said: One giant calls to the other through the intervening spaces of time; and undisturbed by the impish noisy pigmies that crawl at their feet, they continue their high intellectual converse.—No, the *goal of humanity* can not lie at the end, but only *in its highest exemplars*." "All civilization is the creation of great individuals and for them." "Everywhere among a people we find the traces of the lions of the intellect who have passed through it; in morals, in religion, everywhere the masses have bowed to the influence of individuals." "The great men are necessary, the times in which they appear are accidental." A people is only a roundabout way for producing a few great men. "Neither the state nor the people nor mankind exists for its own sake; the climaxes, the great individuals, are the goal—but this goal points far beyond mankind. From all this it is clear that the genius does not exist for the sake of mankind; he is the climax and final goal of mankind." "Such overmen, such happy accidents, have always been possible and will perhaps always be possible. And even whole families, tribes and peoples may under certain circumstances be regarded as such prizes in the lottery of existence." But nature is surprised herself when she produces such a masterpiece; she is a spendthrift and wastes a lot of material. Mankind should try to produce these geniuses consciously and purposely. The purpose of civilization is to hasten the birth and the development of the philosophers, the artists and the saints within us and without us, and thus to cooperate in the highest perfection of nature. The young man should be taught to regard himself "as a failure of nature, as it were, but at the same time as an evidence of the greatest and most marvelous purposes of this artist; she did not succeed, he should tell himself, but I will honor her great purpose by placing myself at her service that she may have better success at some other time." "I do not look for happy periods in history," says our philosopher, "but for such as offer a favorable soil for the production of the genius. The greatest calamity that could befall mankind would be the failure to produce the highest types of life." "We can by happy inventions educate a wholly different and higher individual than the one thus far produced by accident. Here lie our hopes in the breeding of eminent human beings."

The goal, we see, is the overman, the genius, a higher, stronger,

better kind of man than our every-day man. Now sometimes Nietzsche means what we have said above—the ideal or goal is the creation of great individuals. We have had such great personalities all through history and we shall always have them. Only, their appearance has been more or less accidental, and we should and can produce the conditions favorable to their appearance. At other times, however, our thinker means by the overman a new type of man, a new species in the Darwinian sense, as it were a higher, better, finer species. This type is to take the place of the man that is, just as the man that is has taken the place of the brute. “Man is a rope between the brute and the overman, he is not an end or goal, but a bridge. Upward goes our way, from the species to the over-species.” “I teach you the overman,” says Zarathustra. “Man is something that must be overcome. What have you done to overcome him? All beings thus far have created something beyond themselves, and you desire to be the ebb of this great flow and to return to the brute rather than to overcome man? What is the ape for man? A mockery and a painful shame. And just that, man shall be for the overman: a mockery and a painful shame. You have made the way from worm to man, and there is much of worm within you still. Once you were apes, and even now man is more of an ape than any ape. See, I teach you the overman. The overman is the purpose of the earth. May your will say: let the overman *be* the purpose of the earth.” “My heart is wrapped up in the overman; he is my first and only care—and not man, not my neighbor, not the poorest one, not the great sufferer, not the best. Oh my brothers, what I can love in man is that he is a transition and will pass away.”

Here the overman is conceived as a higher, grander, nobler race of men, in comparison with whom our present-day men are as pigmies to giants. Our task is to hasten the coming of the overman. The overman will come, the goal will be realized; only we must not leave his coming to chance. “Could you create a God?” Zarathustra asks. “Then do not talk to me about gods! But you could create the overman. Not you perhaps yourselves, my brothers. But you could transform yourselves into the fathers and forefathers of the overman: and let this be your greatest work.”

The ideal then for Nietzsche is the will for power, the will for strong, healthy life as it manifests itself in the great individuals or in a strong race or type of future men. If that is our ideal, if that is what we desire, then we must also desire everything that this ideal implies. Now life is not an easy thing, it is fundamentally and necessarily hard. “Life,” says Nietzsche, “is *essentially* appropriation, injury and overthrow of foreign and weaker elements, oppression, hardness, the forcing of one’s own forms upon others, the incorporation and at least exploitation, to put it mildly, of foreign elements. Ex-

ploitation is not peculiar to a corrupt or imperfect and primitive society, it belongs to the very nature of living beings; as the fundamental organic function it is the consequence of the real will for power, which is simply the will for life." Life is in its very nature hard and fierce; you can not have life without injury and attack; to live means to appropriate, to assimilate, to exploit, to coerce, to annihilate other elements. Life, the will for power, means struggle, battle, war; it means the exploitation of the weaker by the stronger. From all this it follows that a philosophy that places peace above war is a symptom of decay. If life is hard and fierce, if it is impossible without all these ferocious elements, and if life and power is the ideal, then these things are good. "You shall seek out your foe," says Nietzsche, "you shall wage your war, and for your own ideas, too. And when your idea is vanquished, your integrity shall applaud the deed. You shall love peace as the means to new wars. And the short peace better than the long one. I do not counsel labor, but battle. Let your labor be a battle, let your peace be a victory. You say it is the good cause that justifies the war? I say unto you: it is the good war that justifies any cause. You should have foes only that you can hate, not foes that you despise. You must be proud of your foe, then the triumphs of your foe will also be your triumphs."

In short, life means war and struggle, war and struggle are necessary, inevitable. You can not live and will without asserting yourself, without fighting, without hurting somebody, without being hard. You are bound to be hammer or anvil, you must conquer or be conquered, you must push others to the wall or go to the wall yourself. Life is by its very nature a terrible thing; in order to realize the goal, to produce strong men, it can not but be terrible. "Every moment devours the preceding one, every birth is the death of countless beings; to procreate, to live and to murder are one. We may, therefore, compare glorious civilization to a bloody victor, who in his triumphal procession drags along with him as slaves the vanquished fettered to his chariot wheels." Civilization can not do without the dangerous, hostile and violent passions. "Let envy, hatred and rivalry consume and torture man, let them drive him to extremes. Then perhaps a spark of the terrible energy thus enkindled may fall by the wayside, and from it there may suddenly burst forth the light of genius." "The 'warm sympathetic heart' does not know what it asks when it demands the removal of this violent phase of life; its own warmth is the product of the fire of the very passions which it desires to have suppressed." Whoever affirms life must say yes to the dangerous, violent and hostile phases of it. "The diminution of the hostile instincts is only one of the consequences of the universal decline of vitality." "Hardness, violence, slavery, danger on the highway and in the heart—the fearful, tyrannical, ferocious, serpent-like elements

in man help to improve man." "The serpent must first become a dragon in order that some one may become a hero through it." "Your wildcats must become tigers and your venomous toads crocodiles, for the good huntsman shall have a good chase."

We must make the strong stronger and the weak weaker. The misery of toiling men must even be increased in order to make possible a small number of Olympian men. Whatever will realize the goal is good. The weak must go to the wall, that is unavoidable. "We should not attempt to cure what can not be cured. What is falling we ought even to push down. The weaklings and the failures ought to perish. And we ought even to help them to perish." The world is not a hospital.

Oppression and slavery in some form or other are means to the desired end. "The perfection of the type man has thus far always been the work of an aristocratic society—and it will always be so, the work of a society that believes in a long scale of rank and in a great difference of value between man and man, and finds slavery in some form or other necessary."

Of course, all this means pain and suffering, but remember that happiness is not the end and pity is not a virtue. "My sorrow and my pity—what do I care for these? Am I craving for happiness? No, I am craving for my work." "There are higher problems than all pleasure-, pain- and pity-problems, and every philosophy that culminates in these is a naïve philosophy." "You desire if possible *to do away with suffering*; and *we?*—it seems: *we* desire to intensify it, even to make it worse than it was! Well-being as you understand it—why that is no goal, that seems to be an *end!*—The discipline of suffering, of *great* suffering—do you not know that *this* discipline alone has thus far been the cause of every advance toward perfection in man?" "Such human beings as are near to me I desire to experience suffering, neglect, sickness, ill-treatment, humiliation—I hope that they may become acquainted with extreme self-contempt, the torture of self-distrust, the misery of defeat. I have no pity for them, because I wish them the only thing that can prove in our day whether a man has *worth* or not—that *he fight it out.*" "The most spiritual men also suffer by far the most painful tragedies; but for that very reason they honor life, because it places against them the greatest foes. It almost determines the scale of one's worth how deeply one can suffer." "The man who has become free, and much more the spirit that has become free, tramples under foot the despicable kind of well-being of which grocers, Christians, cows, women, Englishmen and other democrats dream. The free man is a *warrior.*"

The fact is, man does not seek pleasure or happiness, nor does he avoid pain. What man wants, what the smallest part of a living organism wants, is more power. For what do the trees in the forest

struggle with each other? Certainly not for happiness, but for power. Pain as an obstacle to man's will for power is a normal fact, the normal ingredient of every organic occurrence. Man does not avoid pain, he needs it; every victory, every feeling of pleasure, every occurrence, presupposes a resistance overcome. The psychologists have not distinguished between the pleasure of falling asleep and the pleasure of victory. The exhausted want rest, they want to stretch out their weary bones, they want peace and quiet—it is the happiness of the nihilistic religions and philosophies. The robust and active natures desire victory, they want to overcome opponents, to extend the feeling of power over wider areas than before. All healthy functions of the organism have this need—and the whole organism is such a complexus of systems striving for the increase of the feelings of power. “To be preoccupied with oneself and one's everlasting salvation is *not* the expression of a perfect and self-confident nature, for such a nature doesn't care a straw whether it is to be blessed or not—it has no such interest in happiness of any kind, it is power, action, desire—it puts its impress upon things.”

Life in short is hard and cruel and can not help being so; it is full of suffering. But we must not only learn to suffer ourselves, we must learn to see others suffer, yes to make them suffer where it is necessary. “Who can achieve anything great unless he feels the power and the will in himself to *inflict* great pains? The ability to suffer pain is the very least; weak women and even slaves often become masters in this. But not to perish of grief and distrust when we inflict great suffering and hear the cry of anguish—that is great, that is a part of greatness.”

We must not only bear suffering in ourselves and be brave enough to inflict it upon others; we must not pity it. Schopenhauer had made pity or sympathy the sole basis and standard of morality, because it is the negation of the selfish will to live. For that very reason Nietzsche repudiates pity. In the first place pity is by no means so disinterested and admirable a feeling as the moralists make it. The weakling pities those who are beneath him, who do not compete with him, whom he need not fear—it increases his self-love to pity. Pity is the virtue of mediocre souls. Pity is one of the saddest symptoms of decline. Moreover pity crosses the law of evolution which is the law of selection. It preserves what is ripe for destruction. Suffering itself becomes contagious through pity. It augments misery and preserves everything that is miserable, and so becomes the chief means for intensifying decadence. “What is falling we should even push down.” “Oh my brothers, am I then cruel? But I say: what is falling we should even push down! All these things of to-day—they are all falling, they are all decaying; who would keep them from it? But—I would even push them. And him whom you do not teach to fly, why teach him—to *fall*

faster!" "What is more harmful than any vice? Active pity with all failures and weaklings." "War and courage have done more great things than love of neighbor. Not your pity, but your courage, has saved the unfortunate thus far. What is good? To be brave is good. Let the little girls say: good is what is both pretty and touching." "There is a stage of morbid softness and effeminacy in the history of society at which it even takes the part of him who injures it, the criminal. To punish—that somehow seems unjust to it—it is certain that the notion of 'punishment,' of a 'duty' to punish, causes it pain, terrifies it.—Is it not enough to render him *harmless*? Why punish anyhow? Punishment is so terrible."

Pity therefore is bad because it hinders the realization of the ideal: the development of the will for power, the creation of strong men, of great individuals, of powerful personalities. It is not an admirable quality, but characteristic of base, petty souls, of weaklings and decadents. It increases misery and suffering, and diminishes life-energy, and by so much weakens the desire for life and power. It hinders the weak from being eliminated as they ought to be, and so interferes with the proper working of the law of life: the destruction of everything that is not worth saving. Yes, it even preserves the sick, the weak, the failures, the decadents, the degenerates, and makes the world uglier, an eye-sore to the strong and efficient. Pity is a temptation and a danger. "We should put the rein to our hearts; for when we let them go, how they run away with our heads. Alas! where in the world do greater follies happen than among those who pity? And what in the world has caused more suffering than the follies of the pitying?—Myself I sacrifice to my love and *my neighbor as myself*—that is the word of all creators. All creators, however, are hard."

Egoism is worth just as much as the person is physiologically worth who has it. Every individual represents the whole line of development. If he is an advance on this line, then his value is extraordinary, and the care for his preservation and for favorable conditions of his growth may be extreme. But if he represents a retrogression, decay, chronic disease, he has little value, and it is only fair that he take away as little elbow-room and power and sunshine from the sound and healthy ones as possible. In this case society has for its task the repression of egoism. From this point of view a doctrine and religion of love, of repression of egoism, of forbearance, of resignation, can have the highest value because it teaches the weak and sick to keep out of the way of the strong, to let themselves be ruled by the strong. But it must not be forgotten that altruism is a symptom of weakness; the weak and feeble preach love of neighbor and benevolence because they need help themselves. The worship of altruism is a form of egoism; it is the egoism of the failures.

We see, Nietzsche portrays the world as a terrible thing. Life is

full of danger and battle and pain and cruelty. In this he agrees with Schopenhauer. He is not an optimist in the sense of finding everything pleasant and easy and good; it is not a world of sunshine and perpetual joy in which we are living, but a battlefield, a terrible battlefield reeking with blood. But Nietzsche does not conclude from this that we should therefore negate life, that we should fly from it, that we should renounce the world, that we should throw down our arms and give up the fight. All pessimism is a sign of decadence, the expression of a weak will, of a degenerate instinct. The strong and healthy man wills to live—in spite of all suffering and sorrow he wills to live, yes, as we have seen, these very sorrows he makes the means of an intenser, fuller life. “Praised be what makes us hard! I do not praise the land where milk and honey flow.” Nietzsche’s pessimism is a spur to the will; “with this will in our breast we do not fear the terrible and questionable in all existence, *we seek it out.*” “How did I endure it,” he asks, “how did I recover from such wounds? How did my soul again rise up out of these graves? Yea, there is something in me that can not be wounded, that can not be buried, something that can move mountains: that is my *will.*—Yea, thou art still the destroyer of all my graves: Hail to thee my will! And only where there are graves can there be resurrections.”

And because the desire for life and power means self-assertion, will-action, the realization of instincts, asceticism or renunciation or the suppression of instinct is bad. Non-being can not be the goal. Asceticism is a symptom of exhaustion, of weakness of will and degeneracy. There are many forms of asceticism, but all of them ask man to negate his natural instincts, to cease desiring or willing, to do the very thing which according to our philosopher will hinder the realization of life and the higher type of man. “That, however, the ascetic ideal has meant so much for man is an expression of the fundamental fact of the human will: its *horror vacui*; it needs a goal—and it would rather will the *nothing* than *not* to will at all.” But deliverance from life, negation of the will, nirvana, is not the goal, but life, more life. Only when asceticism furthers life, when it makes the will stronger, when it serves as a gymnastic of will, is it good.

Let us now turn to Nietzsche’s anti-democratic teachings and see how they follow from his fundamental principle. If life and power are the ideal, then the strong wills, the great personalities, the higher types of man, the happy few, are better than the many, the masses, the weaklings, the failures, the degenerates. Men are not equal, and it is impossible for them to be made equal. The democratic ideal of equality is a dream. “There is no more venomous poison than the doctrine of equality, for it *seems* to be preached by justice itself when in fact it is the *end* of all justice.” The equality-theory would make of man a dwarf-animal of equal rights and privileges. The herd, of course, is

hostile to gradations of rank; its instinct is in favor of leveling and against the strong individuals, the sovereigns. But, as we have already seen, life is so constituted that some must rule and some must be ruled. The leveling mania is the result of the hatred of the weak for the strong; it means the destruction of power, of will, of individuality. "You preachers of equality, the tyrant's fury of impotence cries out of you for equality; your most secret tyrant-lusts thus masquerade in words of virtue. Offended arrogance, suppressed envy, perhaps your fathers' arrogance and envy: out of you it breaks forth as a flame and as the fury of revenge." The strong man, the genius, should not be sacrificed for the masses. Nay the reverse is true, the masses should be sacrificed for the genius. "The greatness of an advance is measured by what had to be sacrificed for it. Humanity, as a mass, sacrificed to the welfare of a single stronger species man, that would be an advance." "The essential characteristic of every good and healthy aristocracy is that it does not regard itself as the function of the community, but as its aim and highest justification, that it accepts with a good conscience the sacrifice of a countless number of human beings who must for its sake be degraded into incomplete men, slaves, tools."

Therefore all democratic, socialistic, communistic and anarchistic dreams are idle, nay, hostile to life. If men are not equal, they should not be treated as equal. "Equality of rights leads to equality of wrongs. Every right is a privilege." "Equal rights to equals—unequal ones to unequals, that would be the true doctrine of justice: and what follows from it—never to make the unequal equal." All attempts to make the masses, the laborers, equal to the leaders must fail and ought to fail. "For my brothers: the best shall rule and the best *will* rule! And where the teaching is otherwise, *there are no best.*" We need men who will carry out the behests of the leaders, we need executives for the choicest spirits, we need hewers of wood and drawers of water, and there never will be a condition of society when this will not be the case. "Oh my brothers, I consecrate you and point you to a new nobility: you are to be producers and propagators and sowers of the future—verily not to a nobility that you can buy like shop-keepers and with shop-keeper's gold; for little value has everything that has its price.—Oh my brothers, not backwards shall your nobility gaze, but *beyond!* Ye shall be driven out of all father- and forefather-lands. Your children-land shall ye love: this love be your new nobility—the undiscovered land in the farthest sea: to that I bid ye stretch your sails." An aristocratic society of this kind is a necessity of nature, the best must rule, and such an aristocracy makes slavery in some form or other necessary. And, after all, our laborers are no happier than the slaves of Pericles. The original state of nature was not an age of equality, as Rousseau taught, but an age of inequality, and the distance between man and man will be greater instead of less in the future.

The state was in its beginnings probably a terrible tyranny which a hord of mighty beasts of prey combining for rapine and plunder forced upon a peaceful, but poorly organized mass. The modern state, the so-called ideal or paternal state, the idol of the age, is opposed by Nietzsche because it endangers the individuality of creative minds. The ideal state of the socialists is really hostile to life, it is the destroyer of man, it is a crime against the future of man, a sign of exhaustion, a stealthy path to nothingness. It corrupts the soil on which genius grows, it would make humanity tame and uninteresting and happy.

But Nietzsche does not oppose the state as such, he is not an anarchist. He believes in authority, indeed he maintains that healthy vigorous life is not possible without authority. The rabble ought to be made to understand that there are sacred things which they ought not to touch, in the presence of which they ought to take off their shoes and from which they ought to keep their unclean hands. "The society of men is an experiment, a long search; but it *searches for the ruler.*" This ruler is not a brutal arbitrary tyrant, he is strict with himself and gentle with the weak and suffering. He is a man who says: "This pleases me, this I shall take and defend against everyone," "a man who can lead a cause, carry out a resolve, be loyal to an idea, hold fast a woman, punish and overthrow a rascal; a man who has his anger and his sword, and to whom the weak and suffering and oppressed and even animals gladly turn and naturally belong, a man in short who is by nature a *lord*—if such a man has pity, very well! *This* pity has value. But what care we for the pity of those who suffer. Or of those who even preach pity."

For the same reason that Nietzsche opposes the modern democratic tendencies he is against the so-called emancipation of women. The sexes are not equal. Man's strongest instinct is the desire for power; woman's whole life is love, which is merely an episode in man's. "The happiness of man is: This is my will. The happiness of woman is: This is his will." She is made to love and obey, he is made to rule and protect. "Man should be trained for war, and woman for the recreation of the warrior: everything else is foolishness." Where this natural and healthy relation is perverted, where the man is effeminate and the woman masculine, we have decay. "There is too little of the man around here," says Zarathustra, "therefore their women become mannish. For only one who is man enough will *deliver the woman in woman.*"

We are now prepared for a discussion of Nietzsche's conception of morality, one of the most important phases of his teaching. Nietzsche declares that thus far no one has dared to make morality a problem, to criticize it, to call it in question. "The value of these values (those expressed in the moral laws) has been accepted as a matter of fact, as beyond all dispute. In the entire science of morality so far the prob-

lem of morality itself has been absent, even the suspicion has been wanting that there was anything problematical about it. What the philosophers call explanation of morality is merely only a learned form of the firm belief in the prevailing morality, nay, even a kind of denial that morality can be conceived as a problem." But we must examine the prevailing morality; if it really is morality, there will be no danger in such an investigation: whatever can not stand the test must go.

Now such an examination reveals to Nietzsche the perversity of traditional morality. Schopenhauer teaches that pity or sympathy is the basis and standard of morality. Yes, says Nietzsche, pity is the basis of our traditional morality, and therefore our traditional morality is bad. Pity is the negation of healthy egoism, the negation of the desire for life and power; it means renunciation of self, self-denial, self-sacrifice, the suicide of our life-preserving instincts, and therefore pity is bad, and the morality that is based on pity is a symptom of decline. Take out pity and the whole structure of our traditional morality crumbles to pieces. Pity is not a good, as we have already been told, pity is not good because it violates the fundamental principle of existence, the desire for life, the desire for power, and hinders the realization of the true goal: the development of strong men. The morality that is based on pity has corrupted humanity; it teaches men to despise the basal instincts of life, it sets the highest value on unselfishness, the typical goal of decline. "*Entselbstungsmoral* is the typical decadence-morality *par excellence*." The desire for life, for more life, the strong affirmation of life, is the basal law of existence; the production of strong individuals or a strong species the goal, the ideal to be realized, the highest good, the value of values. On this principle our new morality must be based; we must create new values in the light of the highest value; we must transform or re-value, re-evaluate, the old values, reform the traditional morality. Not sympathy-morality, but will-morality, instinct-morality, that is the end.

Our present morality, our pity-morality, is the morality of slaves, the true morality, the will-morality, is the morality of lords, *Herrenmoral*. The slave-morality, the pity-morality, represents the ideals of the weak and oppressed, it incorporates the rules which they desire to be followed in order that they may live their paltry lives in peace. Virtue is for these little people what makes men tame and modest; in this way they have changed the wolf into a dog and have transformed man himself into man's best domestic animal. It is based on their hatred and fear of the lords, the strong, the aristocrats; it represents the instincts of the herd against the strong and independent, the instincts of the sufferers and the failures against those who have succeeded, the instincts of the mediocre, of the average, against the exceptions. These little people call pity of the weak good because they are

weak themselves and need protection; they call the healthy egoism of the lords bad because the lords push them so hard. Their morality is the morality of gregarious animals, *Heerdentiermoral*, it is the morality of the timid, weak and sick; their virtues are the virtues of the herd, and these are praised because they preserve the herd.

But all that is perverse; the traditional pity-morality is a degeneracy. Life, the affirmation of life, the exercise of healthy robust instincts, is good. Life, more life, intenser, fuller life, is the demand. This is clearly brought out in the relations which the states assume to one another; societies do not follow the pity-morality in their treatment of other societies, they are not altruistic towards each other. The study of society is so valuable because man as society is much more naïve than man as individual. Society has never looked upon virtue as anything but a means of power, strength and order. Outwardly, in its dealings with other collective bodies, the herd is hostile, selfish, merciless, greedy for rule, full of distrust.

The lord or strong man, the aristocrat, feels that life is good, and calls everything that makes for his ideal good. He and his equals, the robust natures, are good; their self-assertion, their self-glorification, their love of life, their will for power, their desire for struggle, that is good. The strong and noble despise the weaklings, the slaves; these are *schlecht*, low, base, plebeian, vulgar. The very word *schlecht* means low, base, common, of low descent, despicable. It expresses certain incapacities which are physiologically connected with the type of degeneracy: *e. g.*, weakness of will, vacillation, inability to check the reaction to a stimulus and to control oneself, lack of freedom in the presence of any kind of suggestion on the part of another's will. Fear, cowardice, flattery, baseness, humility, mendacity and weakness are the qualities of the base-born.

Whatever tends to preserve and develop the robust men, the great individuals, the higher type, is good, whatever tends to hinder the realization of this end is bad. The qualities which make for the preservation of the good type are good, whatever acts and qualities tend to keep the stock pure are right. Hence the lords have no duties to their inferiors, but only to their equals. Indeed, the masses are merely so much food for the geniuses, the necessary background and instrument for the higher types. They do not count. The aristocrat fixes the values, and he values himself alone.

It is not correct to say that Nietzsche is a moral nihilist, that he repudiates all morality. He does repudiate the traditional morality, but sets up in its stead a new morality, the *Herrenmoral*, which, as he believes, is the morality of health and power, the original morality, which was displaced by the slave-morality, a heritage of the Jews. Indeed, the main thing for him after all is the principle that should underlie all morality, the principle of the higher type. "I do not

deny," he says, "that many acts which are called immoral are to be avoided and combatted, likewise that many which are called moral ought to be performed and encouraged—but I think these acts ought to be performed or avoided for different reasons from those given hitherto." Nor does Nietzsche preach a code of license and caprice. His ideal man is not a man of license, an unrestrained force, a wild and lawless savage. He does not wish to bring back the 'blonde beast' of early times, the 'human beast of prey,' the tyrant, the despot, the usurper. "The noble man," he says, "honors in himself the man of power, the man also who has power over himself, the man who can speak and keep silent, who delights in being strict and hard with himself and has respect for strictness and hardness everywhere. Confidence in oneself, pride in oneself, belong to aristocratic morality." "As soon as the noble or aristocratic soul is clear on the question of rank, he moves among his equals and those having equal privileges with the same confidence and gentle reverence which he reveals in his intercourse with himself—he honors himself in them and in the rights which he grants them, he does not doubt that the exchange of honors and rights constitutes the essence of all intercourse and the natural condition of things." What is freedom? "That we have the will to take responsibility. That we keep the distance which separates us. That we become more and more indifferent to toil, hardness, privation, yes even to life itself. That we be ready to sacrifice to our cause human beings, ourselves not excluded. Freedom means that the manly, the warlike and the triumphant instincts dominate the other instincts, for example, the instincts for 'happiness.'" The ideal of personality can only be realized by self-discipline. All morality is a long compulsion. "You ought to obey some one or other and for a long time, otherwise you will go to pieces and lose your self-respect." When you obey yourself, when you are a law unto yourself, then you are a free man. Your act should be your act, the expression of your personality, your self ought to be in it as the mother is in her child. Those are commanded who can not obey themselves, who can not control themselves. "Alas! there is so much lust for fame! There are so many convulsions of ambition! Show me that you are not one of the lustful and ambitious! Alas! there are so many big ideas, they do nothing but inflate like bellows: they blow up and make more empty. You call yourself free? Your controlling idea let me hear and not that you have shaken off a yoke. Are you one of those who had the right to throw off the yoke? There is many a man who threw away his last worth when he threw away his obedience. Free from what? What does Zarathustra care for that! Clearly however your eye shall tell me: Free *for what?*"

A great man, a heroic man, a good man, is better than a weakling,

a decadent and a fool. "From time to time," exclaims Nietzsche, "grant me but one look upon something that is complete, something that is finished, something perfect, mighty, triumphant, something in which there is still something to fear. Upon a man who justifies *mankind*, upon a complementary and redeeming accident of man, for whose sake we can hold fast to our *belief in mankind*." That nature can produce a single man of this type is a consolation to Nietzsche, is enough to fill him with admiration and joy. He would agree with old Heraclitus: "To me one man is ten thousand if he be the best."

Traditional morality is repudiated by Nietzsche because and in so far as it contradicts the principle of life. For the same reason he rejects religion, particularly the Christian religion. The leading religions, he thinks, cause the race to deteriorate, they preserve too much of what ought to perish. Christianity, especially, is a crime against life. It falsifies, negates and depreciates reality. It preaches asceticism, the denial of life, pessimism, pity, effeminacy, contempt for the world, peace, non-resistance, opposition to struggle, equality and original sin. It is hostile to nature and the natural healthy instincts, calling them sinful; it glorifies the weak and sick and would have them rule over the strong; it tries to make the unequal equal; it destroys man's pleasure in himself and in the world; it is the religion of the decadent, of the played out, of the unnerved. In short, it condemns and negates this life, and points us in its stead to fictions of another world: to God, an immortal soul, a future life and a free will. It has nothing but imaginary causes (God, soul, ego, spirit, free will); nothing but imaginary effects (sin, redemption, grace, punishment, forgiveness of sins); an intercourse between imaginary beings (God, spirits, souls); an imaginary natural science (anthropocentric: complete absence of natural causes); an imaginary psychology (repentance, pangs of conscience, temptation of the devil, the proximity of God); an imaginary teleology (the kingdom of God, the last judgment, eternal life). This entire world of fictions has its root in Christianity's hatred of the natural (the reality), it is the expression of a profound contempt for reality. But that explains everything. Who alone has reason to *lie himself out* of reality? He who suffers from it. But to suffer from reality is to be a failure of reality. The surplus of the pain-feelings over the pleasure-feelings is the cause of that fictitious morality and religion—such a surplus, however, represents the formula of decadence. Christianity is the insurrection of the failures; it is the religion of the lower classes, women, slaves and plebeians. "Every philosophy that places peace above war, every ethics that gives the notion of happiness a negative form, every metaphysics that makes a state of equilibrium and final rest the goal of development, every esthetic, ethical or religious yearning for a better

world, for some 'hereafter' or other, is radically, perhaps nothing but a symptom of degeneracy."

His own religious feeling Nietzsche expressed in what he called *amor fati*, the love of fate. "My formula for the greatness of a man," he says, "is *amor fati*: that he desire to have nothing except what he has, not in the future nor in the past nor for all eternity. Not only to submit to necessity, least of all not to hide it from himself—for idealism is falsehood, mendacity in the presence of necessity—but to love it." "Verily through many souls have I passed and through hundreds of cradles and pains of labor. Many a farewell have I spoken; I know the heart-breaking last hours. But my creative will, my fate wills it so. Or to put it more honestly: such a fate is just what my will desires. Will is a deliverer, that is the true doctrine of will and freedom." "A new pride my I has taught me and that I teach men: no longer to hide my head in the sand of heavenly things, but to carry it freely, a head of earth, which realizes the purpose of the earth. A new will I teach men: to desire this path which man has blindly trod, and to call it good and no longer to steal away from this path like the sick and dying."

Nietzsche's estimate of the intellect, of knowledge, of philosophy and science, of truth, is based on the same fundamental thought. The will for power, the desire for life is what counts. Instinct, desire, will, are better than knowledge or intelligence as such, or conscious intelligence rather. The mind or intellect is merely an instrument in the hands of instinct, of the will for life and power. "Behind your thoughts and feelings, my brother, stands a mighty ruler, an unknown sage—and his name is self. He dwells in your body, he is your body." Your intellect or mind is the 'little reason,' it is the tool of your body—the creating body created the mind as a hand of its will—your body and its instincts is the 'big reason.' "I am wholly body and nothing else; and soul is but a word for something belonging to the body." "There is more reason in your body than in your wisest wisdom." Mind or knowledge has value only in so far as it makes for life, in so far as it helps you. Now truth does not always help you, it is sometimes harmful; illusion sometimes helps you. If illusion helps us, we want illusion. Nietzsche even goes so far in his opposition to the popular view as to say that illusion is as necessary as truth. "The falseness of a judgment," he says, "is no objection against a judgment. The question is how far it preserves and promotes life, preserves the species, perhaps even develops the species, and we are inclined to assert on principle that the falsest judgments are the most indispensable ones for us, that without assuming logical fictions man could not live, that to give up false judgments would be to give up life, to negate life."

It is a prejudice of the philosopher that truth is more valuable

than error. To put truth above error and illusion, to love truth for its own sake instead of as a means of life, is turning things upside down, is a diseased instinct. Indeed this ideal of truth for truth's sake is only another form of asceticism, it is a denial or negation of life for something else.

Besides, Nietzsche goes on to tell us, there is no universal truth anyhow, there are no eternal truths, no truths accepted by all. The propositions that have been offered as truths are errors. Thinking is really inaccurate perception, it looks for similarities and overlooks differences, thereby producing a false picture of reality. There is no such thing as substance, there is nothing permanent; there is no universal causal nexus; there is no purpose in nature, no definite goal. The universe does not care for our happiness or morality, there is no divine power outside that can help us. Our vanity of course hinders us from accepting the view that there is no purpose, no goal in the universe. "The total character of the universe is for all eternity chaos, not in the sense that necessity is wanting in it, but in the sense that it is without order, organization, beauty, form, wisdom and whatever else our esthetic anthropomorphism may put into it. Judged by our reason the misses are the rule, the exceptions are not the secret goal, and the whole play eternally repeats its air which can never be called a melody; and finally the expression *unlucky throw* or miss, is a human way of talking which implies reproach. But how can we either praise or blame the All?" "Man is a little exaggerated animal that—fortunately—has had its day; life on the earth is only a moment, an episode, an exception without consequence, something that has almost no significance for the total character of the earth; the earth itself, like every star, is a hiatus between two nothings, an event without plan, reason, will, self-consciousness, the worst kind of necessity, *stupid* necessity. Against this view something in us protests; the serpent vanity persuades us: 'all that must be false for it makes us indignant. Could it not all be mere semblance?'"

All these propositions, then, that have been accepted as universal truths are merely errors and illusions, phantoms of the imagination; the belief in a God and in a supersensuous world, in an abiding world, is an illusion. Knowledge is a tool for power. The utility for preservation is the motive behind the development of the organs of knowledge. We arrange the world so in our thoughts as to make our existence possible; hence we believe in something permanent and regularly recurring. We reduce the confused plurality of experiences offered to us, to a rational and manageable scheme by means of formulas and signs which we invent; the purpose being to deceive ourselves in a useful way. In this sense the will for truth is the will to become master of the plurality of sensations—to string the phenomena on certain categories. A species understands so much of reality as is

necessary to master it. Hence logic and the categories of reason are simply a means of arranging the world for utility purposes, of arranging it so that we can handle it. But the philosophers have made the mistake of regarding these categories, these formulas, these handy forms, as criteria of truth, as criteria of reality; they have naïvely made this human way of looking at things for the sake of preservation, this anthropocentric idiosyncrasy, *the measure of things*, the standard of the 'real' and 'unreal.' And in this way it came to pass that the world was divided into a real world and a seeming world, and that the very world to live in which man had invented his reason, this world of change, of becoming, plurality, opposition, contradiction, war, was discredited and calumniated, that it, the real world, was called a world of semblance, a mere appearance, a false world, and that the invented fictitious world, the alleged world of permanence, the unchanging, supersensuous world, the false world, was enthroned as the true world.

All we do know directly is the world of our desires and instincts, and all our instincts may be reduced to the fundamental instinct—the will for power. Every living being strives to increase its power by vanquishing other beings; this is the law of life. Indeed, every specific body strives to become master of the whole of space and to extend its force (its will for power), and to repel everything that resists its extension. But it constantly meets with similar strivings of other bodies and ends by falling in line ('uniting') with those that are sufficiently related to it—and they then conspire for power together. The world is a monster of force without beginning or end, a fixed iron quantity of power which does not become greater or less, which is not used up, but transformed, a household without income or outgo. And this world repeats itself forever and forever. All things return eternally, Nietzsche teaches, and we ourselves with them; we have been here before an infinite number of times and all things with us; and we and all things shall come again eternally, shall live over again the same lives even to the smallest details. The knot of causes returns in which I am tied—that will create me again. I shall come again, with this sun, with this earth, with this eagle, with this serpent—not to a new life or a better life or to a similar life, but to this same life. "And this slow spider which is crawling along in the moon-light, and this moon-light itself and I and you in the doorway whispering to each other, whispering about eternal things—must we not all have been here before? and must we not all come back again, and walk in that highway of eternity stretched out there before us, in that long and hideous high-way must we not return eternally."

These are the fundamental ideas of Friedrich Nietzsche. As we have seen there is a central thought running through his entire work, an ideal, that is they key to his whole philosophy of life and helps us

to understand this remarkable thinker and his opposition to our age. The will for power is the fundamental human instinct, the fundamental human fact. The goal is the creation of a higher type of men, of a race of heroes, as it were. Life in the real sense of the term is impossible without struggle, it is a struggle for existence. Hence war is preferable to peace, indeed peace is a sign of death. War and struggle of course are hard, they bring out the stern elements in man, they can not be carried on without injury, pain and suffering, without hurting the weak. But since all these things are inevitable, since no strong race can be produced without the desire for power, which implies war, struggle, pain, suffering, injury to the weak, they are good and their opposites bad. We must fight, we must inflict injury, we must suffer our pain, because life is impossible without these things. "It is customary nowadays," he says, "even under the guise of science to prate about coming conditions of society which shall be lacking in the ferocious features. That sounds to my ears as though it were intended to invent a life that dispensed with all organic functions." We are not here for our pleasure, for our happiness, we are not here for any purpose, but being here we must hold our own, we must assert ourselves, or go down. Therefore pity is bad, it injures him that gives and him that takes. It saps the strength of the race, it weakens both the strong and the weak, and is bad.

It is true that life is terrible, but that is no reason for pessimism. Indeed, pessimism, renunciation, is impossible except in a diseased and degenerate race, for the desire for life is too strong in a healthy mind to be overcome by pain and battle. Again, life is struggle, it means victory for the strong and defeat for the weak; somebody must win and somebody must lose. It is an experiment, a sifting process in which the sheep are separated from the goats. It is selective, aristocratic. It brings out the inequalities in human nature, it shows that men are not equal. Some men are better than others, stronger in body and mind. The better men, the natural-born aristocrats, should have more privileges because they have more duties than the plebeians, the rabble. The best men should rule. Hence democracy, socialism, communism, anarchism are all impossible, they all contradict the ideal, they all make impossible the development of strong individuals. Slavery in some form or other has always existed and will always exist. The modern laborer has simply taken the place of the ancient slave. Nor can women have the same rights as men because they are not equal to men in initiative, in energy, in will. Our greatest danger to-day lies in the mania for equality. "For thus it stands," says our thinker, "the dwarfing and leveling of the European man constitutes our gravest danger, for this outlook wearies us. We see nothing to-day that promises to become greater, we are vaguely suspicious that things are going down, down, that everything is becoming thinner, more

good-natured, more prudent, more comfortable, more medioere, more indifferent, more Chinese, more Christian—man, there is no doubt, is becoming ‘better’ and ‘better.’ Just here lies Europe’s danger: with our fear of man we have also lost our love for him, our reverence for him, our hope in him, yes our desire for him. The sight of man now wearies us—what is nihilism to-day if it is not that? We are weary of *man*.”

“We have invented happiness, say the last men and blink their eyes. They have left the regions where life was hard, for they need warmth. They still love their neighbors and rub themselves on them, for they need warmth. To become sick and to be distrustful they regard as sinful, they walk circumspectly. A fool who still stumbles over stones or men: A little poison now and then, that makes pleasant dreams. And much poison at the end, for a pleasant death. They still work, for work is a source of amusement. But care is taken that the amusement be not too severe. They no longer grow rich or poor; it is too troublesome. Who is willing to govern? Who is willing to obey? All that is too troublesome. No shepherd and one flock. Everybody desires the same, everybody is equal: whoever thinks otherwise voluntarily goes to the insane-asylum. Once the whole world was insane, say the choicest and blink their eyes. They are wise and know everything that has happened; so they go on mocking. They still quarrel with each other, but they soon become reconciled—otherwise it would spoil their digestion. They have their little pleasures by day and their little pleasures by night; but they take care of their health. We have invented happiness say the last men and blink their eyes.”

Our traditional morality is also rejected by Nietzsche because it is based on pity and favors the weak and decadent against the strong. Religion, too, particularly Christianity, is repudiated for the same reason and his contempt for science and philosophy is to be explained in the same way—by his glorification of the will for power. Peace, happiness, pity, self-denial, contempt of the world, effeminacy, non-resistance, socialism, communism, equality, religion, philosophy and science, are all rejected because they contradict life, and all systems of thought and all institutions which regard these things as valuable and worthy to be sought after for their own sakes are symptoms of decadence.

THE STUDY OF LOCALITY.

BY CEPHAS GUILLET, PH.D.,

TORONTO, CANADA.

A SIMPLE statement of what can be done and has been done with children is attempted in this article by one who for five years maintained a school in Ottawa for boys, limited in number to twenty and ranging in age from eight to fourteen years.

The afternoon work of this school was conditioned by the season. In the fall, the topography and physiography and the geological history of the city and surrounding country were studied. The crust of the earth was examined in outcrops, mines, quarries and excavations, and collections made of soils, shells, fossils and animals for museum, vivarium and aquarium.*

In the winter when animate nature is in a state of torpidity and the earth covered with a mantle of snow, the conditions are less favorable for outdoor study of nature. As nature is asleep, we study her asleep. The forest in particular is a convenient and interesting object of winter study. We observed the general appearance of the tree-skeletons, striving to fix in our minds by memory-drawing the characteristic shapes of the various deciduous trees. We examined the bark of the trunk, the character of the wood (making collections of various woods), the size, form, color, texture, taste and smell of the twigs and buds, and the number and arrangement of the buds. The character of the terminal twigs is an excellent means of distinguishing our trees and shrubs. The various contrivances by which the buds protect themselves are of great interest. The buds, being kept in water, open out, showing how ready they are to cast off their winter clothes when the moisture and warmth of spring shall come.

Approaching Christmas reminded us of the evergreens, which we learned to distinguish, the boys decorating their desks with them. In this connection, I shall describe a typical winter outing. A few days before school closed for the winter holidays, we went to a rugged, swampy brush in search of evergreens, each boy being assigned a particular kind to be responsible for, while all were on the lookout for the rarest in the neighborhood, namely, ground hemlock or American yew. Joyously shouting defiance to the frost king, they trudged over the ridges, plunged down into the gullies, and ran across the tiny ponds. Skirting one of these, they at last found the ground hemlock nestling

* For a full account of the fall work in nature study, see 'A Glimpse at a Nature School,' in *The Pedagogical Seminary* for March, 1904.

at the foot of the taller balsam and spruce. Then one of the boys made the merry discovery of the orange berries of the climbing bitter-sweet shining brilliantly against the bright green of a tall spruce, which it clasped in its tight winding embrace to the very top, while hanging its beautiful clusters down in rich and graceful festoons. At once there was a clambering and a pulling till we had added these gay wreaths to our varied evergreens. Such an outing puts iron into the blood and glad memories into the heart.

One of our favorite haunts was a piece of bush called Beechwood. Last winter we undertook to make a valuation survey of it on snowshoes. We first marked off a strip by tramping from one end of the woods to the other in Indian file. Then we counted all the trees in that strip, but recorded the measurement only of those of a circumference, breast high, of 36 inches or more. Two boys were assigned to each of the principal trees, one of them using the tape while the other kept tally. In the case of the boys in the illustration, it is evident that two of them are measuring one of the large beeches. In this way, we covered the whole woods in four afternoons, and found it to contain 670 trees, of which 270, or 40 per cent., were at least three feet around. All the trees but 90 and all the large trees but 30 were maple, beech and basswood, there being as many large maples as large beeches and basswoods together. The other trees present we found to be elm of two species (American elm and slippery elm), ironwood, yellow birch, hemlock, butternut and white ash.

At the school, we worked out the diameters of the trees whose circumference we had recorded, and then with the aid of lumbermen's tables found the total contents in board feet of the three most numerous species. Counting the lumber as worth \$12 a thousand, we soon found out the value of the standing timber of our little woods to be about \$800. Meanwhile, with compass and pencil in hand we had ascertained the shape and size of the wood, made a chart of it and estimated it to contain about eight acres.

In the spring, we studied the character of the underbrush and of the soil cover and indicated with proper surveyor's signs the large wooded portion, the two small open grassy corners, the marshy ground, the hill and the paths. Scattered through the wooded part, we placed signs for the principal trees, which signs we had invented ourselves from our observation of the character of the trees. The basswood, for example, we found most numerous in the lower parts, the butternut on the ridges. The ironwoods we noticed to be small but thrifty, shade not being so detrimental to these weeds of the forest as to many other species. At the close of the school year, a little lad of eleven summers had the bright idea of presenting me with an enlarged chart of our wood, done neatly in ink. Here surely is an example of self activity.

Early last April, we spent two mornings in the woods sugar-

making. Having obtained permission to tap twenty maples in Beechwood, we bought the outfit and went to work. The first morning we tapped the trees, the boys being taught how to select the best trees and how best to tap them. The reasons for each step were elicited or suggested, science and practise going hand in hand. It was great fun for the boys to watch the sap dropping into the cans, and to see whose cans filled first—proving their owners to have made the best choice of trees or managed the tapping best.

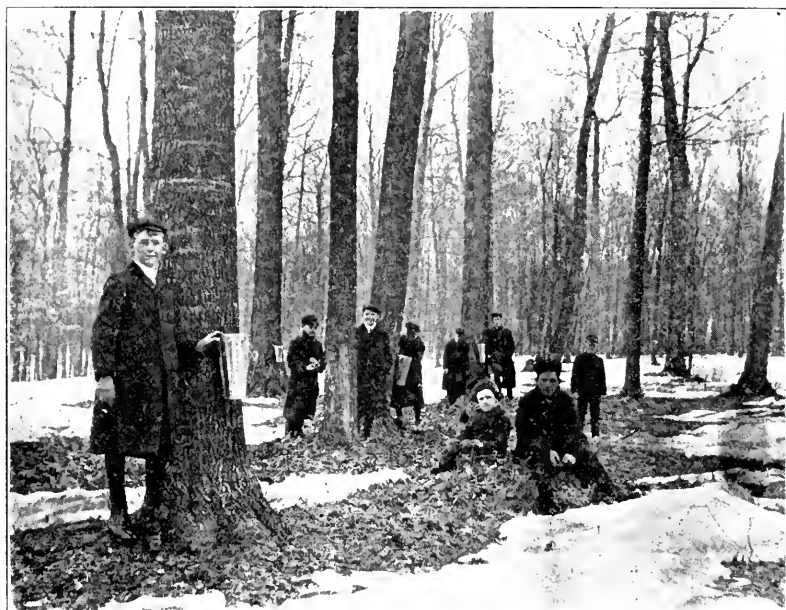
A couple of days later, having on hand a couple of barrels of sap or its product in syrup, we went to the woods to sugar off. First we made taffy by pouring the thick syrup on the snow. Then we boiled the rest down into sugar to take home. The boys in the illustration are enjoying the fruits of their labors in the shape of taffy.



GEOLOGIZING ON PINE ISLAND.

After each of these occupations of surveying and sugar-making, which I have described, and after considerable discussion of the same, the boys wrote compositions on 'Beechwood' or 'A Valuation Survey of Beechwood' and on 'The Maple' or 'Sugar-making.' A boy can write to some purpose after such an experience.

Throughout the spring the study of reviving nature was a never-failing source of delight. The boys took the keenest interest in the return of the birds, the unfolding of leaf and flower, the awakening of frog and snake, squirrel, snail, butterfly and humble-bee. We set up our aquaria and vivaria afresh. We observed the birds in their busy occupations of feeding and nesting. We sketched them in their characteristic attitudes; and learned to distinguish their varied notes and songs. We looked eagerly for the first flowers of spring, the gay hepaticas and sweet Mayflowers or trailing arbutus, and we observed



TAPPING THE MAPLES.



SUGARING OFF.

were asleep beneath a garment of snow and ice three feet thick, as we found by actual measurement.

Hitherto I have been speaking of the study of natural history. I shall now speak of the way we studied culture history: the history of man, his struggles and progress.

As the reader will have gathered, the study of nature in this school was by direct observation. Books were used, to be sure. The school library contained many books about nature, and the readers used were Wood's 'Natural History Readers.' But the books were not the center of the study; they were merely accessory.

As with natural history, so with culture history. We began by observation. To get a large view of their native place, some six outings were spent in compassing the city on foot. Practical elementary lessons in surveying and mapping to scale were given, beginning with the schoolroom. Then a map was made of the city and its environs, and the course followed in the walks indicated, as well as the topography and the important buildings and public works. Visits were paid, mostly in the winter, to various institutions: to Parliament and City Hall and Market; to the shops of the jeweler, furrier, picture dealer, florist and maker of musical instruments; to the various factories and offices to see men wrestling with resistant matter in its various forms of wood, tin, copper, iron, stone; the lumberman, the joiner, the turner, the carver, the stone molder, the mason, the bridge-builder, the diver, the blacksmith, the printer, the bookbinder. We also attended the Ottawa Valley ploughing match just before winter set in, and visited the Experimental Farm at all seasons.

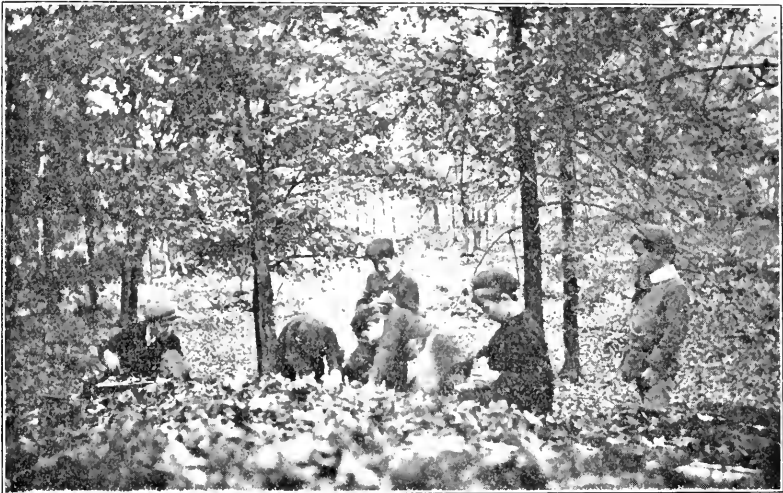
Meanwhile, the history of our city and district from the days of the sturdy backwoodsman to the present was unfolded and maps were made of the county and district. The industries of the locality were studied as conditioned by its peculiar resources in soil, timber, minerals and water-power. Then the early history of the various provinces and of the Atlantic states was narrated. The gist was given (with occasional reading of the more interesting parts) of many works relating to the discovery, exploration and settlement of the various parts of the American continent by the races of Europe. A map was drawn and so marked and colored as to give a bird's-eye picture of the course of discovery and settlement. In another map the native districts of the Indian aborigines were indicated, and something was told of Indian character and legend. Here again the school library was a valuable adjunct in the work, and sometimes the boys brought from their homes books bearing upon the subject in hand.

The parents have freely expressed their appreciation of the methods of the school.

I have tried to describe the value of this natural education, yet I have scarcely touched upon one aspect—perhaps most important of all,

but too subtle to be pictured either in words or in illustrations. I mean the sweet, unconscious influences of nature and of one's native environment. By taking care that the child's associations with home are rich and full, we provide for the man an inexhaustible source of inspiration.

The reader will have observed that all that I have spoken of so far is really history—the history of nature and of man; and he will have seen how impossible it is entirely to separate these two things in any natural treatment of them. This is because they are not so much two separate things as two aspects of the same thing. Does not the reader see the application of this truth to education? Does it not suggest to him the thought that in taking his children away from nature,



STUDYING THE NATURAL HISTORY OF BEECHWOOD.

away from their natural environment, and shutting them up all day in a schoolroom, chained to desks and books, he is doing violence to all that makes boyhood precious—to its naïveté, to its love of all out-doors, to its instinctive craving for activity, and he is depriving it of the most natural means of its own development?

I wish to guard against a possible misapprehension. I am not laying down a school course for teachers. My school was situated in Ottawa, and the choice of culture material was governed largely by that fact. If I were to teach in Halifax, or Toronto, or Calgary, or Vancouver, I should deem it my first duty to study the conditions existing there. For I hold that the teacher will find in the locality, in the environment in which he lives and in which his pupils live, the most appropriate and the most educative material of instruction, far exceeding in value that found in any text-book or in all the text-books.

To the teacher, therefore, this article is purely suggestive. It is for the trained teacher who possesses independence and initiative to work out his own course. His course should grow with his growth and with his increasing knowledge of his pupils and of his environmental conditions. It should be the teacher's task to locate his locality in its relationship to the rest of the country, geologically, geographically, meteorologically, botanically, zoologically, historically, in politics, in art, in literature, in industry, in all its conditions and endeavors, showing the place it has taken and the place it is destined to take in the building up of the national spirit and character.



ON THE BOOM.

THE CAUSE, NATURE AND CONSEQUENCES OF
EYESTRAIN.

BY GEORGE M. GOULD, M.D.,

PHILADELPHIA.

NO questions are so often asked of the oculist by his patients as, 'Why do so many people, and even children, have to wear spectacles nowadays?' 'Are we deteriorating?' 'Are eyes so much poorer than formerly?' 'My grandfather did not wear glasses,' etc. Each oculist meets the questioning in his own way, but the public still remains unconvinced, suspects there may be some mistake about the whole matter, and is at least mystified.

It is hard to give satisfactory answers, at the best and with all one's good will. Not a little of our inability to throw light on the subject comes from our own indecisions and nonunderstandings. About many of the phases of the matter we have not reached a common conclusion and our professional differences of opinion bring further doubt to our patients. Concerning other parts we are also utterly unknowing ourselves, because the mechanics and neurologics of sensation, mentation and even of nervous force and transmission, still remain utter mysteries to all. Of these things the most learned are as ignorant as the most unlearned. We see or conclude that certain trains of ether-waves with a vibrational periodicity of some 400 to 700 trillions per second are transformed somehow into retinal and neural bundles of forces traveling only at the rate of about 125 feet per second; thence proceeding to the cortical visual center they are again transformed into what we call sensations of form, light and color. And innervational forces are sent back to the muscles of the eyeball, which move it as a whole, or modify its internal functions. Although we can know nothing of the intimate nature of these mechanisms and forces, we can deduce many definite, though crude, conclusions as to their causes and their results.

The dominating demand which governs all the processes concerned is for an accurate and accurately focussed image upon the retina of the object upon which the eye is trained. All human physiology centers in that success, and much of our pathology follows from its failure. That there shall be two such images upon 'identical points' of the two retinas only heightens and complicates the difficulty. The clearly-defined perfectly-representing image upon the retina is purely a matter of optics, physical and physiologic, and may be understood by any one who knows how his kodak takes a picture. To realize the difficulty of the kodak of the living eye, one must have an adequate conception of

the variations, only one two-hundredth or one four-hundredth of an inch from the normal in the dimensions of the eyeball or in its corneal curves which may prevent the accurate photographic 'definition' of the retinal image. To this must be added a knowledge of the means or lack of means possessed by the eye to overcome or neutralize these results of deviations from the standard of size and contour. What are the kinds of deviations that may be cancelled, how far the neutralizing is possible, what kinds may not be overcome, and the mechanism of the overcoming, these are all pretty well understood.

In the briefest way we may say that if an eyeball is too long (from the cornea to the retina) it is near-sighted or myopic. One can not see well at a distance, for everything appears blurred and hazy. The focus of the image is in front of the retina, and there is no device of the unaided eye which can transpose it to its proper position upon the retina. Any effort to do so is by the nature of the conditions a negative one, an endeavor, if one may so speak, and of course, unconsciously, to lessen muscular effort. There is as result no eyestrain, no morbid, or wearying, or hurtful attempt at muscular exertion.

The supposition, in this case, is that a pure or uncomplicated myopia exists, and that it is of the same degree or amount in both eyes. In truth, however, that supposed condition never exists. No oculist probably ever tested a pair of eyes having no astigmatism, and having exactly the same over-length, or myopia. And this astigmatism, or the difference in lengths of the two eyeballs, or both factors combined, brings always the possibility of 'eyestrain.' For eyestrain is the name given to any unphysiologic, *i. e.*, pathologic ocular action or function which is wearying, excessive or unnatural. It thus becomes clear how it is that the two eyes by reason of the presence of a difference in their relative lengths, or because of astigmatism in one or both, may result in morbid effort or strain, although if both were alike in over-length, and without other optical defect, there could be no such strain. This general fact makes evident the truth that in general those with (moderately) myopic eyes have far less ocular diseases and pains in the eyes, less headaches and other general disorders, than those whose eyes are hyperopic, or 'far-sighted.' For in all 'far-sighted' eyes there is a never-to-be-renounced effort to overcome the trouble. But this freedom from pain and other symptoms in myopia may lull the patient with a false security and costly neglect. The great danger is that without the attention of a skilled specialist the myopia may increase, become 'malignant,' as it is termed, and the eyeball continue to elongate, with imperilled or fatal loss of vision. The myopic eye is one abnormally elongated, enlarged or stretched, and once having lost its tonicity or normal measurement, it tends to extremes of enlarging.

The far-sighted or hyperopic eye is the reverse of the myopic eye:

it is too small or too short and hence effort and muscular exertion are necessary to bring the image forward, in proper definition upon the retina. Without this exertion the image would be behind the retina. Hence a similar blurring or badly defined picture as in myopia, but from the reversed cause. In this kind of eye the picture is naturally blurred even of the most distant object (making the term far-sightedness a misnomer), and a slight increase of focussing power is required on the part of the 'accommodation' mechanism in each eye, in order to shorten the focus of the image-forming rays of light. With every lessening of the distance of the object, still greater converging power is demanded, as one may understand by tests with different-power glass lenses. When the object is brought within ten or fifteen inches of the eye the greatest effort is required to make the image clear. The degree of this effort will depend upon how much too short the eyeball is, or upon the amount of hyperopia. It will also depend upon the kind and amount of ocular labor, especially the continuance of 'near-work,' the reading, writing, etc., required of the eyes. The farmer, ranchman or sailor will obviously be able to overcome or be indifferent to higher degrees of far-sightedness than those living in cities, while the literary man, bookkeeper or seamstress will experience eyestrain with still lower degrees of hyperopia.

One must carry in the mind another modifying condition—the difference almost always existing between the far-sightedness of one eye and that of its fellow. The two are under more stringent orders than in myopia to work together and in harmony. When the hyperopia differs in the two the chances of strain are obviously increased many times.

These chances already multiplied now become inevitables if astigmatism is a complication of the hyperopia. Alas, also, it is very certain to complicate. I have measured something like ten thousand pairs of eyes, and not one of these pairs was without some imperfection of shape, size or curvature, either in one or both of the eyes. An absolutely perfect pair of eyes does not probably exist.

'And do tell me, what is astigmatism?' is the puzzling question put to the oculist every day. It is one, fortunately, very simply and easily answered. The front part of the eye, that behind which lies the pupil, is called the cornea. It should be round or equally curved like the central portion of the end of an egg. It is usually not uniform in its curvature, but is more curved in one meridian than in the reverse meridian—that is, it is, approximately, of the shape of the side of the egg. When symmetrically curved it will naturally refract, or help to focus, correctly, the entering cone of light which is to form the picture on the retina. If it is unsymmetrically curved, like the side of the egg, it will produce a misshapen and unsymmetrical picture which does not accurately represent the object. The condition of safety,

right movement and proper 'senseing' of the world thus depends upon the exactness of this image-making power of the eye. It seems probable, indeed, that one of the greatest factors in the survival of the fittest or in the elimination of the unfit, in biologic and social evolution, has been this overlooked optical inaccuracy of the eye. In the chase, in battle, in games, in all tribal and industrial competitions and tasks, the imperfectly-seeing must have gone down before those whose eyes saw more perfectly and whose answering hand and foot executed the precedent ocular command more speedily and precisely.

The malcurvature, or astigmatism, of the eye, may obviously be of widely varying degrees, and may be placed in any possible one of the 180 degrees of its half-circle. So infinite are the permutations of these amounts and placings, and so complicated may astigmatism be with any kinds of short-sightedness or long-sightedness that, as emphasized, in all probability no one eye in the world has identically the same optical measurements and powers as another. No pair is without optical imperfections and none has exactly the same ones as those of any other. The chief and continuous cause of astigmatism is the pressure of the upper lid upon the cornea just at the upper edge of the pupil. The astigmatism in the vast majority of all eyes shows that the cornea is curved more in its approximately vertical than in its horizontal meridian. The few cases in which this kind of curvature is not present are really 'exceptions which test the rule.' The habitual placing of the upper lid at this precise line of the cornea is caused by the necessity of shading the cornea or protecting it from the light which would enter from above and dazzle or harm the delicate retina. Every one when facing a bright light has found how bad vision is for at least some minutes afterwards. This semi-paralysis of retinal function would make activity slow and inconsequent, if not often jeopardize life. It has been a helpful factor during the evolutionary struggle in preserving the organism.

A study of the position of the upper eyelid and coordinated pupillary movements in animals would show each type meeting or avoiding the difficulty by many devices. In such animals as fishes, birds, owls and many forest-roving animals there is danger from above as well as below, so the upper lid is kept well retracted and the pupil wide open. In the owl the pupil is large even in daylight, and hence this bird is then in a dazed condition of mind, and flight is dangerous. The mechanisms designed to give definition to the retinal image, to shade the retina so that it may recuperate its sensibility for the next instant's instantaneous image, accentuate the fact that the formation of the retina was perhaps the most difficult task encountered in the development of higher forms of life on the globe. All organic success depended upon that special success.

And few have the most dim notion of the complexity of the organ of vision in man, or of the amazing difficulties of 'Biologos' in fashioning and perfecting it. Millions of finger tips are bunched together in the one-inch cup of the eyeball, from whence run about 425,000 nerve fibrils to a topographic mechanism of sensation in the occipital lobe. The eye can see an object $1/1,000$ of an inch in diameter. The cones and rods are only $1/10,000$ or $1/14,000$ of an inch in diameter, and a million cones at the macula occupy a space of only $1/10$ of an inch square. These crowded finger tips perceive the shape of the picture and the intensities of the light stimuli of all illuminated objects, of a millionth of a millionth of the kinetic power of any other physiologic force, and of so short a duration as the 0.00144 of a second. And out of these infinitesimal waves the sensations called light and color are created. The mechanism which creates them must be in intimate and instant connection with the centers initiating and controlling every other sensation, of every motion, of every muscle of the body. Imagine for an instant what takes place in every animal and human being every day of its existence: *e. g.*, a traveler tells of a monkey pursued by another, and running over and through the tops of the trees of an African forest faster than a deer could run on open ground. The flashing repetitive momentary glances of the eyes, before, back and all about a hundred objects must be coordinated with a mathematical precision to accurate unity and brilliant action of every muscle of the body. Similar perfection of eye and motion has been evolved in every higher animal of the world, and in every savage, and in every child. In man there is no danger from above, the eyes are rarely raised to the sky; the pupil consequently has a wide range of movement, and to shade the pupil the lid drops to its upper border. Doubtless we possess a more appropriate color sense, retinal discrimination and visual judgment because of the device.

The need of a shading of the retina to produce clear and quick imaging, 'resensitizing of the visual purple' it has been called, is so great that there are distinguishable a surprising number of separately-acting mechanisms, all working to this end:

1. The shadows cast by the retinal arteries, veins and capillaries.
2. Reflections and shadings from the individual corpuscles of the blood in these vessels.
3. The shadings of vitreous cells called *muscæ volitantes*.
4. The pigmentary layer of the front part of the retina continuous with that of the iris.
5. The iris-pigmentation, lack of which constitutes the tragedy of albinism.
6. The continuous narrowing and widening of the pupil.
7. The pigmentation of the skin of the lid, and the comparative opacity of the lid-structure itself.
8. The eye-lashes have an additional screening function, while allowing vision or suggestion of an object above.

9. Winking shades the retina entirely every few seconds of the waking life.

10. The possession of two eyes with their associated movements constantly varies the light-stimulus, shading, etc., more than would be the case in a cyclopean eye.

11. Incessant movement of the eyes accomplishes the same object. Looked at steadily an object is lost from view, especially if it be brightly illuminated.

12. The eyebrow serves as a shading device. In old men, when the retinal sensibility is dulled, and more slowly recuperated than in youth, the eye-brow hairs often take on a luxuriant growth.

13. The retraction of the eyeball, by the absorption of the orbital fat, especially in the aged, serves in the same way toward additional shading.

14. The habitual position of the upper lid across the upper edge of the pupil works clearly to the same end. It is so necessary that it must be allowed although it brings with it a new source of evil.

For with this pressure of the lid comes astigmatism—one of the greatest causes of suffering in all civilized societies. There is probably little or no astigmatism in the eyes of those animals whose lids are habitually retracted—‘wide open,’ as the birds, fishes and many of the mammalia. The outward pressure of the fluids within the eyeball tends to keep the cornea taut and symmetrically curved.

The ‘accommodation’ function of our eyes is their power to focus equally clearly the images of objects at a distance and those near the face. Its mechanism is the crystalline lens, controlled by the ciliary muscle. The lens has an innate and spontaneous elasticity which gives it the ability to increase its refractive power required as an object is brought nearer the eye. This increased refraction is incited by the contraction of the ciliary muscle. This act is called accommodation. As has been said, it is little exercised in myopia, and hence there is little pain or ‘eyestrain’ in purely myopic defects. In the condition called emmetropia, or optical normality (only approximately existing), it is called into use, and increasingly with every increase of nearness of the object looked at, until its extreme is reached when the object is so near the eyes that it is not clearly seen, that is, with accurate focus, or clear photographic definition.

With this point reached in our exposition we come upon the heart of the matter, which is this: In the ages of past evolution the safety of the organism has depended upon sharp distant vision—the more or less distant, from the horizon to a few feet from the eyes. The mechanism of accommodation has been evolved in answer to this need. The nearer an object the less continuously must accommodation act, the less uninterruptedly was the contraction of the ciliary muscle. The extreme of muscle tension or contraction, the full force of its innervation can only be carried out for the shortest periods of time. That is the great law which dominates the action of every muscle of the body. If its contraction is kept up continuously for too long a period the result is not only weariness, but spasm, exhaustion, pain, disease, etc., and physiology passes into pathology. Carefully analyzed there

will be found no muscle in the body which can endure continuous contraction except for a short time. Tests of holding the arm out straight, carrying a light satchel in one hand, etc., are familiar. Most muscles called into continuous action show that the continuity is an interrupted one, and that there are necessary rhythms of contraction, relaxation and rest. The genius of evolution, so far as the eye is concerned, never foresaw the demands to be made upon the organ by our modern life. In but one or two hundred years since printing, urbanization, commerce and the rest have sprung into existence, the entire process, ocularly speaking, has been reversed; before this it was an intermittent and temporary function, while that of reading, writing, sewing and handicrafts demands a focussing of the image of objects at twelve or fifteen inches from the eye; this for millions has now become a continuous one. For all hyperopic and astigmatic eyes the act of accommodation is required for ten or fifteen hours a day, often for hours with hardly a moment's interruption. This unwonted demand requires the continuous innervation and contraction of the ciliary muscle. To comply necessitates an impossible task, considered physiologically; the result is eyestrain with its host of sequent diseases, far-away reflexes, headaches, nervous diseases and kinds of ill-health too numerous to enumerate.

If the hyperopia were alone present, and especially if the amount were alike in each of the two eyes, cerebral ingenuity could cope with it with far less disastrous results than are everywhere shown. The eyes are seldom alike and the evils multiply. But they become genuinely morbid with the complication of the usually-present astigmatism.

The ciliary muscle is a 'sphincter muscle,' fashioned in a circular manner about a central point, and by its very nature it must act by an equal, or comparatively equal, contraction of all its parts. Astigmatism is a defect acting in a line across the structure, and hence to neutralize or compensate, the ciliary muscle is called to act against its structure and nature upon two opposite sides, those parts at right angles not acting. Hence the impossibility of overcoming the defect, at least in but a limited and partial, and always unnatural, way. The higher the astigmatism the greater the limitation and impossibility. In the high degrees it is frankly out of the question, and the retinal together with the sensation-making function is hurt by the false and blurred image, and vision deteriorated. 'The old ophthalmology,' still ruling unquestioned in Europe and largely everywhere, looks upon the correction of astigmatism by glasses only as a means of giving better vision, and so corrects only the large errors. It forgets that in these large optical defects the ciliary muscle renounces effort, and that the smaller ones are precisely those which produce the worst morbid results, because the strain of accommodation, or continuous

contraction of the ciliary muscle, can never be renounced. This constitutes the predominant source of eyestrain.

There are several other misfortunes or imperfections of the accommodation mechanism which may not be neglected if we wish to understand the matter in all its bearings. The crystalline lens must of course be transparent, hence it can not be nourished directly by the blood with its red corpuscles. Its healthful action is, therefore, dependent upon nourishment by blood-serum alone—plainly a difficult task, especially as this serum must reach it indirectly by osmosis, filtration, etc. It has also no nervous connection with the brain, and the three conditions named conspire to bring about two most noteworthy faults in its life-history. It is prone to become non-transparent or opalescent and, finally, almost opaque in the old, and this is cataract. Its elasticity also decreases steadily from childhood until it is so inelastic at about 45 years of age that the ‘range’ or degree of accommodation becomes too limited to enable it to focus the images of objects clearly on the retina except by holding the book, for instance, too far from the eye. This is the beginning of ‘presbyopia’; at about sixty all the elasticity of the lens is lost and accommodation is at an end. Moreover, oculists have been hitherto unmindful of the fact that the accommodation may be less than normal in many young patients, even for short tasks. It is always so for long and continuous ones. For presbyopia, there is no prevention and no cure. There is a makeshift device (spectacles) whereby we may supply the lost focusing power of the living lens, by glass lenses placed in front of the crippled ‘crystalline lens.’ Of cataract, however, there is a pretty sure method of prevention, and this, again, is spectacles.

The science and art of correcting or neutralizing these optical defects of the eyes—myopia, hyperopia and astigmatism—is by means of artificial optical lenses. First, be it noted, it is a medical art and science, which no optician can compass. He has neither the legal nor the ethical right to attempt it, and surely he has not the scientific and medical knowledge requisite for its accomplishing. However poorly the medical man has executed his task, the optician will do it far more blunderingly. This *verbum sapienti* should be sufficient warning until, as with the druggist, we have also with the optician, passed laws to prevent him from attempting to fill the office of physician. There will then not be so many ruined eyes, and far less suffering from eyestrain.

Spectacle lenses have the power of changing the shape and direction of the image-forming cone or bundle of rays of light entering the eye so that its faulty optical construction and powers are neutralized, and the image is at last accurately focussed, and perfectly pictures the object. The outside lenses are in a way reversely unnatural, so that the inner eye-defect is met with an outer cancelling modification,

whereby the direction of the parts of the rays making the image are so modified as to restore the picture about to be formed to normality. Plus is met by minus, minus by plus, astigmatic one-sidedness by its reverse. If the living eye were a dead mechanical one, if it were not subject to many diseases, if the results of eyestrain did not end in a multitude of diseases of the entire body and mind, then the optician might learn to prescribe glasses. But even for the highest medical intellect the work is a science and art demanding his best powers. Some one said that there are nine and forty distinct and separate ways of achieving damnation, while there is but one of salvation. There are twice that number of separate ways of failing to get right spectacles, and seventy-eight of them are set forth by an American oculist, reasons being given why, if any one is neglected, there will be no relief of eyestrain. Even if the physician's prescription is right, even if the lenses are properly ground and mounted, even if the spectacles are properly adjusted to the wearer's peculiarities of face, etc.—and these are all hazardous suppositions—there remains the wearer's carelessness, prejudices and ignorances, to thwart the entire proceeding. There are microscopists, and astronomers who will spend lifetimes of self and others, in care to correct the optical inaccuracies of their microscopes and telescopes, and yet whose own eyes that look through the instruments have far more glaring optical defects than Clark eliminated from his objectives by years of patient labor. The eye that sees everything can not see itself. So slow is man to study the student, himself. He will even investigate the brain and its functions before he will the eye: although embryology demonstrates that it was the brain which developmentally came out to see; the eye did not at first exist apart from the brain, and then send in to the mind the message of its discoveries. When once the million threads of brain substance were pushed out to the surface, the product called intellect resulted. For all useful thinking is in visual terms, and the *sine qua non* of civilization, the alphabet, is only a series of conventionalized pictures of things seen. The problem of our being here, the primal conditions of organic and social evolution, have depended and will always depend upon visual function. Is it then to be wondered at that our difficulties, bodily and social, our diseases, imperfections, our wants, failures and miseries, most frequently have also their source in visual difficulties and imperfections? Error is the softest and best word we have for human failure to reach the best attainable aims and ideals. It is more than an accident that the technical name for the great mass of ocular woes, and for the causes of multitudes of others, is 'errors of refraction.' The compulsion of fate as well as an error of evolution has brought it about that the unaided eye must persistently struggle against the astonishing difficulties and errors inevitable in its structure, function and circumstance. This struggle wrecks health, happiness and life, because by no device can the

brain steadily innervate a muscle to continuous contraction. There results eyestrain—an error, the result of an error, the consequence of an older error; all may be done away with by an easily-obtained, at present usually unobtainable, device. The obtaining of that device is a matter of more importance to civilization than all the universities and wars of the last century. ‘Exaggeration?’ Not so!

For what are the consequences of eyestrain? Wherever there is eye-labor ‘at near-range,’ as in reading, writing, sewing, mechanics, art, science, commerce, etc., there, beyond question in one half the workers, is eyestrain of a disease-producing kind. What kinds of diseases?

Firstly, those of the eye itself, for surely all good oculists agree that a large majority of local eye-diseases are themselves directly or indirectly due to eyestrain. The only exceptions are albinism, loss of accommodation generally (presbyopia), some tumors and a few minor affections. Cataract, it is being recognized, is due to the morbid function of denutrition set up by the strain to neutralize errors of refraction, and may be prevented by wearing correcting spectacles long prior to the ‘cataract age.’ Almost all other inflammations of the eye, not excepting often the infectious ones, are usually due to the same morbid function. Function, as all good physiologists know, always precedes structure, and malfunction, as all good physicians know, also precedes the morbid and fatal organic pathology. Eyestrain is almost always the cause of eyes turning in, or out, that is, squint or strabismus, a trouble that is ‘innervational in nature and refractional in origin.’

The next of the series of bad results of eyestrain are cerebral. The brain comes out to see, but owing to the enormous difficulty of the task, it sees poorly and with exhausting or irritating labor. As its every process and act is bound up with and the product of vision, visual disorders by reflex and passed-on malfunction induce cerebral affections, evidenced primarily by headache, migraine, etc. Although the medical text-books give little or no hint of this, it is true, as thousands of good physicians and patients well know, that headaches, ninety per cent. at least, are due to eyestrain. Many observant physicians believe that the so-called ‘paroxysmal neuroses,’ periodic headaches, migraine, epilepsy, asthma, etc., as well as hysteria, neurasthenia, ‘brain-fag,’ ‘nervous breakdown’ are very frequently caused by years of morbid ocular struggle.

Mental diseases follow: weariness, alternating with hyperexcitability, an amazing need of walking, truancy (escaping from ocular labor), morbid introspection, nameless torments and self-tormentings, diseased habits, hopelessness, melancholia, manias, incipient and functional insanities and indirectly occupational failure, crime and many other errant trends.

The methods by which morbid ocular function induce various bodily

diseases are so varied, differing almost in each individual, that it is impossible to set them forth in detail. Primarily it seems certain that the process is essentially one of waste and exhaustion of nervous force; all corporeal activities depend upon right-seeing. All subordinate cerebral centers are drawn upon to restore the balance when clear and easy seeing drains too severely the optical store-houses and regulating mechanisms. But the peculiarity of nervous action is that often under-supply and even exhaustion ends in irritation and excessive nerve action. Hence we find hyperesthesia attending or consequent upon lowered vitalities and tensions. But at least and always come disordered functions and these naturally form two types or proceed by two routes. The first disorders, often the more distinctive cerebral incoordinations, are those classed as nutritional or digestional. Certainly one half of all sufferers from eyestrain have dyspepsia of some kind. 'Liver,' 'stomach,' loss of digestive power, loss or fickleness of appetite, are the complaints that constantly occur in the biographies of great literary workers, and of the majority of our patients.

The second class comprises those whose blood-supply and tension is morbidized—the so-called 'vasomotor' cases. Skin-affections, as was long ago found, are often due to 'migraine,' and migraine, we now know, is due to eyestrain. It is remarkable how often diseases of the kidneys have been preceded by years of suffering from eyestrain. Secondly almost any affections, even surgical diseases, may supervene, caused by the lowered nutrition, disordered blood-supply or the derouted nerve influences. The terminal diseases, as they are called, because they perform the final act of killing, are often but the executioners of long precedent eyestrain. Even the infectious diseases find their best soil—and soil is as important as seed—in the lowered vitality following years of headache, dyspepsia, etc. By careful count and trustworthy statistics 27 per cent. of school children have lateral spinal curvature. This astounding source of sickness and invalidism, directly or indirectly, is due to ocular defects, functions and laws.

And if the child is father to the man, let us add, and to the woman, what a havoc of the future generation we have been preparing by our neglect of the care of children's eyes! Take it only in the aspect of a saving of time. The results of Dr. Baker's examination of the eyes of the Cleveland, Ohio, school children show that those with defective eyes are six or seven months older than the others of the same grade and that one in four have eyes that keep them behind in their studies. In the last few years the examination of the eyes and health of school children shows an appalling condition which fully bears out all that oculists have been warning against. The examiners in Quincy, Mass., state:

Many school children who appear dull and inattentive, who are nervous, irritable, morose or disorderly, who suffer from headache, dizziness, nausea or

pains in the eyes, owe these ills largely or wholly to such defects. Generally neither they nor their parents nor their teachers are aware of the cause of their troubles. The examination of hundreds of thousands of school children has demonstrated that from twenty-five to thirty-five per cent. of them need the services of an oculist or of an aurist or of both; these handicaps can be removed and the children be able to receive the full benefits of instruction. In Utica, New York, an examination of over 6,000 pupils showed that about thirty-five per cent. were defective, and the report says "Our tests revealed many sad and critical cases which were remediable because discovered at this stage of development. Many parents could not strongly enough express their gratitude to the teachers. Cases of what had been considered dullness or willful inattention on the part of pupils were shown to have been due to inability to see or hear." In Chicago it was found that on entering school at the age of six years thirty-two per cent. of the pupils had defective eyes. In the schools thirty-seven per cent. of the girls and thirty-two per cent. of the boys, or an average of thirty-five per cent., were defective and these tests were made by an expert. In Minneapolis out of 25,696 pupils examined 8,166, or thirty-two per cent., had defective eyesight. Similar conditions differing only in degree, have been found wherever tests have been made.

In New York City Dr. Cronin finds that over 30 per cent. of the school children are suffering from the gross forms of defective eyesight. It must be remembered that the worst defects are not included in these statistics.

Lastly, the greatest of the misfortunes which may be traced to this cause are those connected with intellectual progress, the literary workers being those who suffer most. In direct and indirect ways the advances of civilization are most frequently conditioned upon use of the eyes in writing and reading. Certainly one half or more of the great writers and thinkers of the world have had their lives turned into tragedies of personal affliction by this unsuspected cause. The biographies of Swift, Nietzsche, Parkman, George Eliot, the Carlyles, Whittier, Darwin, Wagner, Taine, Symonds, Heine, De Quincey, Huxley, Lewes, Margaret Fuller, Jules Verne, de Maupassant, Balzac, Berlioz and many others are filled with pathetic evidences of the truth. It is noteworthy that in the monumental 'Life of Wagner,' Dr. Ellis, who is at once physician, musician and biographer, after exhaustive research, confirms the theory that eyestrain was the chief cause of the poignant physical sufferings of that great genius. And what influences such afflictions have on the character of the men and of their works only the discerning can surmise. The large majority of the men and women mentioned above have a striking likeness as regards a certain harshness, even bitterness, and a peculiar and pitiless insistence on logical distinctions; all but one or two were pessimistic and unreligious. Only art saved Wagner from an acerbity and skepticism, illustrated by his enemy-friend Nietzsche and his philosopher, Schopenhauer. It does not require a great mind to recognize the profound influence of disease upon character and philosophy.

THE STATUS OF AMERICAN COLLEGE PROFESSORS
ONCE MORE.BY PROFESSOR JOHN J. STEVENSON,
NEW YORK UNIVERSITY.

ABOUT a year ago, the writer discussed some matters bearing upon the condition of college instructors in America. A restatement of some parts of that discussion is necessary, as events occurring during the interval have tended to divert attention from the more important issues.

An impression seems to prevail that the Carnegie foundation has rendered unnecessary further discussion of the salary question. But the provisions of that trust, perhaps intentionally, are such as to provoke further discussion, for the salary accorded to emeritus professors is to be in direct relation to that received prior to retirement. As the payments will be only to men of sixty-five years and upward, they will affect at best only a few years at the close of a long period of service, and in all probability, they will be of personal interest to a very small proportion of the whole number of college instructors.

The writer has been criticized for laying stress on the matter of salary and for thus introducing a mercenary feature which is degrading to the profession. But education is no longer in charge of ecclesiastics pledged to lifelong celibacy, and theoretically at least, to lifelong poverty. The notion that teachers should be indifferent to pecuniary matters is a survival, which still holds in the minds of some youthful students and occasionally gains control of a college trustee, but it has never found favor among tradesmen. While it is true that no man should become a college instructor merely to gain a livelihood, it is equally true that the matter of income should not be ignored, for in our day one is hardly to be commended for choosing a profession in which poverty or the observance of the strictest economy must be his lot through life—provided always that he is fit for anything else. And this is what makes the question of salary so important from the standpoint of the college. Statistics show that in the leading eastern institutions and in the leading state universities the average salary of professors is about 2,000 dollars; but this is the salary of a full professor and is the maximum which most men may hope to receive after years of service. Such being the case one must recognize the danger to which colleges are exposed especially on the side of pure science, which for educational purposes is the more important.

To the greater number of those who have become teachers of science in our colleges, the chief attraction has been the promise of leisure for study. But in the greater number of our institutions, that leisure has practically disappeared and young men recognize the fact. On the other hand, the applications of pure science have been multiplied; the chemist, physicist, geologist and biologist have become, each of them, the mainstay of industries not only requiring many millions of capital, but also contributing in equal proportion to the welfare of mankind. In each of these industries competition is so earnest that incessant investigation along lines of pure science is essential. There is here promised a greater reward of fame than the college instructor can hope for, while in addition there is a prospect of pecuniary reward for the wise and industrious man, compared with which the maximum college salary is a pittance. It is quite in accord with human nature that young men after completing graduate study, costly both in time and money, should think applied science, which promises both fame and money, preferable to college teaching, which promises in our day not very much of either.

It has been said that a change has passed over the minds of American college professors, that, whereas formerly they regarded investigation as the all-important and teaching as the unimportant part of their duties, they now regard themselves as chosen especially to teach. This is a somewhat belated discovery, for the American college professor has always been preeminently a teacher, to whom investigation has always been, as it were, a side-issue. But for a generation, owing to rapid expansion of curricula without corresponding increase in number of teachers, there has been an increasing neglect of investigation. For the most part, small colleges to-day are as well off for men and equipment as not a few of our larger institutions were fifty years ago, but their contributions to the sum of human knowledge, at least on the scientific side, are in no sense comparable with those made by college men of the earlier period. This reacts on the college, for men who are not investigators by nature and to some extent, at least, in practise can never be genuine teachers. They may be good disciplinarians, masters in the art of hearing recitations, adepts in compelling students to learn lessons, but as retailers of merely second-hand information they never can be makers of men.

Beyond all doubt there will always be an ample supply of candidates, whatever the salary may be, but ambitious young men will not take up a profession which threatens to dwarf them intellectually and socially; rather will they turn aside to business or to other professions in which great prizes await diligence and common sense. The sentimental grounds on which many chose college work no longer exist, since opportunities for service to others abound everywhere even for the busiest

of men. Such opportunities were rare formerly and, for their sake, college work was chosen by many to whom pecuniary reward was, in comparison, a secondary matter. And this led in no small degree to the high esteem in which college professors were held, for the corporate boards were composed chiefly of professional men, who believed that they had chosen their work for similar reasons. But the boards of to-day are made up largely of men of affairs, strong men of the business world, who are apt to regard indifference to material success as evidence of native weakness.

While the matter of salary is important in its bearing on the future of American colleges, it is of less immediate importance than that of relations between the teaching and the corporate board. This is the vital matter.

Theoretically, the corporate board of to-day and the college president of to-day are the same as they were one hundred years ago; but in fact they are essentially different. The boards and presidents of the former days were so familiar with the conditions of their little schools and of the narrow curriculum that they were competent to take charge of them. To-day the curriculum is so broad that neither board nor president can be familiar with the needs of the several chairs even in institutions of moderate size, while in universities it is barely possible for them to have any personal knowledge whatever. Yet the teaching board is wholly subordinate to the corporate board. Such complete legal subordination was well enough as long as the chief purpose of colleges was to prepare men for the ministry and subordination may be well enough still in purely denominational colleges, whence it is fit and wise to eject summarily those 'courageous, independent thinkers' who would hold to their salaries while rejecting denominational tenets; but the university has outgrown the swaddling clothes of the semi-theological college and the method of control should be adapted to the new conditions.

It is well understood that the corporate board as a rule is not composed of men familiar with educational matters. The rapidly increasing financial interests of colleges and universities necessitate the selection of men possessing thorough business ability. Examination of college catalogues shows that the boards are made up chiefly of men beyond middle age, eminent lawyers, prominent business men, with some clergymen and physicians, all of highest standing; all of these are busy men, whose prominence proves that for many years they have been engrossed in the work of their several callings so intensely as to be disqualified for some of the duties devolving upon college trustees; most of them are far removed in thought and occupation from educational work and few of them are in any degree familiar with the changes in scope and methods of college teaching. Nor, as

has been said elsewhere, have they opportunity to acquire the necessary familiarity after assuming office, for business matters occupy most of the time at board meetings and matters affecting work by the teaching board are largely incidental. It would be strange if the trustee did not regard his board's responsibility as the more important.

The change for the worse in relations of the boards is due in no small degree to a change in character of the president's duties. That officer is no longer primarily a teacher; in many of the larger universities he does no teaching, is simply the executive officer; while in many of the smaller institutions he does little teaching because efforts to raise money occupy most of his attention. The chronic impecuniosity of most colleges prevents trustees, when seeking a president, from inquiring closely respecting a candidate's fitness to represent the educational side of the institution; money and more students are the crying needs. The appointee is usually a man of great expectations—on the board's part; he will find money, gather students, advertise the institution, awaken interest everywhere and convert indifferent alumni into hustling canvassers. But once appointed he is left practically to his own resources, to be praised by the board if he succeed, to be blamed if he fail—a rather uninviting post, whose holder deserves more sympathy than is contained in the libel that he has every grace except that of resignation. He has been appointed not to elevate the institution as an educational power, but to make of it a 'big thing.' One may not censure him severely for emphasizing what may be termed the non-educational side or for resorting at times to odd expedients for increasing the total of students and instructors; but the results have been disastrous, for thus it has come about that the vast majority of people and the vast majority of prospective students measure an institution not by the character of its instruction or by the fitness of its instructors, but by the mass of its buildings, by the number of students and by its prominence in the semi-professional athletics which so disgrace American colleges.

The president is practically the only source whence the trustees may obtain information respecting internal affairs of the institution, as, with rare exceptions, the faculties have no representatives on or before the corporate board. He is the responsible head, the only element known to the trustees; in the nature of the case, he formulates the business to be presented, so that, if he possess a fair degree of tact, the board merely carries out his wishes. If successful in securing money and students, he is liable to be human enough to forget that he has done this work as the professors have done theirs and to think of himself as creator with consequent right to control policy and to direct expenditure. Business presented to the trustees is not likely to be such as to encourage great inquisitiveness respecting details of internal

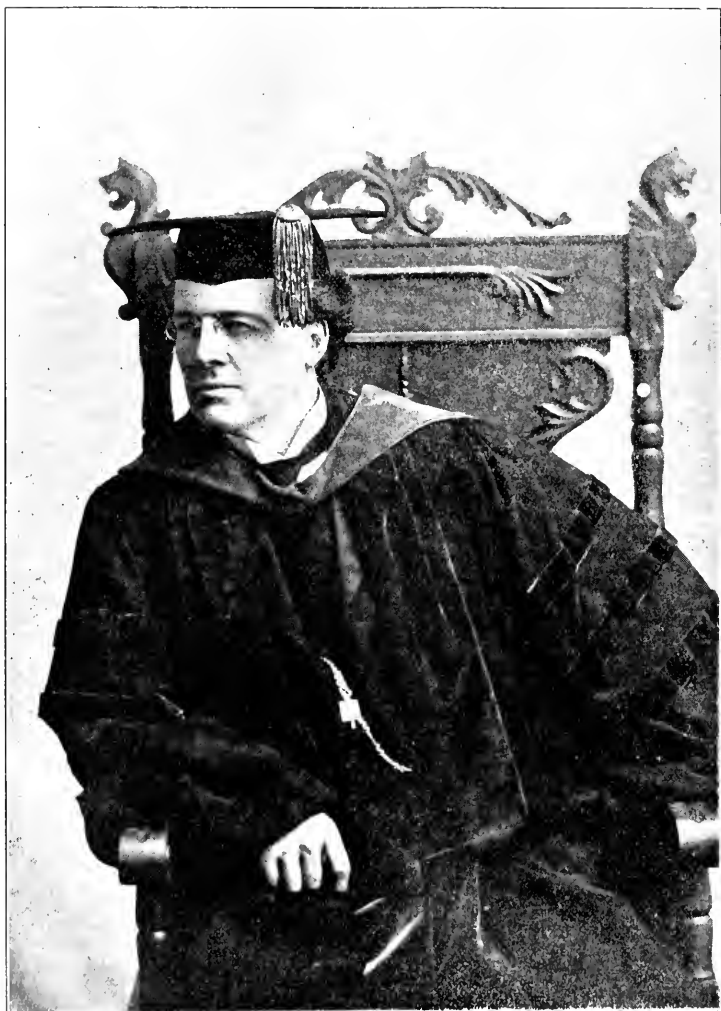
affairs. And all this is thoroughly compatible with a strict sense of honor and with conscientious devotion to what he believes to be the best interests of the institution. But the result is unfortunate. The executive duties of his office render the president less and less fitted as the years go by to represent the purely educational side of the institution, yet every year strengthens his control of all the interests. This condition is not in accord with business common sense.

If the proper status of the faculties is to be restored, and if the proper standard of educational efficiency is to be regained, there must be a radical change in relations of the teaching and corporate boards. In church organizations, the religious interests are ordinarily in care of one board and the secular interests in care of another; but the former, being charged with the interests for which the church was organized, is superior to the latter, although this represents the corporate body before the law. A similar grouping and relation should exist in educational organizations. The trustees should not control in any degree the internal affairs of the college or university, their duty being to relieve the teaching board from the burden of caring for business matters and to represent the institution before the state. They should fill vacancies in their number, subject to veto by, say, two thirds vote of the full professors; but the faculties should have complete control of all matters relating to the actual work of the institution and they should make all appointments to the teaching staff, subject to merely *pro forma* confirmation by the trustees, as representing the corporate body, or to veto by them in case there are not funds to warrant the expenditure. The office of college president, as it now exists, should be abolished; each faculty in a university or the single faculty in a college should choose its own executive head, who should be simply *primus inter pares* and should be the mouthpiece of his faculty in conference with other faculties or with the trustees. In a university, the several executives would be a council to determine matters affecting the policy of the institution as a whole.

Some appear to dread such reconstruction as liable to bar all progress, for it has been said that, somewhere, the most important advances have been made in face of earnest opposition by professors. Possibly. But it may be that some steps, advances in the opinion of a president, might be retrogression in the opinion of an educator. The dread, however, is unnecessary in view of the fact that the remarkable elevation of standard in legal and medical education within the last twenty years is due wholly to the professors themselves and largely, in most cases, at their expense. This statement is equally true of schools of applied science and it is well understood that in colleges the professors constantly struggle for maintenance of high standards. More than this. Professors have been known to show themselves capable of attending

to the business affairs of their institution; have been known indeed to take up the burden of business, after it had been abandoned by the corporate board, and so to care for teaching and business that in time both were returned in excellent condition to the control of the trustees.

No doubt it is true that in some cases the faculty gathered under the present system may not be fully competent to undertake management such as has been suggested; but that is no reason for continuance of a system which can bring about such a condition. Serious errors are less likely to be made by those who know something about the requirements than by those who know very little or practically nothing about them. A not very skillful carpenter is a far better judge of carpentry than the ablest statesman can be. A faculty of not very high grade can judge better respecting the all-around fitness of a candidate than can a board composed of eminently successful bankers, lawyers and clergymen—better even than can a college president, who at one time was a typically good professor, but who by force of circumstances has been diverted from educational work to become a strong man of business.



PRESIDENT EDMUND JANES JAMES.

THE PROGRESS OF SCIENCE.

THE INSTALLATION OF PRESIDENT JAMES AND THE UNIVERSITY OF ILLINOIS.

THE installation of Dr. Edmund James as president of the University of Illinois, on October 18, gave occasion for an academic celebration of more than usual magnitude and significance. The exercises were extended over the greater part of a week, and delegates were in attendance from about two hundred colleges and universities. There were religious services on Sunday, October 15. On Monday the Women's Building, a view of which is shown below, was dedicated, and in the evening the university address was given by the Rev. Frank W. Gunsaulus, of the Armour Institute. On Tuesday there was in the morning a discussion on the 'State and Education,' and in the afternoon the National Conference

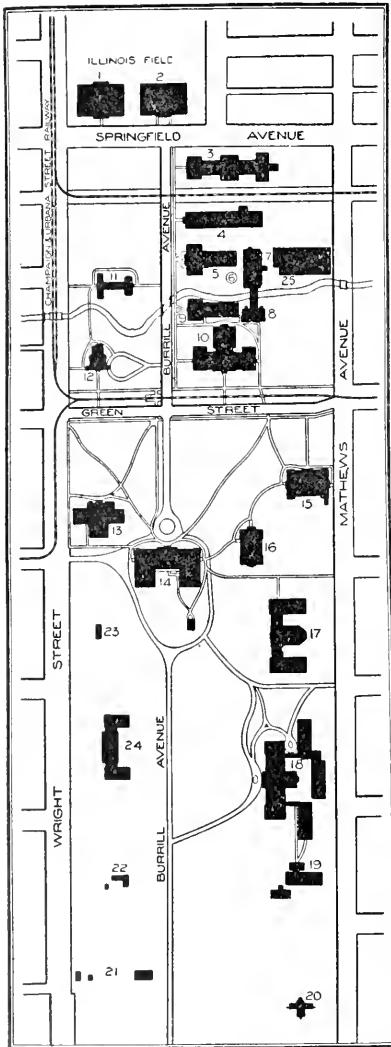
of University Trustees began their sessions. These sessions were continued on Thursday, and at the same time there was a Conference on Religious Education in State Universities and Colleges, and a Conference on Commercial Education, which was continued on Friday. There were in the meanwhile assemblages of the various colleges, the presentation by students of Robert Greene's Friar Bacon and Friar Bungay and other arrangements. The formal inaugural exercises were on Wednesday. In the morning there was a reception of delegates with a roll call of the universities and responses by selected delegates. In the afternoon there were addresses by the Governor of Illinois, the president of the board of trustees and Dr. Andrew S. Draper, former president of the university, followed by the inaugural address of



LIBRARY BUILDING.

President James and the conferring of degrees.

Some part of the ceremony, such as



1, Men's gymnasium; 2, Armory; 3, Woodshop and foundry; 4, Metal shop; 5, Electrical and mechanical laboratory; 6, Reservoir; 7, Heating plant; 8, Pumping plant; 9, Applied mechanics; 10, Engineering hall; 11, Greenhouse; 12, President's house; 13, Library building; 14, University hall; 15, Natural history hall; 16, Law building; 17, Chemistry building; 18, Agricultural buildings; 19, Greenhouse; 20, Observatory; 21, Warehouse; 22, Veterinary building; 23, Insectary; 24, Woman's hall; 25, Mechanical engineering laboratory.

processions in cap and gown, the formal reception of delegates with the presentation of Latin addresses and the conferring of degrees, may be more in place in an English university, where the medieval tradition has been continuous, than at the center of the population of a democratic nation. The conventional academic ceremonial has, however, certain advantages in a somewhat crude civilization, and it is easier to assume than the democratic dignity of Lincoln, who amid the distractions of the civil war signed the bill which laid the foundation for the university of his native state.

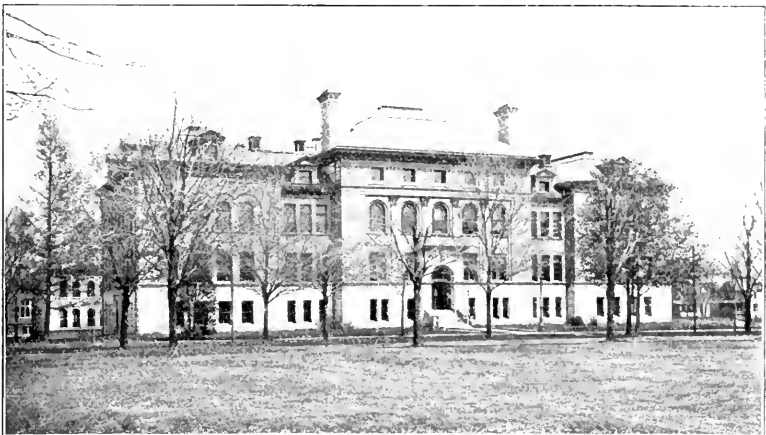
No one at that time could have foreseen the future of the university. Its growth did not begin so soon as that of Michigan and Wisconsin, but the three universities will soon stand in friendly rivalry to perform the greatest service, and will equal and may surpass Harvard, Yale and Columbia in number of students and probably in all the functions of a great university. It was only in 1885 that the Illinois Industrial University assumed its present name. The campus is shown in the accompanying illustration. There are now on it some twenty-five buildings, nearly all of pleasing architectural design, well-placed among grass and trees. Ten years ago there were in the university 550 students; there are now 3,594 students with 487 professors and other teachers. This remarkable growth, chiefly under the administration of President Draper, will doubtless be continued under the administration of President James.

Dr. James was born in Illinois in 1855. He was educated at the Illinois State Normal School, and later at Northwestern University, Harvard University and the University of Halle. He was principal of schools for four years, and in 1883 became professor of political science in the University of Pennsylvania, going in 1896 to the University of Chicago. Since 1902 he has been president of Northwestern University. He is the author of a num-

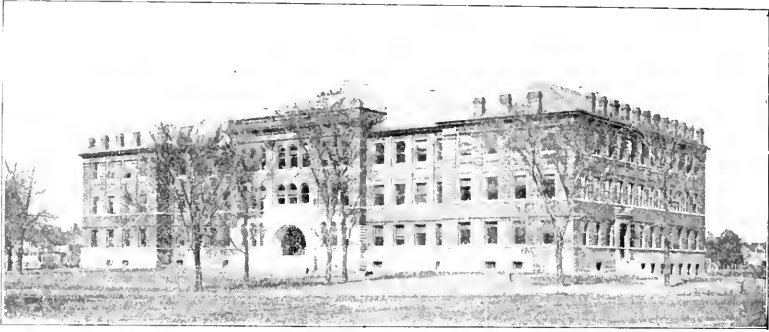


THE WOMEN'S BUILDING.

ber of books and papers on economic, public and educational questions, and has always taken a leading part in all movements for the advancement of his science and the extension of education. President James's views on education were clearly outlined in his inaugural address. He holds that the state university should be the central factor of the education in the state, but should cooperate with other institutions, public and private. He believes that the standard of the university should be continually raised, leaving to the colleges and schools the work of the lower classes and letting the university give the ultimate institutional training of the youth of the



THE ENGINEERING HALL.



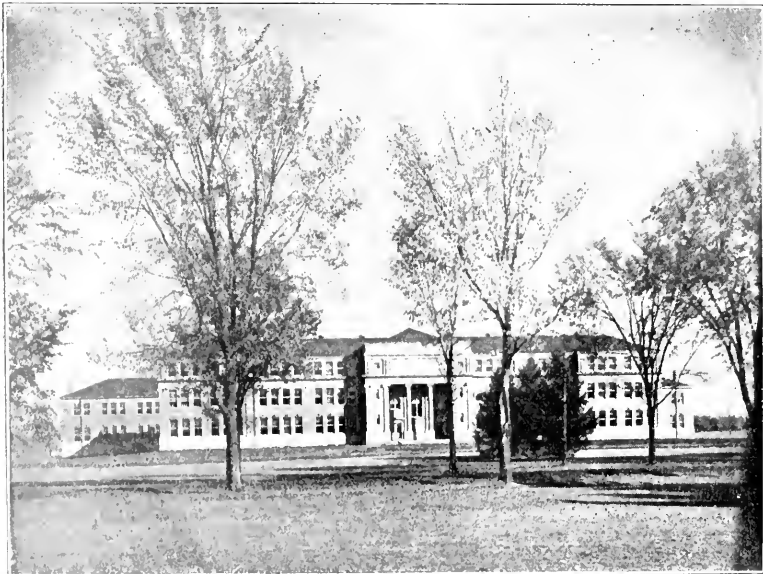
THE CHEMICAL LABORATORY.

country for all the various callings for which an extensive scientific training, based upon liberal preparation is valuable and necessary.'

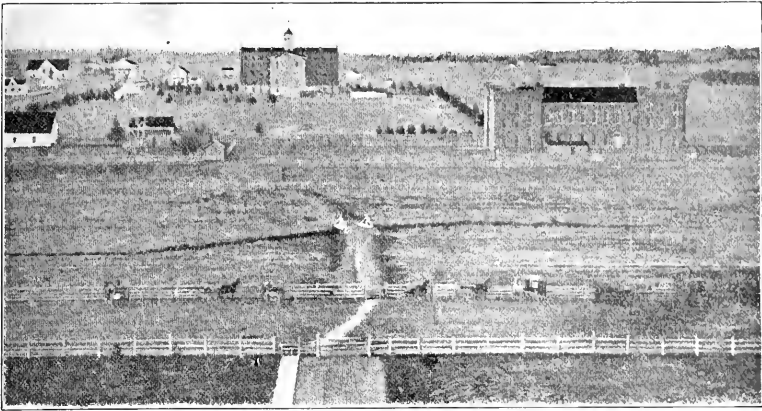
A CONFERENCE OF COLLEGE AND UNIVERSITY TRUSTEES.

ONE of the most interesting features of the program at the University of Illinois was the conference of trustees of American colleges and universities. The invitation to this meeting was itself a document of real educational

significance as it outlined with clearness certain problems of deep concern for higher education in the United States. Thus it said: "In England the old universities are self-governing bodies, controlled largely by the faculties; in France and Germany they are departments of the government, and so far as they are not directly under the control of the government, they are autonomous, that is, ruled by the faculties. In the United States alone we felt it necessary to create a third organ, an independent, often self-



THE COLLEGE OF AGRICULTURE.



THE UNIVERSITY TWENTY YEARS AGO.

renewing body of non-experts, in whose hands the entire legal control has usually been placed"; and the first of the ten questions proposed for discussion was: "What should be the real administrative body of a college or university, the faculty or the trustees?"

The clear and frank statement of the problem in the invitation was maintained in the papers and discussions. Dr. Draper opened the conference with an eloquent address on the university presidency. He held that the chief duty of the trustees is to select a great man for president and thereafter to give him a free hand in all directions. He should be the supreme legislator, executive and judge. This point of view was questioned by Mr. J. P. Munroe, a trustee of the Massachusetts Institute of Technology, Professor Joseph Jastrow, of the University of Wisconsin, and Professor C. E. Bessey, of the University of Nebraska. It was argued that while the autocratic president may gather wealth and produce an efficient machine, such an officer is subversive of democratic ideals and true scholarship, tending in the end to demoralize the academic career.

Dr. Draper was careful to abstain from any laudation of what he had himself accomplished during his presidency of the University of Illinois, but

the impressive material progress of the institution was evident on all sides, and was the strongest argument in favor of a benevolent despotism. It seems therefore fair to call attention to two facts. It is not certain that the University of Illinois is as great a center of education, scholarship and research as might be hoped from its generous support, and its material progress may have been due to a socialistic governor of the state rather than to an autocratic president of the university.

It is indeed an open question as to how far the increasing wealth of our universities, whether from private gifts or from legislative appropriations, is due to the office of the president. It may be that the office is the result of the fact that wealth and numbers have increased more rapidly than they can be assimilated. The ways of scholarship, like the ways of democracy, are slow; but creative scholarship and a free democracy are high ideals, not to be lightly sacrificed to machinery whose only possible use would be the attainment of such ideals.

THE DISTRIBUTION OF STARS.

MAN has speculated on the extent and structure of the visible universe ever since the beginning of history. But however ingenious and plausible some



PHOTOGRAPH OF THE MILKY WAY IN SAGITTARIUS AND ADJACENT REGIONS — SHOWING EXTREMES IN STELLAR DISTRIBUTION.

of the resulting cosmologies may be, they must, nevertheless, be regarded as little more than guesses, since the scientific data necessary to a sound conception of the problem are still lacking. The chief elements required are the determination of the number, distribution, constitution, brightness, distance and motions of the stars. All these determinations are now possible to science, at least in part, although only a few decades ago several of them would have seemed impossible.

A recent contribution of great importance in this line is a study of the 'Distribution of Stars,' by Professor Edward C. Pickering, director of the Harvard Observatory. The memoir forms Part V., Vol. XLVIII., of the *Annals of the Observatory*. This research was rendered possible only as a result of the extended work in stellar photometry which has been carried on by the author during the last quarter of a century. Nearly two million observations of the brightness of the stars have been made by him and his assistants at the Cambridge and Arequipa stations of the observatory. Upon these results especially, and also upon the various *Durchmusterungs*, and the work of Father Hagen, the investigation is based.

Two very important facts are brought out by this research. Hitherto it has been supposed that the proportion of faint stars to the whole number is much greater in the milky way than in other parts of the sky. This may still be true for very faint stars, but Professor Pickering shows conclusively that, for all stars whose magnitudes have been determined, the proportion of bright and faint stars is practically the same in the milky way as elsewhere in the sky, and that the stellar density is only about twice as great.

From theoretical considerations Professor Pickering derives the formula, $\log N = 0.60 M + A$, in which N is the number of stars brighter than a given magnitude M . A comparison of the

results of observation, however, shows that the coefficient of M is never greater than 0.52, and that this value, which is fairly uniform for the brighter stars, grows rapidly less for the faintest stars whose magnitudes have been determined. An inspection of Table XXI. of the memoir shows that for the stars visible to the naked eye, the whole number brighter than a given magnitude is from three to four times as great as that of the next lower magnitude; that is, for example, there are 3.3 times as many stars of the fifth magnitude and brighter, as of the fourth magnitude and brighter. For fainter stars the ratio steadily decreases, until for the twelfth magnitude the number is little more than twice that for the eleventh magnitude. This curve of distribution is remarkable. If the rate of decrease continues with equal rapidity for successive magnitudes, it would lead apparently toward the ratio unity at the eighteenth or twentieth magnitude, which would imply the limit—possibly very ill-defined—of our universe. This conclusion is, however, still very uncertain, since reliable observations of brightness are available only to the twelfth magnitude. Professor Pickering is careful to draw few conclusions beyond the reach of actual observation. He says, however, 'As estimates are given which are still more uncertain than these, it may be stated that the number of stars corresponding to the magnitude 15, or which would be visible in a telescope of 15 inches aperture, would be about eighteen million, and the increase for larger apertures would be surprisingly small.' With the mounting of the great five-foot reflector at Cambridge, however, there seems to be little doubt but that the determinations of brightness will be extended to the faintest stars which can be reached at the present day. Before many years we shall perhaps know whether our universe is simply a limited region in the infinite.

*THE PROPORTION OF CHILDREN
IN THE UNITED STATES.*

THE Bureau of the Census has issued a bulletin on the proportion of children in the United States, containing valuable statistics secured at the last census and a discussion by Professor Walter F. Willecox, of Cornell University. There is unfortunately very little exact knowledge concerning the birth rate or the size of families in the United States; but in some ways the proportion of children to the total population or to the number of women of child-bearing age is more significant than the birth rate. The birth rate, which is usually given as the number of births each year per thousand population, is only significant when taken in connection with the death rate. The birth rate has been steadily decreasing in all civilized countries, and most rapidly in the countries that are regarded as the most civilized, but at the same time the death rate has been decreasing nearly in same proportion, so that the increase of population per thousand inhabitants has remained nearly stationary in recent decades. But these figures require further analysis. In so far as the decreased death rate is due to the saving of the lives of healthy infants, it can to real advantage supplement the decreasing birth rate. In so far, however, as the decreasing death rate is due to the prolongation of life beyond the age at which children are likely to be born, or in so far as it is due to saving the lives of children who are constitutionally feeble, the result in the next generation will be a sharp decline in the birth rate without any further decrease in the death rate. The size of family again is not significant unless taken in connection with the number of children that survive and the proportion of people who are married.

The number of children under five years of age compared with the number of women from fifteen to forty-nine years of age is given in the census,

and these figures are perhaps as simple and convenient as any for the study of changes in the fertility of the population. They should, however, be correlated with the birth rate and death rate and the size of family, and require further analysis, immigration and alteration in the frequency of death at different ages being complicating factors. The bulletin shows that at the beginning of the nineteenth century the children under 10 years of age constituted one third and at the end less than one fourth of the total population. The decrease in this proportion began as early as the decade 1810 to 1820, and continued uninterrupted, though at varying rates, in each successive decade. This of itself, however, is not enough to prove a declining birth rate, as the decrease in the proportion of children in the total population may indicate merely an increase in the average duration of life and the consequent survival of a larger number of adults.

But by taking the proportion of children to women of child-bearing age we are able to get a more satisfactory index of the movement of the birth rate. Between 1850 and 1860, the earliest decade for which figures can be obtained, this proportion increased. But since 1860 it has decreased without interruption. The decrease has been very unequal from decade to decade, but if twenty-year periods are considered, it has been very regular. In 1860 the number of children under 5 years of age to 1,000 women 15 to 49 years of age was 634; in 1900 it was only 474. In other words, the proportion of children to potential mothers in 1900 was only three fourths as large as in 1860. One is thus led to the conclusion that there has been a persistent decline in the birth rate since 1860.

A comparison is made between the proportion of children born of native mothers to 1,000 native women of child-bearing age and the proportion of children born of foreign-born mothers

to 1,000 foreign-born women of child-bearing age. In 1900 the former proportion was 462, the latter 710, the difference indicating the greater fecundity of foreign-born women. The comparison also indicates that the total decrease in fecundity of white women between 1890 and 1900 was the result of a decrease for native white women partly offset by an increase for foreign-born white women.

*THE INTERNATIONAL CONGRESS
ON TUBERCULOSIS AND PRO-
FESSOR VON BEHRING'S
ANNOUNCEMENT.*

MEDICAL journals have now reached this country giving an account of the Congress on Tuberculosis, held in Paris, in October, of which the most dramatic episode was the announcement by Professor von Behring of an alleged cure for consumption. A report of his statement was cabled to the daily papers and was doubtless received with too great hope on some sides and too great scepticism on others. It will be remembered that when Professor Koch announced the discovery of tuberculin in 1890, the results did not fulfil the promises. It remains true, however, that tuberculin has proved a valuable method of diagnosis, and that it has certain remarkable effects on the tuberculous foci present in the body. These foci are in fact thrown off in matter that is dead so far as tissue cells are concerned, but which unfortunately still contain living bacilli, which are likely to be again distributed through the body. Modifications of tuberculin have been proposed by Koch himself, by Klebs, by Landmann, by Maragliani and by others, but never with results that have commanded the assent of the scientific world.

It appears that Professor von Behring's communication to the congress was made at the closing session, contrary to his intentions, as a result of pressure brought to bear on him in one way or another. His statement was so brief

that such importance as it may have consists mainly in the facts that he announced that the details of his researches are in press for publication and his own confidence that he had found a curative principle for tuberculosis. This principle, to which he gives the name 'TC,' is obtained from the tubercle bacilli after various toxic portions, including Koch's tuberculin, have been removed. The substance is resorbable by the lymphatic cells, differing thus from the humeral immunity of the antitoxins. The state of immunity of the organism evolves parallel with the metamorphosis of the cells under the influence of TC. Professor von Behring has as yet only made experiments with laboratory animals, but he expects that the harmlessness and therapeutic value of the remedy will be demonstrated by clinicians within a year. Professor von Behring's announcement would be received with pretty complete scepticism if it were not for the fact that the curative effects of his diphtheritic anti-toxin have been accepted by the medical world.

It appears that no other papers of special importance were presented to the congress. The time was spent largely in receptions, dinners and excursions, the last mentioned being of much value to the delegates as illustrating the most advanced French methods of treating tuberculosis. The next meeting of the congress will be in Washington in 1908, the invitation being presented by Drs. Flick, Jacobs, Beyer and Knopff.

SCIENTIFIC ITEMS.

WE regret to record the deaths of Sir William Wharton, F.R.S., hydrographer of the British Navy; Major General Sir Charles Wilson, F.R.S., director-general of the British Ordnance Survey; Dr. Sylvester Dwight Judd, formerly assistant biologist in the U. S. Department of Agriculture, and Dr. Wilhelm Johann Friedrich von Bezold, professor of physics and

meteorology at the University of Berlin.

THE Bolyai prize of the Hungarian Academy of Sciences has been awarded to M. Poincaré.—The eightieth birthday of Dr. F. A. March, professor of English and comparative philology at Lafayette College, was celebrated on October 25, when Professor W. B. Owen made an address of congratulation. The trustees of the college have offered to retire Professor March with full salary, but he prefers to continue his usual duties.

PROFESSOR ROBERT KOCH, who has been at Amaris in West Usambara and at Uganda to complete his researches on trypanosomes and sleeping sickness, expected to reach Berlin on October 23. —Dr. Arthur Stähler, assistant in the chemical laboratory of the University of Berlin, has been sent by the minister of education to Harvard University to pursue studies in inorganic chemistry under Professor T. W. Richards.

THE inaugural meeting of the British Science Guild was held on October 30, at the Mansion House, London. The objects of the guild are (1) to bring together as members of the guild all those throughout the empire interested in science and scientific method, in order, by joint action, to convince the people, by means of publications and meetings, of the necessity of applying the methods of science to all branches of human endeavor, and thus to further the progress and increase the welfare of the empire; (2) to bring before the government the scientific aspects of all matters affecting the national welfare; (3) to promote and extend the application of scientific principles to industrial and general purposes; (4) to promote scientific education by encouraging the support of universities and other institutions where the bounds of science are extended, or where new applications of science are devised.

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