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## THE ELECTRONIC THEORY OF ELECTRICITY.

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CONSIDERABLE progress has been made of late years in our knowledge concerning the structure and relations of atoms and electricity. Recent discoveries have moreover placed in a new light old theories and experimental work. The remarkable investigations and deductions made from his own experiments and those of others, which have led Professor J. J. Thomson to the conclusion that atoms can be split up into, or can give off, smaller masses, which he calls corpuscles, were explained by him in a most interesting article in the *POPULAR SCIENCE MONTHLY* for August, 1901.\* There seems to be good evidence that in a glass vessel exhausted to a high vacuum through the walls of which are sealed platinum wires, we have a torrent of small bodies or so-called corpuscles projected from the kathode or negative wire, when the terminals are connected to an induction coil or electrical machine.

Twenty-five years ago Sir William Crookes explored with wonderful skill many of the effects due to electric discharge through such high vacua, and came to the conclusion that they could only be explained by the supposition that there was present in the tube matter in a *fourth state*, neither solid, liquid, nor gaseous, but 'radiant matter' projected in straight lines from the surface of the negative pole or kathode, the particles moving with immense velocity, and all charged

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\* See *POPULAR SCIENCE MONTHLY*, Vol. LIX., p. 323, 'On Bodies Smaller than Atoms,' by Professor J. J. Thomson, F.R.S. See also by the same author a paper in the *Philosophical Magazine* for December, 1899, 'On the Masses of the Ions in Gases at Low Pressures.'

with negative electricity. He showed by beautiful experiments that this radiant matter bombarded the glass walls and produced phosphorescence, could be focused on to metal sheets and render them red hot, and could drive round little windmills or vanes included in the tube. It therefore possesses the quality of inertia and in virtue of the electric charge it carries, it is virtually an electric current and can be deflected by a magnet. The proof which has been given by Professor Thomson that this 'radiant matter' consists of corpuscles, a thousand times smaller than an atom of hydrogen in mass, and that they are shot off from the kathode with a velocity which is comparable with that of light, explains at once both their kinetic energy and also the manner in which they are able to pass through windows of aluminium, as shown by Lenard, and get into the space outside the tube. Furthermore, evidence has been put forward to show that the electric charge carried by each one of these tiny corpuscles is exactly the same as that which a hydrogen atom carries in the act of electrolysis or when it forms a hydrogen ion.

It seems tolerably clear from all the facts of electrolysis that electricity can only pass through a conducting liquid or electrolyte by being carried on atoms or groups of atoms which are called *ions*—i. e., *wanderers*. The quantity thus carried by a hydrogen atom or other monad element, such as sodium, silver or potassium, is a definite natural unit of electricity. The quantity carried by any other atom or group of atoms acting as an ion is always an exact integer multiple of this natural unit. This small indivisible quantity of electricity has been called by Dr. Johnstone Stoney an *Electron* or *atom of electricity*. The artificial or conventional unit of electric quantity on the centimeter, gram, second system as defined by the British Association Committee on Electrical Units is as follows:

An *electrostatic unit* of electric quantity is the charge which when placed upon a very small sphere repels another similarly charged sphere, the centers being one centimeter apart, with a mechanical force of one dyne. The *dyne* is a mechanical unit of force and is that force which acting for one second on a mass of one gram gives it a velocity of one centimeter per second. Hence, by the law of inverse squares the force in dynes exerted by two equal charges  $Q$  at a distance  $D$  is equal to  $Q^2/D^2$ . Two other units of electric quantity are in use. The *electromagnetic unit*, which is thirty thousand million times as great as the electrostatic unit, and the *practical unit* called the coulomb or ampère-second which is three thousand million times the electrostatic unit. We can calculate easily the relation between the *electron* and the *coulomb*; that is, between *nature's unit* of electricity and the British Association unit, as follows:

If we electrolyze any electrolyte, say acidified water which yields



up hydrogen at the negative electrode, we find that to evolve a volume of one cubic centimeter of hydrogen gas at 0° C. and 760 mm. we have to pass through the electrolyte a quantity of electricity equal to 8.62 coulombs. For 96,540 coulombs are required to evolve one gram of hydrogen and 11,200 cubic centimeters at 0° C. and atmospheric pressure weigh one gram. The number 8.62 is the quotient of 96,540 by 11,200.

Various arguments, some derived from the kinetic theory of gases, indicate that the number of molecules of hydrogen in a cubic centimeter is probably best represented by the number twenty million million million  $= 2 \times 10^{19}$ . Hence it follows, since there are two atoms of hydrogen in a molecule, that in electrostatic units the electric charge on a hydrogen atom or hydrogen ion is

$$\begin{aligned} \frac{96540 \times 3 \times 10^9}{11200 \times 4 \times 10^{19}} &= \frac{65}{10^{11}} \text{ of a C. G. S. electrostatic unit} \\ &= \frac{22}{10^{20}} \text{ of a coulomb.} \end{aligned}$$

Accordingly, if the above atomic charge is called *one electron* then the conventional British Association electrostatic unit of electric quantity is equal to 15±0 million electrons, and the quantity called a coulomb is nearly five million million million electrons. The electron or the electric charge carried by a hydrogen atom or ion is evidently a very important physical constant. If we electrolyze, that is decompose by electricity aqueous solutions of various salts, such as sodium chloride, zinc chloride, copper sulphate, silver nitrate, we find, in accordance with Faraday's Laws of Electrolysis, that the passage of a given quantity of electricity through these solutions decomposes them in proportional amounts such that for every 46 grams of sodium liberated there are 65 of zinc, 63.5 of copper and 216 of silver. These masses are called chemical equivalents. Accordingly, if we imagine a number of vessels placed in a row containing these solutions and by means of platinum connecting links or plates we pass an electric current through the series, for every atom of copper or zinc carried to their respective kathodes, we shall have two atoms of silver or sodium similarly transported. Since the same quantity of electricity must pass through every vessel in the same time it is evident that the above fact may be interpreted by assuming that whilst an atom of silver or sodium acting as an ion carries one electron, an atom of zinc or copper carries two electrons.

In the same way we may have atoms which carry three, four, five or six electrons. Thus we may interpret the facts of chemical valency and Faraday's Law of Electrolysis in terms of the electron.

We are thus confronted by the idea, long ago suggested by Weber and by Helmholtz, that the agency we call electricity is *atomic in structure*, that is to say, we can only have it in amounts which are all exact multiples of a certain small unit. Electricity therefore resembles those articles of commerce like cigars, which we can buy in exact numbers, 1, 10, 50, 100, 1000, but we cannot buy half a cigar or five sixths of a cigar. If then the law which holds good for electricity in association with atoms during electrolysis holds good generally, a very important advance has been made in establishing the fact that there is a small indivisible unit of it which can be multiplied but not divided, and every quantity of electricity, small or large, is an exact integer multiple of this unit, *the electron*.

### *Theories of Electricity.*

Various answers have been given at different times to the question—What is electricity? It has been defined as an imponderable fluid, as a force, as a mode of motion, a form of energy, an ether strain or displacement or a molecular motion.

At one time physicists have considered it as a single entity or fluid; at others it has been pronounced to be duplex in nature and positive and negative fluids or electricities have been hypothesized.

The state of electrification has been looked upon at one period as due to an excess or defect of a single electricity, at others as a consequence of the resolution of some neutral fluid into two components. An electrical charge on a conductor has been regarded as something given to or put upon the conductor and also as a state of strain or displacement in the surrounding non-conductor. The intelligent but non-scientific inquirer is often disappointed when he finds no simple, and as he thinks essential, answer forthcoming to the above question, and he asks why it cannot be furnished.

We must bear in mind, however, that scientific hypotheses as to the underlying causes of phenomena are subject to the law of evolution and have their birth, maturity and decay. Theory necessarily succeeds theory, and whilst no one hypothesis can be looked upon as expressing the whole truth, neither is any likely to be destitute of all truth if it sufficiently reconciles a large number of observed facts.

The notion that we can reach an absolutely exact and ultimate explanation of any group of physical effects is a fallacious idea. We must ever be content with the best attainable sufficient hypothesis that can at any time be framed to include the whole of the observations under our notice. Hence the question, What is electricity? no more admits of a complete and final answer to-day than does the question, What is Life? Though this idea may seem discouraging, it does not follow that the trend of scientific thought is not in the right

direction. We are not simply wandering round and round, chasing some elusive Will-o'-the-wisp, in our pursuit after a comprehension of the structure of the universe. Each physical hypothesis serves, however, as a lamp to conduct us a certain stage on the journey. It illuminates a limited portion of the path, throwing a light before and behind for some distance, but it has to be discarded and exchanged at intervals because it has become exhausted and its work is done.

The construction and testing of scientific theories is therefore an important part of scientific work. The mere collection of facts or even their utilization is not the ultimate and highest goal of scientific investigation. The aim of the most philosophic workers has always been to penetrate beneath the surface of phenomena and discover those great underlying fundamental principles on which the fabric of nature rests. From time to time a fresh endeavor has to be made to reconstruct, in the light of newly acquired knowledge, our scientific theory of any group of effects. Thus, the whole of electrical phenomena have become illuminated of late years by a theory which has been developed concerning the atomic structure of electricity and this hypothesis is called the Electronic Theory of Electricity.

#### *The Atomic Theory.*

The opinion that matter is atomic in structure is one which has grown in strength as chemical and physical knowledge has progressed. From Democritus, who is said to have taught it in Greece, to John Dalton who gave it definiteness, and to Lord Kelvin who furnished the earliest numerical estimate of the size of atoms, it has been found to be the best reconciler of very diverse and numerous facts. Let us consider what it really means. Suppose we take some familiar substance, such as common table salt, and divide a mass of it into the smallest grains visible to the eye. Each tiny fragment is as much entitled by all tests to be called table *salt*, or to give it the chemical name, sodic chloride, as a mountain of the material. Imagine that we continue the subdivision under a good microscope; we might finally obtain a little mass of about one hundred-thousandth of an inch in diameter, but beyond this point it would hardly be visible even under a powerful lens. We may, however, suppose the subdivision continued a hundred fold by some more delicate means until we finally arrive at a small mass of about one ten-millionth of an inch in diameter. A variety of arguments furnished by Maxwell, Boltzmann, Loschmidt, Lord Kelvin and others show that there is a high degree of probability that any further subdivision would cause the portions into which the salt is divided to be no longer identical in properties, but there would be two kinds of parts or particles, such that if all of one kind were collected together they would form a metal called sodium, and if all

of the other kind were similarly picked out they would form a non-metal called chlorine. Each of these smallest portions of table salt, which if divided are no longer salt, is called a *molecule* of sodic chloride, and each of the parts into which the molecule is divisible is called an *atom*, of sodium or of chlorine. In dealing with the dimensions of these very small portions of matter an inch or a centimeter is too clumsy a unit. To express the size of an atom in fractions of an inch is worse than stating the diameter of an apple in fractions of a mile. Every one knows what is meant by a millimeter; it is nearly one twenty-fifth part of an inch. A meter is equal to a thousand millimeters. Suppose a millimeter divided into a thousand parts. Each of these is called a *micron* and denoted by the Greek letter  $\mu$ . This however is still too large a unit of length for measuring the size of atoms, so we again divide the micron into a thousand parts and call each a micromillimeter or *micromil*, and denote it by the symbol  $\mu\mu$ . Lord Kelvin's estimate of the diameter of a molecule is that it lies between one hundredth of a micromil and two micromils, that is between  $.01 \mu\mu$  and  $2 \mu\mu$ . This is certainly a very wide estimate, but it is the best yet to hand, and for present purposes we may take it that an atom is a small portion of matter of approximately one millionth of a millimeter or one micromil ( $1 \mu\mu$ ) in diameter. On the same scale the wave length of a ray of yellow light is about  $0.6 \mu$  or  $600 \mu\mu$ , that is six hundred times the size of an atom. We know nothing as yet about the relative sizes of different kinds of atoms. In the next place as regards the number of molecules in a given space, various distinguished physicists, Maxwell, Kelvin, Boltzmann, Van der Waals and others, have given estimates for the number of molecules in a cubic centimeter of air at ordinary temperature and pressure, which vary between  $10^{18}$  and  $10^{21}$  or between a million billion and a thousand million billion. All we can do is to take a rough mean of these different values, and we shall consider that in one cubic centimeter of hydrogen or other gas at  $0^\circ$  C. and 760 mm. or freezing point and ordinary pressure there are about  $2 \times 10^{19}$  or twenty million million molecules. To understand what this enormous number means we must realize that if we could pick out all the molecules in one cubic inch of air and place them side by side in a row, small as they are individually, the row would extend nearly twice the distance from the earth to the sun.

Having provided ourselves with a rough idea of the sizes and numbers of the molecules of any gas we proceed to obtain an idea of their weight or mass. Since 11,162 cubic centimeters of hydrogen gas at  $0^\circ$  C. and 760 mm. weigh one gram, it follows from the above facts that each molecule of hydrogen has a mass of nearly  $1/10^{23}$  of a gram. To weigh these tiny atoms we must therefore take a

unit of weight equal to one billionth of one billionth of a gram, and then on this scale the hydrogen molecule weighs 10 such units. We may obtain in another way an illustration of the mass size and number of the molecules of any gas in the following manner:

First as to size. We can in a good Whitworth measuring instrument detect a variation in length of a metal bar equal to one millionth of an inch. This short length would be occupied by 25 molecules placed in a row close together. We can in a good microscope see a small object whose diameter is one hundred-thousandth of an inch. In a small box of this size we could pack 16 million molecules close together. The smallest weight which can be weighed on a very good chemical balance is one hundredth of a milligram. The united weight of one million million million molecules of hydrogen would therefore just be detectable on such a balance.

#### *Ultra-Atomic Matter.*

Until a few years ago our knowledge of the divisibility of matter may be said to have ended with the chemical unit, the atom. But of late years information has been steadily accumulating which has made us acquainted with matter in a finer state of subdivision. For a long time a controversy was carried on, whether the radiation in a high vacuum tube which proceeds from the kathode was a material substance or a wave motion of some kind. But no fact yet found is inconsistent with the notion which originated with Sir William Crookes that the transfer which takes place is that of something which has the inertia quality of matter, and his term 'radiant matter' is a peculiarly suitable phrase to describe the phenomena. The great advance which has since been made, by Professor Thomson and others, is that of measuring accurately the amount of bending which a stream of this radiant matter experiences under a known magnetic force and from this deducing the ratio between the mass of the radiant particle and the electric charge carried by it. This measurement shows that if the radiant matter consists of corpuscles or particles, each of them carries a charge of one electron, but has a mass of about one thousandth of a hydrogen atom.

The evidence therefore exists that Crookes' 'radiant matter' also called the 'kathode rays' and Thomson's 'corpuscles' are one and the same thing and that these corpuscles may be described as fragments broken off from chemical atoms and possessing only a small fraction of their mass. These particles are shot off from the negative terminal or kathode of the vacuum tube with a velocity which is from one fifth to one third the velocity of light.

Moreover it has been shown that when the kathode rays pass through a thin metal window in a vacuum tube and get into the space



outside, thus forming Lenard's rays, they are likewise only the same or similar corpuscles in the space outside rather than inside the vacuum tube. Finally it has been proved that these electrified corpuscles are present as well in the mass of a gas through which Röntgen rays have passed, also in the mysterious radiation called Becquerel rays which proceeds from uranium and other radio-active substances, also in all flames, near all very hot bodies and in the air near certain metallic surfaces on which ultra-violet light falls. In every case the corpuscle is charged with an electron charge of negative electricity. If a corpuscle originates as a fragment chipped off from an electrically neutral atom and is negatively charged, it follows that the remainder of the atom of matter is left positively charged.

The word 'atom' therefore, as far as it signifies something which *cannot be cut*, is becoming a misnomer as applied to the chemical unit of matter, because this latter is capable of being divided into two parts of very unequal size. First, a small part which is negatively electrified and which is identically the same, no matter from what chemical atom it originates, and secondly, a much larger mass which is the remainder of the atom and is positively electrified, but which has a different nature depending on the kind of chemical atom broken up. The question has then begun to be debated whether we can distinguish between the corpuscle and the electric charge it carries and if so in what way. In other words, can we have an unelectrified corpuscle or is the corpuscle so identified with its electric charge that they are one and the same thing? It has been shown experimentally that an electric charge in motion is in effect an electric current, and we know that an electric current possesses something equivalent to inertia, that is, it cannot be started and stopped instantly, and it possesses energy. We call this electric inertia *inductance*, hence the question arises whether the energy of the corpuscles when in motion is solely due to the electric inductance or whether it is partly due to what may be called the ponderable inertia of the corpuscle.

This very difficult question has not yet been even approximately settled. At the present moment we have no evidence that we can separate the electron charge from the corpuscle itself. If this is the case, then the corpuscles taken together constitute for all practical purposes negative electricity, and we can no more have anything which can be called electricity apart from corpuscles than we can have momentum apart from moving matter. For this reason it is sometimes usual to speak of the corpuscle carrying its charge of one electron of negative electricity simply as *an electron*, and to drop all distinction between the electric charge and the vehicle in or on which it is conveyed.

It is remarkable that so far no one has been able to produce or find a corpuscle positively electrified. Positive electricity is only known in

association with masses as large as atoms, but negative electricity is identified with corpuscles or masses only a small fraction of the size of an atom. This does not prove that an atom may not include positive corpuscles or electrons, but only that so far we have not been able to isolate them.

*The Electronic Theory of Electricity.*

From this point of view a theory of electricity originates called the electronic theory. The principal objects of consideration in this theory are these electrons which constitute what we call electricity. An atom of matter in its neutral condition has been assumed to consist of an outer shell or envelope of negative electrons associated with some core or matrix which has an opposite electrical quality, such that if an electron is withdrawn from the atom the latter is left positively electrified.

A neutral atom *minus* an electron constitutes the natural unit of positive electricity and the electron and the neutral atom minus an electron are sometimes called negative and positive ions. Deferring for a moment a further analysis of possible atomic structure we may say that with the above hypothesis in hand we have then to express our statements of electrical facts in terms of the electron as the fundamental idea.

All that can be attempted here is a very brief exposition of the success which has so far attended this effort to create a new range of electrical conceptions. Let us consider first the fundamental difference between substances in respect of electrical conductivity. In the electronic theory what is the distinction between conductors and non-conductors? It must be remembered that on the electronic hypothesis an electric current is a movement of electrons. Hence a conductor must be a substance in which electrons free to move exist. It is considered therefore that in metals and good conductors a certain proportion of the atoms are broken up into positive and negative ions or into electrons and remainders of atoms which we may call coelectrons. There may be a constant decomposition and recombination of atoms taking place, and any given electron so to speak flits about, now forming part of one atom and now of another and anon enjoying a free existence. It resembles a person visiting from house to house forming a unit in different households and in between being a solitary person in the street. In non-conductors on the other hand the electrons are much restricted in their movements, and can be displaced a little way but are pulled back again when released. The positive and negative ions or electrons and coelectrons never have the opportunity to part company very far.

The reader who is familiar with the modern doctrine of the ionization of salts in solution will see that a close similarity exists between this view of the atomic state of a metal and the chemical state of a salt in solution. The ionic theory of solution is that if some salt, say

sodic chloride, is placed in water a certain proportion of the molecules of sodic chloride are dissociated into sodium and chlorine ions, that is to say, atoms possessing electric charges, and the electric conductivity of the solution is due to the mobility of these saline ions.

On the electronic theory a certain proportion of the atoms of a conductor are similarly in a state of electronization. The application of an electromotive force to the conductor thus at once causes the electrons to begin to migrate. If we compare conductors and non-conductors we shall see that the former are mostly elementary bodies, the metals and alloys or graphitic carbon, whilst the latter are all very complex substances such as glass, ebonite, the oils, shellac, gutta-percha, etc. These last have large and complex molecules but the good conductors have all simple molecules and small atomic volumes. The exceptions apparently are sulphur and carbon in the form of diamond. When, however, we remember that carbon and sulphur are elements very prone to polymerize and so to speak combine with themselves they may not really be an exception. The electrons may therefore have much more difficulty in exchanging from atom to atom or in making their way between or through the molecules when these are very complex than when they are simple.

The question then may be asked why these free electrons do not all escape from the conductor. The answer is that there must be an equal quantity of electrons and coelectrons or remainders of atoms or of so-called negative and positive ions, and the stronger attraction between these involves the expenditure of work to separate them. The radioactive substances, such as uranium, polonium, radium, actinium and others, to which so much attention has been paid lately, do seem to have the power of emitting their corpuscles or electrons and scattering them abroad, and hence can only do this at the expense of some of their own internal molecular energy or else drawing upon the heat of surrounding bodies.

We come next to the explanation of the familiar fact of electrification by friction. Why is it that when we rub a glass rod with a bit of silk the two things are equally and oppositely electrified? To explain this on the electronic theory we have to consider the state of affairs at the surface of any substance immersed say in air. At the surface where the air and glass meet there will be an electronization of atoms which appears to result in the formation of a double layer of electrons and coelectrons or negative and positive ions. This is probably an attempt on the part of the glass and air to combine chemically together. The same state exists at the surface of the silk. When we rub these two things together these double layers are very roughly treated and are broken up. The whole lot of electrons and coelectrons or residual portions of atoms get mixed up and more or less divided up between the

two surfaces. As however every negative electron has its positive coelectron, it follows that what one surface gains the other must lose. Hence in the end we may have a majority of negative ions or electrons left on the one surface and a majority of positive ions or coelectrons left on the other surface, and the glass and the silk are then electrified with equal quantities but opposite sign. Owing to the mutual repulsion of the similar electrons the charge resides wholly on the surface.

This conception of the existence of a double layer of opposite electricities or ions at the surface of contact of two substances has been put forward to account for the familiar effect of the electrification of air by falling drops of water. It has long been known that the air in the neighborhood of waterfalls of fresh water is electrified negatively, whereas the air in the neighborhood of splashing salt water, as at the seaside, is positively electrified and the explanation that has been given by Professor J. J. Thomson is that this is due to the breaking up of this double layer of ions at the surface of the drop when it strikes the ground.

#### *Atomic Valency.*

At this stage it may be well to indicate that any valid theory of electricity must involve an explanation of the facts of chemical combination and chemical valency as well. At present all ideas on the structure of atoms must necessarily be purely speculative. So much advance has been made however in the development of a department of chemistry called stereo-chemistry that we need not despair of coming to know in time much about the architecture of atoms and molecules. The way is cleared, however, for some consistent explanations if we can assume that one or more free electrons can attach themselves to a neutral atom and so give it a negative charge of electricity. We may suppose as a first assumption that in a neutral atom which is otherwise complete there exist localities at which one or more electrons can find a permanent attachment. The atom is then no longer neutral but negatively electrified. If the atom can as it were accommodate *one* electron it is a monovalent element, if *two* it is divalent and so on. If it cannot accommodate any at all it is an *avalent* or *non-valent* element.

Consider the case of gaseous molecules. Chemical facts teach us that the molecules of free gaseous hydrogen, oxygen or other gases contain two atoms, so that these free molecules are represented by the symbols  $H_2$ ,  $O_2$ , etc. In these cases hydrogen and oxygen are so to speak combined with themselves. We can explain this by the supposition that most neutral atoms are unstable structures. In contact with each other some lose one or more electrons and an equal number gain one or more electrons. Hence in a mass say of hydrogen we have some atoms which are positively electrified and some which are negatively electrified then called atomic ions, and these ions united pair and pair

form the molecules of hydrogen which may be represented by  $(\text{H}^+, \text{H}^-)$  similarly for other gases. Certain neutral atoms such as those of argon are monatomic and non-valent and these appear to be unable to enter into combination either with each other or with other atoms. Accordingly, in a mass of free hydrogen there are no free electrons and all the positively charged and negatively charged H atoms are in union. Hence the gas is a non-conductor of electricity. But we can make it a conductor by heating it to a high temperature. The explanation of this is that a high temperature dissociates some of the molecules into atoms and these under the action of electric force move in opposite directions, thus creating an electric current. Thus air at ordinary temperatures is an almost perfect non-conductor, but at a white heat it conducts electricity freely.

The monovalent elements like hydrogen are those neutral atomic structures which can lose one electron or take up one electron, becoming respectively positive atomic ions and negative atomic ions. In the same way the divalent elements such as oxygen are those neutral atomic structures which can part with two electrons and take up two and so on for trivalent, quadrivalent, etc., atoms. The work required to remove the second electron probably is very much greater than that required to remove the first. Hence in polyvalent atoms the valencies have unequal energy values.

Consider now a mass of intermingled oxygen and hydrogen consisting of neutral molecules. The state is a stable one as long as all the molecules are neutral. If, however, we dissociate a few of the hydrogen and oxygen molecules by an electric spark or by heat then there is a recombination. A positive oxygen ion unites with two negative hydrogen ions and a negative oxygen ion with two positive hydrogen ions and the result is two neutral molecules of water. This combination takes place because the union of oxygen ions with hydrogen ions to form water evolves more heat and exhausts more potential energy than the combination of oxygen with oxygen and hydrogen with hydrogen ions in equivalent quantity. The energy set free by the union of the O and H is sufficient to continue the dissociation of further gaseous molecules so the action is explosive and is propagated throughout the mass.

There is however a broad distinction between the elements in this respect, viz.: that some atoms are prevalently electropositive and others electronegative. A metallic atom for instance is electropositive, but the atoms of non-metals are mostly electronegative. Moreover metals in the mass are electrically good conductors, whereas non-metals in the mass are non-conductors or bad conductors. This may be explained by the varying degree of force required to detach electrons from neutral atoms and conversely the varying degree of attachment of electrons



for neutral atoms. Thus we may consider that the metallic atoms lose very easily one or more electrons and also that there is a somewhat feeble attachment in their case between the neutral atom and the free electron. Hence metals in the mass are conductors because there are plenty of free electrons present in them. On the other hand, in the case of non-metallic atoms the force required to detach one or more electrons from the atom is much greater and conversely the attachment of free electrons for the neutral atom is larger. Accordingly, in non-metals there are few free electrons and they are therefore non-conductors. Moreover the presence of positive and negative atomic ions causes them to link together into more or less complex molecules and they exhibit polyvalency and act as the grouping elements in molecular complexes. This is a very characteristic quality of the elements, sulphur, silicon and carbon.

Helmholtz long ago laid stress on the fact that certain physical and chemical effects could only be explained by assuming a varying attraction of electricity for matter. The same idea followed out leads to an hypothesis of chemical combination and dissociation of salts in solution. Thus a molecule of sodic chloride is the electrical union of a monovalent sodium ion or sodium atom *minus* one electron with a chlorine ion which is a chlorine atom *plus* one electron. It may be asked why in this case does not the extra electron pass over from the chlorine to the sodium ion and leave two neutral atoms. The answer is because the union between the electron and the chloride is probably far more intimate than that between the atomic groups. These latter may revolve round their common center of mass like a double star, but the electron which gives rise to the binding attraction may be more intimately attached to the atomic group into which it has penetrated.

#### *Voltaic Action.*

Any theory of electricity must in addition present some adequate account of such fundamental facts as voltaic action and magneto-electric induction. Let us briefly consider the former. Suppose a strip of copper attached to one of zinc and the compound bar immersed in water to which a little hydrochloric acid has been added.

All chemical knowledge seems to point to the necessity and indeed validity of the assumption that the *work* required to be done to remove an electron from a neutral atom varies with the atom. Conversely the attraction which exists between a free electron and an atom deprived of an electron also varies. Accordingly the attraction between atomic ions, that is, atoms one of which has gained and one of which has lost electrons, is different. Upon this specific attraction of an atomic ion for electrons or their relative desire to form themselves into neutral molecules depends what used to be called chemical affinity. Mr. Ruther-

ford has shown that negative ions gave up their charges more readily to some metals than others and most readily to the electro-positive metals. Hence a zinc atomic ion is more ready to take up electrons and again become neutral than a copper ion.

Consider then the simple voltaic couple above described. In the electrolyte we have hydrogen ions which are *H* atoms *minus* an electron, and chlorine ions which are chlorine atoms *plus* an electron. These are wandering about in a menstruum which consists of water molecules and hydrochloride acid molecules. Then in the metal bar we have zinc and copper divalent ions which are these atoms each minus two electrons, and also an equivalent number of free and mobile electrons.

If we adopt Volta's original view of contact electricity, we must assume that at the surface of contact of the metals there is some action which drives electrons across the boundary from the zinc to the copper. This may be due to the neutral copper atoms having a slightly greater attraction for electrons than the neutral zinc atom. The zinc is therefore slightly electrified positively and the copper negatively. Accordingly in the electrolyte the negative chlorine ions move to the zinc and combine with positive zinc ions, forming neutral zinc chloride, two chlorine ions going to one zinc ion. The hydrogen ions therefore diffuse to the copper side and each takes up a free electron from the copper, becoming neutral hydrogen atoms and there escape.

In proportion as the zinc atomic ions are removed from the zinc bar and the corresponding free electrons from the copper, so must there be a gradual diffusion of electrons from the zinc bar to the copper bar across the metallic junction. But this constitutes the voltaic current flowing in the circuit. It is a current of negative electricity flowing from zinc to copper and equivalent to a positive current from copper to zinc. The energy of this current arises from the differential attraction of zinc and copper ions for chlorine ions and is therefore the equivalent of the exhaustion of the chemical potential energy of the cell. Thus the electronic theory outlines for us in a simple manner the meaning of voltaic action. Even if we do not admit the existence of a metallic junction volta contact force, the theory of the cell may be based on the view that the movement of the saline ions in the electrolyte is determined by the law that that motion takes place which results in the greatest exhaustion of potential energy. Hence the chlorine ions move to the zinc and not to the copper.

In the same manner the electronic theory supplies a clue to the explanation of the production of an electric current when a conductor is moved across a magnetic field. Every electron in motion creates a magnetic force. Hence a uniform magnetic field may be considered as if due to a moving sheet of electrons. The 'cutting' of a conductor

across a magnetic field will therefore be accompanied by the same reactions as if a procession of electrons were suddenly started in it. This, however, would involve at the moment of starting a backward push on surrounding electrons, just as when a boat is set in motion by oars the boat is pushed forward and the water is pushed back. Hence there is an induced current at the moment when the field begins in the conductor. Similarly the reaction at stopping the procession would drag the surrounding electrons with it. Accordingly the induced currents when the field ceases is in the opposite direction to that when it begins.

The electronic theory has in the hands of other theorists such as Professors P. Drude and E. Riecke been shown to be capable of rendering an account of most thermomagnetic effects on metals, contact electricity, the so-called Thomson effects in thermoelectricity, and also the Hall effect in metals when placed in a magnetic field.

#### *Electrons and Æther.*

The ultimate nature of an electron and its relation to the æther has engaged the attention of many physicists, but we may refer here more particularly to the views of Dr. J. Larmor whose investigations in this difficult subject are described in his book on 'Æther and Matter' and also in a series of important papers on the transactions of the Royal Society of London, entitled 'A Dynamical Theory of the Electric and Luminiferous Medium' (*Phil. Trans. Roy. Soc.*, 1893, 1895, 1898). Larmor starts with the assumption of an æther which is a frictionless fluid, but possesses the property of inertia; in other words he assumes that its various parts can have motion with respect to each other and that this motion involves the association of energy with the medium. He regards the electron as a strain center in the æther, that is as a locality from which æther strain radiates. Electrons can therefore be either positive or negative according to the direction of the strain and to every positive electron there is a corresponding negative one. Atoms according to him are collocations of electrons in stable orbital motion like star clusters or systems.

An electron in motion is in fact a shifting center of æther strain and it can be displaced through a stationary æther just as a kink or knot in a rope can be changed from place to place on the rope.

An electron in vibration creates an æther wave but it radiates only when its velocity is being accelerated and not when it is uniform.

The type of æther which Larmor assumes as the basis of his reasoning is one which has a rotational elasticity, that is to say, the various portions of it do not resist being sheared or slid over each other, but they resist being given a rotation round any axis. Starting from these postulates and guided by the general and fundamental principle of Least

Action he has erected a consistent scheme of molecular physics in which he finds an explanation of most observed facts.

The discovery by Zeeman of the effect of a strong magnetic field in triplicating or multiplying the lines in the spectrum of a flame placed in a magnetic field meets with an obvious explanation when we remember that the effect of a magnetic field on an electron in motion is to accelerate it always transversely to its own motion and the direction of the field. Hence it follows that a magnetic field properly situated will increase the velocity of an electron rotating in one direction and retard it if rotating in another. But a linear vibration may be resolved into the sum of two oppositely directed circular motions and accordingly a magnetic force properly applied must act on a single spectral line, which results from the vibration of an electron in such manner as to create two other lines on either side, one representing a slightly quicker and the other a slightly slower vibration.

The notion of an electron or point charge of electricity as the ultimate element in the structure of matter having been accepted, we are started on a further enquiry as to the nature of the electron itself. It is obvious that if the electron is a strain center or singular point in the æther, then corresponding to every negative electron there must be a positive one. In other words electrons must exist in pairs of such kind that their simultaneous presence at one point would result in the annihilation of both of them.

On the view that material atoms are built up of electrons we have to seek for a structural form of atom which shall be stable and equal to the production of effects we find to exist.

The first idea which occurs is that an atom may be a collection of electrons in static equilibrium. But it can be shown that if the electrons simply attract and repel each other at all distances according to the law of the inverse square no such structure can exist. The next idea is that the equilibrium may be dynamic rather than static. That an atom may consist of electrons, as suggested by Larmor, in orbital motion round each other, in fact that each atom is a miniature solar system.

Against this view, however, Mr. T. H. Jeans ('Mechanism of Radiation,' *Proc. Phys. Soc. Lond.*, Vol. 17, p. 760) has pointed out that an infinite number of vibrations of the electrons would be possible about each state of steady motion and hence the spectrum of a gas would be a continuous one and not a bright-line spectrum.

If we are to assume an atom to consist wholly of positive and negative electrons or point charges of electricity, Mr. Jeans has indicated that we may obtain a stable structure by postulating that the electrons, no matter whether similar or dissimilar, all repel each other at very small distances.

We might then imagine an atom to be built up of concentric shells of electrons like the coats of an onion alternately positive and negative, the outermost layer being in all cases negative. The difference between the total number of positive and negative electrons is the valency of the atom.

On this view an atom of hydrogen would consist of from 700 to 1,000 positive and negative electrons arranged in concentric layers in a spherical form. The vibrations which emit light are not those of the atom as a whole but of the individual electrons which compose it.

The reason for assuming that in all cases the outermost layer of electrons is negative is that if it were not so, if some atoms had their outer layers of negative and some of positive electrons, two atoms when they collided would become entangled and totally lose their individuality. There would be no permanence. Hence our present atoms may be, so to speak, the survivors in a struggle for existence which has resulted in the survival only of all atoms which are of like sign in the outer layer of electrons. We see an instance of a similar action in the case of the like directed rotation of all the planets round the sun which is due to the operation of the law of conservation of angular momentum. As a consequence of the equality of sign of the outer layer of electrons two atoms cannot approach infinitely near to each other. They mutually repel at very small distances. This suggestion makes it clear why we only know at present free negative electrons; it is because we can only detach a corpuscle or electron from the outer layer of an atom. It is clear, however, that the complete law of mutual action of electrons has yet to be determined. We have also to account for gravitation and this involves the postulate that all atomic groups of electrons without regard to sign must attract each other. Hence we need some second Newton who shall formulate for us the true law of action of these electrons which form the 'foundation stones of the material universe.' Facts seem to suggest that the complete mathematical expression for the law of mutual action of two electrons must show:

1. That at exceedingly small distances they all repel each other without regard to sign.

2. That at greater distances positive electrons repel positive and negative repel negative, but unlike electrons attract, with a force which varies inversely as the square of the distance.

3. Superimposed on the above there must be a resultant effect such that all atoms attract each other at distances great compared with their size without regard to the relative number of positive and negative electrons which compose them, inversely as the square of the distance.

In this last condition we have the necessary postulate to account for universal gravitation in accordance with Newton's law.

It is conceivable, however, that this differential or resultant uni-

versal attraction to which gravitation is due is only true of electrons when gathered together so as to form atoms. In other words, every atom attracts every other atom; but every electron does not attract every other electron. Universal gravitation may be an effect due to the collocation of electrons to form atoms and molecules, but not an attribute of electrons in themselves, though, if the gravitative effect is proportional to the product of the total number of electrons in each mass, the Newtonian law will be fulfilled. It has been also suggested that a sufficient source for the necessary resultant mass attraction may be found in a slight superiority of the attractive force between two opposite electrons over the repulsion between two similar electrons.

#### *Conclusion.*

In the above sketch of the electronic theory we have made no attempt to present a detailed account of discoveries in their historical order or connect them especially with their authors. The only object has been to show the evolution of the idea that electricity is atomic in structure, and thus these atoms of electricity called electrons attach themselves to material atoms and are separable from them. These detachable particles constitute as far as we yet know negative electricity. The regular free movements of electrons create what we call an electric current in a conductor, whilst their vibrations when attached to atoms are the cause of æther waves or radiation, whether actinic, luminous, or thermal. The æther can only move and be moved by electrons. Hence it is the electron which has a grip of the æther and which, by its rapid motions, creates radiation, and in turn is affected by it. We have therefore to think of an atom as a sort of planet accompanied by smaller satellites which are the electrons. Moreover the electrons are capable of an independent existence, in which case they are particles of so-called negative electricity. The atom having its proper quota of electrons is electrically neutral, but with electrons subtracted it is a positive atomic ion, and with electrons added to it it is a negative atomic ion. It has been shown from a quantitative study of such diverse phenomena as the Zeeman effect, the conductivity produced in gases by Röntgen rays or by ultra violet light and from the magnetic deflection of cathode rays, that in all cases where we have to deal with free moving, or vibrating electrons, the electric charge they carry is the same as that conveyed by a hydrogen atom in electrolysis.

There is good ground for the view that when a gas is made incandescent, either by an electric discharge or in any other way, the vibrating bodies which give rise to the light waves are these electrons in association with the atom. The energy of mass movement of the atom determines temperature, but the fact that we may have light given out without heat, in short, *cold light*, becomes at once possible if it is the

vibrating electric particle attached to the atom which is the cause of eye-affecting radiation or light.

Lorentz, Helmholtz, Thomson and others have shown that such a conception of atomic structure enables us to explain many electro-optic phenomena which are inexplicable on any other theory. Maxwell's theory that electric and magnetic effects are due to strains and stresses in the æther, rendered an intelligible account of electric phenomena, so to say, in empty space, and its verification by Hertz placed on a firm basis the theory that the agencies we call electric and magnetic force are affections of the æther. But the complications introduced by the presence of matter in the electric and magnetic fields presented immense difficulties which Maxwell's theory was not able to overcome.

The electronic theory of electricity, which is an expansion of an idea originally due to Weber, does not invalidate the ideas which lie at the base of Maxwell's theory, but it supplements them by a new conception, viz., that of the electron or electric particle as the thing which is moved by electric force and which in turn gives rise to magnetic force as it moves. The conception of the electron as a point or small region towards which lines of strain in the æther converge, necessitates the correlative motion of positive and negative electrons. We are then led to ask whether the atom is not merely a collocation of electrons. If so, all mechanical and material effects must be translated into the language of electricity. We ought not to seek to create mechanical explanations of electrical phenomena, but rather electrical ones of mechanical effects. The inertia of matter is simply due to the inductance of the electron, and ultimately to the time element which is involved in the creation of æther strain in a new place. All the facts of electricity and magnetism are capable of being restated in terms of the electron idea. All chemical changes are due to the electric forces brought into existence between atoms which have gained or lost electrons. If moving electrons constitute an electric current, then electrons in rotation are the cause of magnetic effects. In optics it is capable of giving a consistent explanation of dispersion, absorption and anomalous dispersion and the relation of the index of refraction to the dielectric constant. A scientific hypothesis, with this wide embrace, which opens many closed doors and enables us to trace out the hidden connection between such various departments of physical phenomena, is one which must continue to attract investigators. Physical enquirers are at present, however, groping for guiding facts in this difficult field of investigation, but we have confidence that mathematical and experimental research will in due time bring the reward of greater light.

## SULFURIC ACID AND ITS MANUFACTURE BY THE CONTACT-PROCESS.\*

BY DR. R. KNEITSCH.

THAT the subject on which you ask me to speak is of the greatest interest from an industrial standpoint needs no argument. The sulfuric acid industry is rightly looked upon as the foundation of inorganic technology, but it has also in the last few years, aside from its importance in so many departments of the various textile branches, become of equal necessity in the manufacture of the organic dye-stuffs. This is especially the case in the field of the alizarin dyes, and more recently, as was shown just a year ago from this platform by Heinrich Brunck, in the manufacture of synthetic indigo. If then in industries of such importance a complete revolution is taking place, a description of the discoveries and experiments which have made such a revolution possible can not fail to be of interest. In the limited time at my disposal it would be of course impossible to treat exhaustively the great mass of material bearing on the subject, and hence I must confine myself chiefly to the results of the work which has been carried on at the *Badische Anilin und Soda-Fabrik*.

The chemistry of the sulfuric acid manufacture is exceedingly simple, indeed chemistry seems at first sight to play but a subordinate rôle. Nevertheless this simple process presents an exceedingly interesting and important example of a gas reaction which occurs only at high temperatures. The reaction between sulfur dioxide and oxygen, although it is exothermic, takes place, as is well known, with extraordinary slowness, and therefore every effort has been made from an industrial standpoint to discover methods of hastening it by the use of catalytic substances. Indeed the lead chamber process itself depends upon the use of nitric acid and the lower oxides of nitrogen as such catalytic agents.

There are, however, many solid substances which have this same catalytic action, though only at high temperatures, and which in virtue of their state of aggregation suffer no loss in the process. These also possess a further great advantage over their gaseous rivals, in that their action goes on in the absence of water, thus rendering possible the

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\* Lecture before the German Chemical Society, October 19, 1901. Translated into English by Professor Jas. Lewis Howe, Washington and Lee University.



production, not of dilute acid only, as in the chamber-process, but of the strongest acids and of sulfur trioxid itself.

### *Historical.*

In the historical development of the contact-process we recognize four periods, the first of which was ushered in by the discovery in 1831 by Phillips of the catalytic action of platinum in the manufacture of sulfuric acid. The second period dates from the discovery by Woebler and Mahla, in 1852, of a similar catalytic action on the part of a number of other substances, and the explanation of the mechanism of the reaction in some of these cases. The third period, which begins with Winckler, is characterized by the use of certain gaseous mixtures which, according to the conception of that time, were especially favorable for the reaction from a quantitative standpoint. In the fourth period there is a return to the use of the gases from the pyrites-burners. As their ultimate goal, the early efforts, like those of the present period, seek by the aid of the catalytic process, entirely to replace the lead chambers in the manufacture of ordinary sulfuric acid, while the workers of the third period, profiting by the large number of earlier failures, confined themselves to the attempt to make the expensive fuming acid.

The discoverer of the catalytic action of platinum in general was Sir Humphry Davy, who found that when a heated platinum wire was brought into a mixture of oxygen or air with hydrogen, carbon monoxid, ethylene or cyanogen, it became red hot, and the gas mixture was burned, generally slowly, but sometimes with great rapidity. Three years later Edmund Davy discovered that finely divided platinum, prepared by evaporating the nitrate and treating the residue with alcohol, was brought to a glow by moistening with alcohol, the alcohol itself being ignited. Doebereiner found in 1822 that the residue left on heating ammonium platinum chlorid, acted in the same manner, and in 1823 he discovered that when a stream of hydrogen impinged on finely divided platinum, it took fire. The next year he brought out the celebrated Doebereiner lamp, which depended on this phenomenon.

The honor of having applied this catalytic action of platinum to the manufacture of sulfur trioxid belongs, as has already been said, to Peregrine Phillips, Jr., a vinegar-maker of Bristol. In 1831 he received an English patent for his discovery. This discovery of Phillips' was confirmed in 1832 by two distinguished German scientists, Doebereiner and Magnus. Seventeen years passed with no further developments, and then the Belgian chemist, Schneider, announced that he had solved the problem of manufacturing sulfuric acid without the aid of lead chambers. He believed that he had found in a specially prepared pumice-stone a catalytic substance of extraordinary activity,

but although great claims were made, no practical results followed.

The hopes of this period are well characterized in a letter which was written by Clement-Desormes to Schneider in 1835, only four years after Phillips' discovery. A portion reads as follows:

I am convinced that within at the most a decade sulfuric acid will be made upon a large scale without the use of lead chambers, nitric acid, or nitrates; do not let your courage fail, but press forward to this important goal.

Thus early was the goal definitely pointed out. . . . In the year 1852 came the discovery of Woebler and Mahla, that the oxids of copper, iron and chromium exert a similar catalytic action upon a mixture of sulfur dioxid and oxygen, to that of platinum sponge and platinum foil. The mixture of copper and chromium oxids was found to be particularly active in this respect. This was followed by the discovery of many other catalytic substances, such as 'spent' pyrites, highly heated quartz, platinized pumice, platinized asbestos and platinized clay.

This second period in historical development is, like the first, characterized by the attempt to solve the problem of the manufacture of ordinary sulfuric acid without recourse to the chamber process. These efforts, however, were crowned by no practical success, indeed it was not found possible even to make fuming sulfuric acid cheaply enough to compete with that obtained by the distillation of the iron vitriol shales.

We now come to the turning point of our subject, the work of Clemens Winckler. By his experimental investigations he reached the conclusion that for complete conversion into sulfuric acid, it was necessary that the mixture of sulfur dioxid and oxygen should be in stoichiometric proportions, that is, two volumes of the oxid to one of oxygen and that all other gases, even oxygen in excess, exercised an injurious effect upon the reaction. This mixture Winckler prepared very simply by the decomposition of ordinary aqueous sulfuric acid with heat, subsequently removing the water. In this manner, by combining the gases, he obtained sulfur trioxid or fuming sulfuric acid at will.

This conception of the suitable conditions for the success of the contact process seemed at that time exceedingly obvious, and well calculated to explain all the failures which had attended every attempt to utilize the gases of the pyrites-burners by Phillips' process. Winckler's work attracted great attention and for a long time dominated all further experimentation in connection with the contact process. At about this time a similar process for the manufacture of fuming acid was discovered in Messel's works and was protected by patents. Winckler also brought out a more advantageous method of preparing

the contact substance, that of reducing the platinum by the use of formic acid salts. This keen discovery of Winckler's brought at once into existence a new industry, that of the synthetic manufacture of fuming sulfuric acid. A number of works immediately adopted Winckler's process, among them first the *Badische Anilin- und Soda-Fabrik*, while the monopoly of Stark in Bohemia was broken. The whole industry therefore owes Winckler a debt of gratitude for this advance in technology.

Further work in this field was wholly under Winckler's influence. This is true of the patent secured ten years later by Haenisch and Schroeder, who replaced pure oxygen by atmospheric air, retaining, however, the use of pure sulfur dioxide, and compensating for the diluting influence of the nitrogen by carrying on the reaction under pressure, in order, as the patent reads, that the molecules of the gases may be brought closer together. This process also was put into practical application in the *Badische Anilin- und Soda-Fabrik*.

Messel and Lunge proposed a method of obtaining a stoichiometric mixture and at the same time excluding the atmospheric nitrogen by burning the pyrites with pure oxygen. All these processes were unsuited by their very nature to compete with the lead chamber process and were necessarily confined to the manufacture of the fuming acid. Nevertheless attempts at the solution of the larger problem were by no means wanting; little, however, regarding them made its way to the notice of the public. Winckler especially published nothing regarding his new work along this line, so that it only became known last year, through the striking lecture of Lunge and Winckler in Hannover on the development of sulfuric acid manufacture, that at his instance it had been found possible at the Mulden works to convert from two thirds to three fourths of the sulfur dioxide in the pyrites-burner-gases into sulfuric acid.

#### *Purification of the Gases.*

The solution of the problem of the complete conversion of the burner-gases into sulfuric acid remained unsolved, and indeed at that time, as far as was known, theoretically or practically, was unsolvable. Nevertheless, as I attacked the problem at the *Badische* works, it was chiefly theoretical considerations which made the possibility of attaining this great goal seem not absolutely out of the question.

It is well known that in the lead chamber process there is always an excess of six volumes per cent. of oxygen in the gases as they leave the chambers. In working with pyrites-burner gases under similar conditions, there would naturally always be this excess of oxygen, whatever contact-method was employed for making the acid, and it could not be understood why in spite of such an excess of oxygen the reaction should not proceed quantitatively. The question was tested

experimentally with gases which were intentionally much diluted, pure sulfur dioxid with a large excess of air being used, and it could be demonstrated that the reaction did not fully cease, under certain circumstances, until the sulfur dioxid was almost completely converted into sulfuric acid. Strangely enough, even when double the theoretical amount of air was present, it seemed to have no untoward influence upon the reaction, indeed it rather appeared as if the large excess of oxygen exercised a favorable effect upon the quantity of sulfur trioxid obtained from a given quantity of the dioxid. From this it followed that the earlier conceptions, according to which the dilution of the sulfur gas was unfavorable for the contact-process, must be submitted to a critical examination.

From now on the experiments were carried out upon the gases which came directly from the pyrites-burners. For this purpose the gases were brought directly from the pyrites-burners to the laboratory through a long lead pipe. This pipe acted as a long dust catcher, and the gases in their passage through it were thoroughly freed from every mechanical impurity, such as ashes, burner-dust, etc. The gases were further passed through several bottles filled with sulfuric acid, before they reached the contact mass. The experiments were very satisfactory, for quite as favorable results were attained as had been the case with the mixture of pure gases. No diminution in the activity of the contact mass could be observed, although the experiments extended over several days, and the hope seemed well justified that in this simple manner it would be possible to manufacture sulfuric acid directly from the burner-gases without loss of sulfur.

The experiments were now carried out on a larger scale. Here, however, it soon appeared that the activity of the contact-mass rapidly diminished in strength and finally ceased. The results were the same, even after the gases had been not only purified as in the laboratory experiments, by cooling in long tubes and washing repeatedly with sulfuric acid, but in addition had been passed through a dry coke and asbestos filter; they were then as pure as was technically possible. We were, therefore, obliged to consider the experiments on a large scale as a failure.

Although by these unlooked-for results a hard blow was given to the hope of success, nevertheless further experiments were undertaken in the laboratory for the purpose of investigating the cause of the apparently inevitable deterioration of the contact-mass.

The surprising observation was soon made that there are substances which, when present in exceedingly small quantities, are capable of inhibiting the catalytic action of platinum to an extraordinarily great degree. Among these substances are first of all arsenic, mercury and phosphorus, while antimony, bismuth, lead, iron, zinc and the other sub-

stances, which are liable to be present in the burner-gases, are only injurious to the extent to which, when present in large quantities, they cover up and choke the contact mass. The injurious action of arsenic, for example, is so great that when present to the amount of only one or two per cent. of the platinum in the contact-mass, the latter becomes completely inert. Hence by these investigations, it was incontrovertibly proved that there are substances which are capable of exerting a specific action, 'poisonous,' one might almost call it, upon the contact-mass. The question now was as to whether there was present in the burner-gases, in spite of the efforts at purification, such a substance.

There was, in fact, in these gases a trace of white fume of sulfuric acid which could not be removed, and this was found still to contain arsenic derived from the pyrites. But even if the failure of the process on a large scale was owing to a now known cause, the remedy was not apparent. At that time the complete precipitation of this white fume, the so-called 'huttenrauch,' was considered by the most distinguished experts as technically impossible.

Although after such long and careful work, the prospects of future success had become very slight, nevertheless, since the cause of the previous failures was known, fresh energy was applied to the solution of the new problem. This was nothing less than the attempt to free the burner-gases completely from *all* impurities, so that finally there should remain absolutely nothing but the pure gases, that is, sulfur dioxide, oxygen and nitrogen.

With an enormous expenditure of time, care, money and patience, experiment after experiment was undertaken in the effort to reach this goal, and it may well be said without exaggeration that it has been one of the most difficult problems of modern industry which has had to be solved, in order to render possible the present revolution in the manufacture of sulfuric acid. It would carry us too far to go into the particulars of the various experiments. Even since the process has been put into operation on a large scale, it has demanded several years of the most assiduous work, before it has become possible to look upon the purification of the burner-gases as absolutely assured. The great difficulty of the task lay in the fact that it was a continual struggle with an invisible enemy, as one might say, and that every mistake paid the penalty of permanent damage to the plant as regards the amount of production. The final result of these labors was that it was in fact found possible to free the burner-gases from every trace of every impurity, if after appropriate treatment and cooling, they are made to undergo a thorough, systematically continued scrubbing with water or sulfuric acid. This must be continued until both optical and chemical examination of the gas assures us of complete purification from every injurious substance. How this thorough scrubbing is carried out with

the purifying fluids is a matter of indifference in the final result. Thorough scrubbing and wet filtration, each by itself, or both together, bring us at last to the same point. Only a few of the difficulties which appeared in the application of gas purification on a large scale may be mentioned here.

For the success of the process it had proved necessary that the gases should be cooled slowly. It is a curious fact, and one as yet without due explanation, that the sulfuric acid fume from the pyrites-burners is far more difficult to remove when the gases are cooled rapidly than when they are cooled slowly.

For this purpose long iron conductors were used, which were kept cool by the circulation of the air. As far as our knowledge went at that time, these iron conductors could occasion no untoward influence upon the contact-process; for when dry pyrites are used in the burners, the sulfuric acid in the gases has a concentration of at least ninety per cent. Should this act on the iron at all, it would result in the formation of sulfur dioxide, and this could of course do no damage in the process.

But now in spite of the fact that the gases were freed from every mechanical impurity, so that the optical test, which was at that time considered sufficient, betrayed not the slightest sign of any solid or liquid particles (for the sake of absolute certainty the gases were finally passed through a kind of wet cloth filter, somewhat like a filter press), still the contact-mass gradually diminished in activity. This diminution was very slow it is true, being apparent only after weeks or perhaps months, but it was nevertheless certain to occur. It was only after long and difficult labor that the presence of arsenic was again proved to be present in the contact mass, and this, after it was supposed that every trace of the element had been eliminated in the process of purification. The contact-mass, however, showed unmistakably that arsenic was in evidence, and the suspicion arose that the cause of all the trouble might be due to the action of the condensed sulfuric acid upon the iron cooling-conductors. Further investigation showed that this was probably the case, and that by this action some gas which contained arsenic must have been formed. This gas was probably arsine, the hydride of arsenic.

A change in the arrangements was now made so that the condensed sulfuric acid could no longer come into contact with the iron conductors, and from this time on the contact-mass remained undiminished in its activity. It appears from this that, contrary to the generally received ideas, hydrogen can be evolved by the action of concentrated sulfuric acid upon iron, and that when arsenic is present, arsine may be also formed.

With this indeed ended the hardest struggle which met us in the attempt to introduce the new sulfuric acid process into technical industry. It was, however, by no means the last contest. When the process came to be put in operation on a larger scale, new difficulties in purifying the gases appeared, whose cause was almost as problematical and unforeseen as those which have been already described.

When the pyrites-burners were used to their full capacity, fumes were formed which seemed to mock every effort at absorption. Their cause was finally found to be the presence of unconsumed sulfur in small quantities. Like the quickly cooled sulfuric acid fume, this sulfur proved exceedingly difficult to remove. But how could this unburned sulfur be detrimental, when in the contact-apparatus it would burn to sulfur dioxid and sulfur trioxid? The explanation rests in the fact that this sulfur fume again contains traces of arsenic. This also it was unconditionally necessary to remove.

A radical means for this was finally found in thoroughly mixing the gases while still hot, so that the combustion of the last trace of sulfur was ensured. This mixing was accomplished by the injection of steam, which was found to have other and not less important advantages. It especially served to dilute the concentrated sulfuric acid in the gases, so that they were no longer condensed in the preliminary cooling conductors, and hence the evolution of arsin was avoided; when finally condensed in the chief cooling apparatus which was made of lead, they were so much diluted that they ceased to corrode the metal. Furthermore the formation of hard dust-scale in the various conductors was prevented, and danger of these becoming stopped up was avoided.

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In closing this lecture I may be permitted to place before you what a development the sulfuric acid manufacture has enjoyed in our works alone, since the introduction of this contact-process. The annual production of sulfuric acid anhydrid has been:

In 1888.....	18,500 tons.
In 1894.....	39,000 tons.
In 1899.....	89,600 tons.
In 1900.....	116,000 tons.

For the accomplishment of such a work the powers of a single individual were naturally far too limited. It required the powerful assistance of an establishment like the Badische Anilin- und Soda-Fabrik, the keen and far-seeing direction of a Heinrich Brunck, the experience of a Gustav Jacobsen, and the intelligent help of distinguished engineers, to bring to a successful completion such results as those I have endeavored to describe in this lecture, and which stand as an honor to the industrial progress of our fatherland.

## THE PHYSICAL BASIS OF HEREDITY.\*

BY PROFESSOR CARL H. EIGENMANN,

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'HE is a chip of the old block' is the popular expression used in applying the best known general law of heredity that 'like begets like' to a particular case. But in saying so we state but half the truth. The chip is like the block and not like the block. Each individual is unique; no two were ever cast in the same mold.

There are always two phenomena associated in the development of a new individual. One is the repetition in the offspring of characters possessed by his ancestors, either near or remote. The second is the formation of new characters which have never appeared before in any individual. I shall confine myself to the first of these phenomena.

What characters has any individual inherited from his ancestors and what ones are new to him is always a question of the first consideration in a study of heredity. The consideration of which of these he may transmit to his offspring naturally follows.

He has always inherited and always transmits those characters that distinguish his species, race or family from other species, races or families. A backbone, four limbs and hairiness are always inherited and transmitted by a mammal, as backbone, four limbs and feathers are always transmitted by a bird. The erect position, peculiarities of hand and foot and those other features which together make a man are always inherited and always transmitted. The inheritance and transmission of the racial characters of the Jews distinguish them from all the various peoples with which they are found. The same is true of the Chinese, Indians, Negroes and, to a less degree, of the less pure races of Teutons and Anglo-Saxons.

Aside from characters that are *always* inherited and transmitted, there are groups of characters that may have been inherited and that are transmissible, but that are not necessarily *transmitted*. It is the peculiar combination of some of these characters that constitutes family traits. These transmissible, but not necessarily transmitted, characters may be anatomical and range from the height of the individual to such minute details as moles, a few long hairs in the eyebrows or even smaller details.

They may be physiological. Longevity is transmissible; so are a

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\* Photographic illustrations by D. W. Dennis.



tendency to fatness and leanness and, in the males of certain families, a tendency to baldness. The members of some families have a tendency to become corpulent at a certain period, and no reasonable amount of starving seems to affect this tendency. After half the inmates of Andersonville prison had made their escape, one of these hereditarily stout individuals even after weeks of starving became fastened in the tunnel, preventing the escape of the rest of the prisoners. The members of other families remain 'hungry Cassiuses' however well they may be fed.

Mental peculiarities are transmissible. Sometimes one mental trait of the parents is transmitted to one child while others are transmitted to another. Weit Bach, a baker who lived in the middle of the sixteenth century, was a mild form of a musical prodigy. He transmitted his musical talent through at least eight generations, and hundreds of descendants, twenty-nine of whom became famous musicians. The case of the Jukes family is well known. In the course of six generations of descendants from one woman 52% of the female descendants became public women, 23% of the children were illegitimate. There were seven times more paupers among the women than among all women, and nine times as many among the men.

We have, then, characters that are always transmitted and characters that may be transmitted. As a third group we have characters concerning which we have doubt, and, at present, much discussion. This third group of characters includes individual peculiarities which have not been inherited, but are acquired during the lifetime of the individual as the result of his education, his activities and the effect of the climate and other elements of his environment. Whether or not these are transmissible has been the question of the past ten years. The discussion was started by Weismann, who denied, for theoretic reasons, that any of the characters so produced are transmissible. It is agreed that the individual characters that result from accidental or voluntary mutilations are not transmitted. Wooden legs are never transmitted. Wooden heads sometimes are!\* Many instances have been brought forward to prove the transmissibility of acquired characters, but none of these cases has been accepted as conclusive. From my own studies of the effect of disuse on eyes and the absence of light on color, I am convinced that the results of the activities and the characters due to the environment are transmissible. Mehnert goes so far as to maintain that races are progressing in so far as marriage does not take place until comparatively late in life, and children are not born till the molding effects of activities and environment have individualized the parents. Sargent, of the Harvard gymnasium, evidently convinced of the transmissibility of acquired characters, advises the delay of marriage

\* With apologies to Dr. E. G. Conklin.

among Cubans until full maturity, as a means of raising their physical standard. He found that at present the average Cuban man is, in size and weight, the equal of the American female student.

An illustration of environment, including education, overcoming hereditary tendencies has recently been brought to my notice by Mr. A. J. Redmon. Mr. Redmon reared two murderous sparrow-hawks in a cage with young larks and wrens. "They all grew up together; the little wrens would creep under the sparrow-hawks for protection at night. The two hawks never attempted to hurt the larks or wrens." Mr. Redmon tried to starve the hawks into killing birds, but they utterly refused to disgrace their education.

Galton has determined just how much, on an average, each ancestor contributes to the peculiarities of an individual. The parents together contribute one half of the total heritage, the four grandparents together one fourth, the eight great-grandparents one eighth, the sixteen great-great-grandparents one sixteenth and all the remainder of the ancestry one sixteenth.

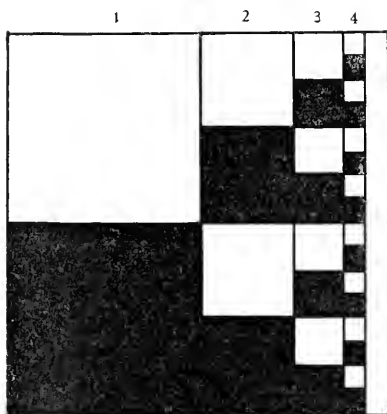


FIG. 1. AVERAGE CONTRIBUTION TO THE PECULIARITIES, OR DEVIATION FROM THE AVERAGE, OF THE INDIVIDUAL, by the first, second, third, fourth and remaining generations: father and mother each contribute one fourth together one half of the total heritage. Each one of the grandparents contributes one sixteenth or together one fourth. The great-grandparents together one eighth, the great-great-grandparents together one sixteenth, and all the remoter ancestry together one sixteenth. *After Meston.*

This law explains another—that the offspring of exceptional parents are, on an average, less exceptional than their parents. Supposing that the average height of two parents exceeds the average height of the race by three inches. The average of the grandparents and remoter ancestors will differ from the average height of the race by much less than this. Since the ancestors beyond the parents contribute one half the entire heritage of the individual, they will act as a drag to pull the individual toward mediocrity, in the present case by one inch. This law acts impartially, so that the offspring of the extremely good and the extremely bad are both saved from the fate of their parents.

This regression toward mediocrity may readily be overcome by selective breeding. In race-horse breeding if the ancestry has been good for three or four generations the rest are not considered.

Galton has devised a forecast machine by which, if the height of the parents is known, the average height to which the offspring will grow

may be determined. "Of the individual we can assert nothing as certain, only state the probable."

It is evident from these laws that, if any fond parents feel that they are in any way remarkable, their apparently remarkable offspring are on an average only two thirds as remarkable as they themselves. Also if there are any fond sons or daughters who rely on really gifted parents for their standing among their fellows, the sooner they begin to look to themselves to make up by individual effort their probable loss by the law of regression the better, for, on an average they are but two thirds as gifted as their parents. I should not mention this fool-killing law if it did not have its bright side. If any individual feels it in him to do and be something, a mediocre parentage need not discourage him, for, on the average, exceptional individuals, as we all think ourselves to be, exceed the average of humanity by one half as much again as their parents exceeded this average. (Fig. 3.)

It is a reassuring fact that, starting from any standpoint above the average, our relatives are on the average not quite equal to us. Moreover, a gifted individual is more likely to be the exceptional offspring of mediocre parents than the average offspring of gifted parents. "Among mankind we trust largely for our exceptional men to extreme variations occurring among the commonplace."\*

\* Galton in his 'Hereditary Genius' found one hundred gifted men to possess on an average the following number of relatives equally gifted:

	Gr.-grandfathers	3	
	Grandfathers.....	17	
Brothers.....	41	Fathers.....	31
Nephews.....	22	Gifted Men.....	100
Grandnephews..	10	Sons.....	48
		Grandsons.....	14
		Great-grandsons..	3
		Cousins.....	13
		Granduncles.....	5
		Uncles.....	18

The isolation of gifted men is graphically illustrated by arranging the facts given in the middle line in a frequency polygon. (Fig. 4.)

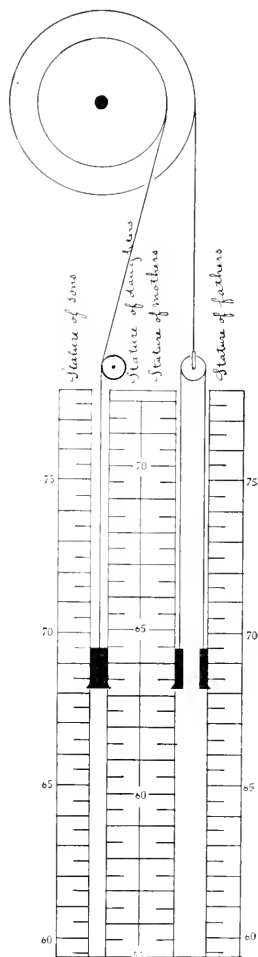


FIG. 2. GALTON'S FORECAST MACHINE FOR STATURE, SET AT MEDIOCRITY OF THE RACE; The average height of men being about 68.25, that of women 63.25. The circumference of the wheels at the top are to each other as two to three. If the average height of the parents is increased or decreased above or below mediocrity by a given quantity the average height of the offspring is increased or decreased by two thirds such amount. To convert the female statures into the corresponding male stature, multiply the female stature by 1.08.

What is the physical basis—the vehicle for the transmission of all the characters large and small, from one generation to the next?

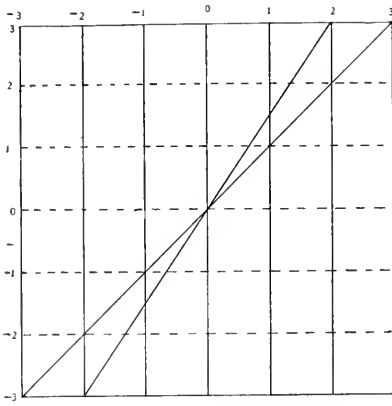


FIG. 3. GALTON'S REGRESSION DIAGRAM. Horizontal lines indicate the deviation of the average of the height of the father and mother above or below the race, 0; the vertical lines indicate the average filial deviation from the average of the race.

If the deviation of the sons from the average of the race equaled the deviation of the parents a line joining the various filial heights would give us the diagonal from 3 to 3. Actually the line joining filial heights is the one from 2 to 2, which is only two thirds as far from 00 as the line 3, 3.

buds develop at certain regions and grow into a new individual. Here any one group out of a large number of groups of cells may build up a new individual. If a hydra be cut in any one of hundreds of possible ways each part will regenerate the portion lost, and so form a new individual. Every group of cells is here adjusted to reproduce the entire individual if the inhibition exercised by the presence of other cells is removed. The method of budding is the commonest means of transmitting the characters in plants. Those individuals produced by buds are usually exactly, or very nearly, like

In many minute animals and plants where the individual consists of a single cell it simply divides into two, so that it is impossible to say which of the two is the parent, which the offspring. Heredity is here simply a process of growth and division. If one of these individuals is cut into halves each half will regenerate the part lost. Normally the whole animal or plant is concerned in heredity. In fact, an individual may be divided in any way and each fragment will regenerate the lost part so long as the fragment contains part of the nucleus.

In many other animals, of which we have a representative in our ponds and streams in *Hydra*,

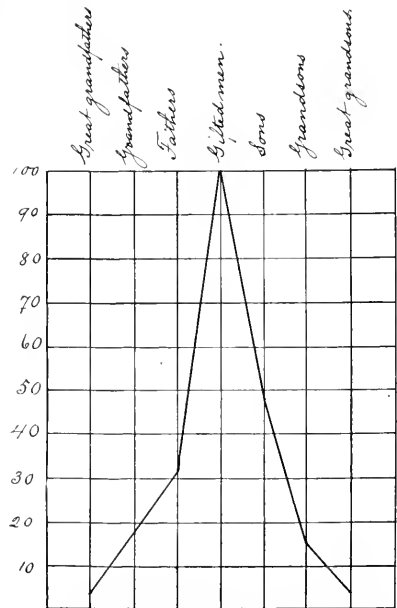


FIG. 4. DIAGRAM SHOWING THE SMALL PERCENT. OF RELATIVES OF GIFTED MEN WHO ARE GIFTED.

the parents, a fact of which advantage is taken to preserve the peculiar characters of our varieties of fruit, all of which are perpetuated by grafting, or by means of runners.

In some worms the power of developing a new individual if part of the old one has been lost has been modified so that the lost parts are reformed before they are really lost. A given limited part of the middle of the body has the habit of forming a new head for the part behind, and a new tail for the part in front. A string of individuals is formed in this way joined tandem. These separate after some time and each new individual repeats the process.

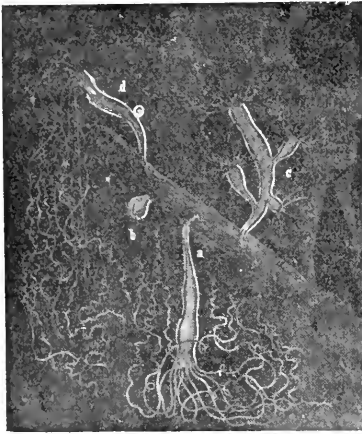


FIG. 5.

FIG. 5. HYDRAS: THE ONE AT *c* WITH BUDS; THE ONE AT *d* WITH SEX-ORGANS. FROM LEUCKART.



FIG. 6

FIG. 6. AN ARM OF A STARFISH REPRODUCING FOUR LOST ARMS.

These methods of forming new individuals are occasional. Each method is restricted to some limited group of species. In practically all animals in which these occasional methods of reproduction occur, they alternate with sexual reproduction. In the great majority of animals sexual reproduction is the only means of transmitting characters to a new generation.

By sexual reproduction we understand the development of a new individual from a single cell which is usually produced by the fusion of two cells.

Just a word as to what we mean by a cell. The word has a penitentiary flavor that may be misleading. A cell is a mass of protoplasm enclosing a differentiated portion or nucleus. The nucleus contains, among other things, during certain phases of cell life a definite number of thread-like bodies called chromosomes. The number of chromosomes differs in different animals, but is always the same in the different cells of the same animal.

In unicellular plants, and in some protozoans, two individuals physically alike, or nearly alike, and moving about in water, unite to form a single individual. In animals more complicated entire individuals no longer merge into one; but this function has become restricted to certain cells, just as the function of moving the animal from place to place has become restricted to certain cells. In the majority of animals living in water these cells are liberated in the water, and here two cells unite, as in lower forms two individuals unite.

The cells uniting are equally important in transmitting hereditary characters, and in their essential structure. As an adaptation to the necessity of the union of two cells and to the necessity that the combined volume of the two cells be sufficient to give the new individual a fair start, the cells, as the result of a division of labor, have become very different in shape and action. One has taken upon itself the function of providing the nutriment necessary to start the new indi-

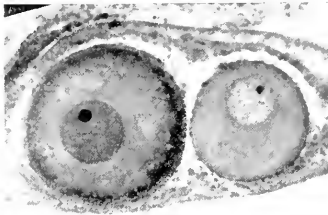


FIG. 7.

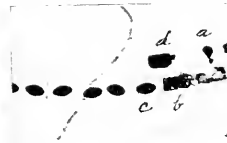


FIG. 8.

FIG. 7. TWO TYPICAL CELLS; OVARIAN EGGS OF CYMATOGASTER.

FIG. 8. PHOTOGRAPH OF THE CONJUGATION OF TWO STRINGS OF SPIROGYRA: at *a* the contents of one individual are passing over into the next; at *b* the contents of two individuals are united within the wall of one; at *c* the two uniting individuals have been metamorphosed into a spore; *d*, a bachelor which missed a mate.

vidual, and has become comparatively large and inactive. The other has taken upon itself the function of providing the mobility necessary to insure the union of the two cells. It has become excessively minute, and very mobile. The differences in the cells concerned in sexual reproduction extend to the ducts through which the cells are emitted, and secondarily to the whole individual, so that in every organ, function and psychical trait male and female are different.

Into the question of the advantages of the production of a new individual by the union of two cells we can not enter in detail. Suffice it to say that on the part of some it is looked upon as the union of two hereditary tendencies, which eliminates extreme badness, or what amounts to the same thing, extreme goodness that may be inherent in one of these tendencies, and at the same time insures new combinations of characters from which nature may select the fit.\* On the

\* Pearson has demonstrated mathematically by comparing parents with offspring that 'whatever be the physiological function of sex in evolution, it is not the production of greater variability.'

part of others it is looked upon as a means of rejuvenescence or union of energies to insure the continuance of life for another span. Loeb has found that an egg that will under all normal conditions develop only after a male cell has entered it, may be caused to develop without the male cell by placing it for a short time in a solution of higher osmotic pressure than that in which it is normally found. It is thus seen that one function of the male cell is either to supply stimulation to the egg to cause it to develop, to regain the lost power of dividing, to rejuvenate it or to act as a catalyzer. But it has long been known that the child may inherit from the father. Indeed, Boveri has shown that the male cell can also develop alone into a new individual if it is supplied with a proper medium of sufficient size.

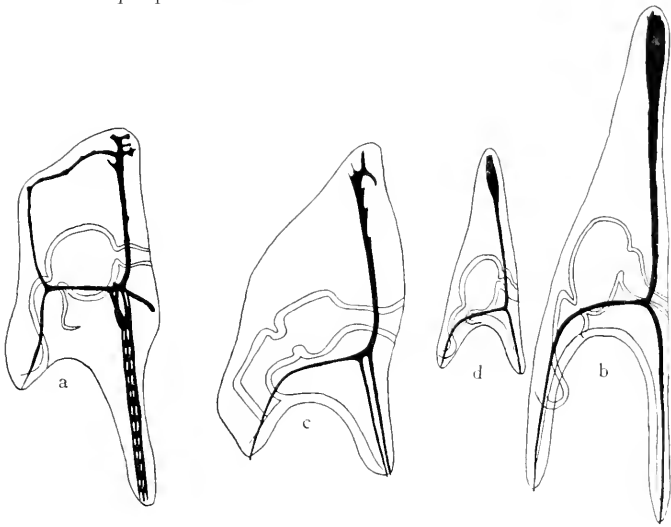


FIG. 9. *a.* LARVA OF SPHERECHINUS GRANULARIS. *b.* Larva of *Echinus microtuberculatus*. *c.* Hybrid of *Sphaerechinus* egg and *Echinus* sperm, showing blended characters. *d.* Fragment of *Sphaerechinus* egg, fertilized with an *Echinus* sperm, showing paternal characters only.

The egg and the sperm are thus seen to equally contain the hereditary tendencies necessary to form a new individual. Since the offspring frequently resembles both parents this result is evidently caused by the mingling of the two hereditary tendencies.

Boveri's experiment brings us naturally to the question as to where in the hereditary cells the power of reproducing all the complicated transmissible parts lies. In spite of the fact that it is inconceivable that the many hereditary qualities of, say an elephant, should be compressed into two cells, one just large enough to be seen with the unaided eye and the other far too small to be seen without the microscope, he has demonstrated that the hereditary plasma is restricted even to certain parts only of these cells.

The eggs of a sea urchin, *Spharechinus*, which normally develop into a well-known larva, were broken by Boveri into two in such a way that the nucleus was all contained in one fragment. Male cells of another species of sea urchin, *Echinus*, having a well-known, but quite different, larva, he then caused to enter the fragment without a nucleus. A larva developed which possessed all the characters of the larva normal to the male used in the experiment. Since cell contents of both species were present and nuclear structures of only one, and the larva resembled the species represented by a nucleus, it was concluded that the hereditary substance is located in the nucleus. The nucleus, then, contains the physical basis of heredity.

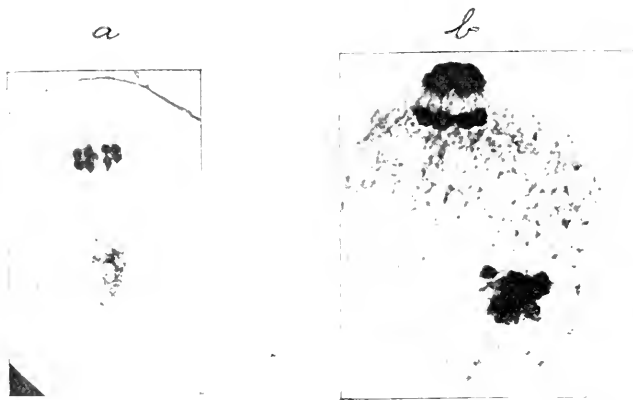


FIG. 10. *a*. THE EARLY STAGE IN THE MATURATION OF THE EGG. The four chromosomes have been reduced to two tetrads. Eventually three out of each group of four granules will be eliminated from the egg. *b*. The elimination of two of the granules of each tetrad in the formation of the first polar body.

Boveri's results were looked upon with much suspicion until they were confirmed by Delage. With a German and a Frenchman agreeing we may safely consider this point as settled.

The intimate process of the preparation of the hereditary cells for their union and the union of the cells have been the subjects of many monographs during the last twenty years.

Since each cell has a definite number of chromosomes and this number would be doubled by the union of two cells elaborate provisions are made by the cells to reduce this number to one half before the union of the two cells takes place. The study of the methods of this reduction has engaged a host of cytologists during the past ten years, and innumerable papers have resulted.

It is evident that the great difference between the two cells is simply an adaptation to insure their union, for, after uniting, their nuclei, the physical basis of heredity, become alike (*c* in figure 11).

Credit for the great activity in research along this line must be



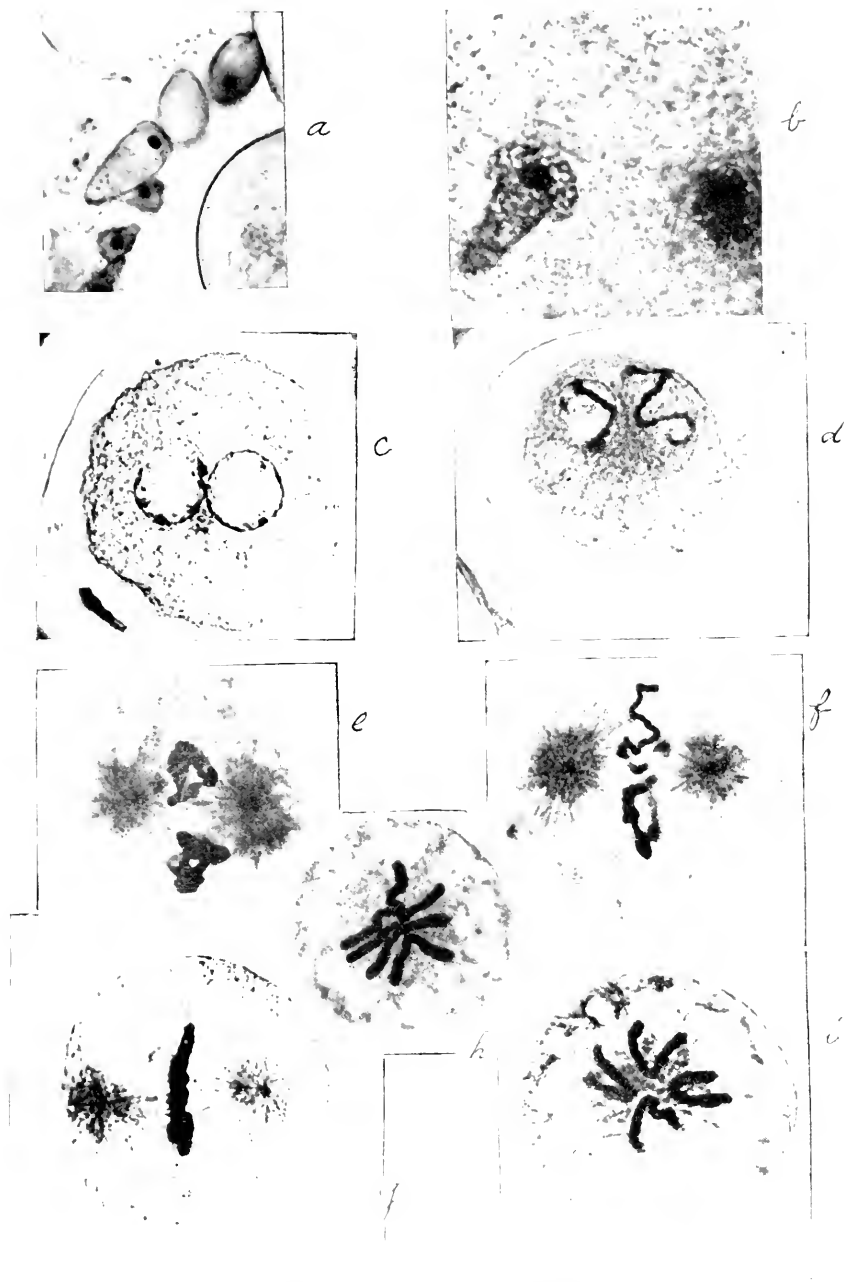


FIG. 11. INTIMATE PROCESSES IN THE UNION OF TWO REPRODUCTIVE CELLS FROM PHOTOGRAPHS OF ASCARIS, all but *b*, with an initial magnification of 1,500 diameters. *a*. A spermatozoon. *b*. A spermatozoon in the egg very highly magnified. *c*. Male and female nuclei after assuming the resting stage. *d*. Male and female nucleus coming out of the resting stage, the chromatic threads assuming definite shape. *e*. The threads from two nuclei being pulled together. *f*. A late stage of the same process. *g*. The completion of the process. *h* and *i*. Two eggs in the stage presented by *g*, but seen from one of the poles of the egg; two of the threads shown in both *h* and *i* are derived from the father and the other two from the mother.

largely given to Weismann. The method of reduction imagined by him accounted for the origin of variation in the offspring, and thus furnished him with an explanation of the advantages, and therefore the existence of sexual reproduction. It was the attempt to verify or reject his theory which called forth so many monographs on this subject.

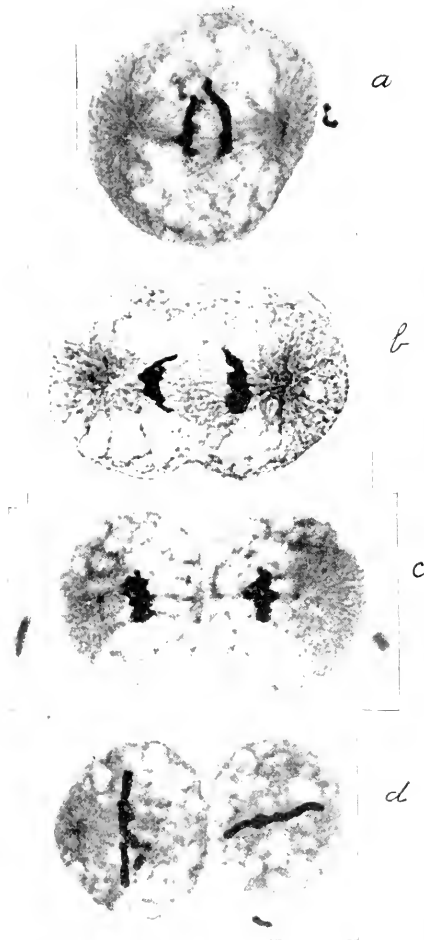


FIG. 12. THE EARLIEST STAGES IN THE DEVELOPMENT OF THE NEW INDIVIDUAL. *a*. The separation of halves of the chromatic threads. *b*. Further separation and beginning of division of the egg. *c*. Complete separation and complete division of the egg. *d*. The two cells with their chromatic threads ready to divide again.

We shall not here go into details of the process of the reduction of the number of chromosomes. The most favorable objects for demonstrating many of the processes of maturation and fertilization are the reproductive cells of *Ascaris*. In *Ascaris* each of the nuclei is finally seen to contain two chromatic threads and the ultimate and intimate process of fertilization is seen from the photographs to be the union of these two groups of two chromosomes into one group of four chromosomes ready to divide. The dynamic agents in their union are two darkly stained bodies from which rays emanate, the centrosomes. In the present case one of these enters the egg with the sperm and this is the usual method of its origin in developing eggs. At the completion of the process of fertilization we have a cell containing a nucleus with the number of chromosomes normal to the species. One half of these chromosomes came from the father, one half from the mother. When this cell divides each one of the chromosomes divides longitudinally, and one

half of each chromosome goes to one of the new cells and the other half to the other cell. The observations of Rückert, Häcker and Moenkhaus

make it probable that this process is continued with every division, so that ultimately each cell of the adult contains chromosomes, one half of which are the lineal descendants of the chromosomes coming from the father, the other half lineal descendants of the chromosomes coming from the mother. Rückert has found that in a late stage of development in a crustacean the chromosomes were in two groups, presumably maternal and paternal. Moenkhaus has found that in crossing two species of fishes with structurally and physiologically different chromosomes these retained their structural and physiological differences for a number of divisions. From the elaborate provisions to insure the union of the chromatic threads it is quite certain that they, finally, are the carriers of the hereditary power.

The character of any cell is controlled by the nucleus it contains, and, since we have seen that the nucleus contains two different groups of chromosomes, one group containing the peculiarities of the father and the other the peculiarities of the mother, the cause of the blending of the two sets of characters in the offspring becomes apparent and the greater resemblance in some characters to one parent and in other characters to the other parent may readily be inferred.

Without attempting to review the recent speculations and observations on the origin of the hereditary cells, I want to give an outline of some observations I made about ten years ago, and which have recently been confirmed by Beard. Very early in the development of one of the California viviparous fishes certain cells apparently lose their interest in the development. They undergo very little change, while the rest of the cells are busily engaged in multiplying and forming themselves into the various organs of the young fish. These cells become shifted somewhat and probably engage in active migrations. Late in the development they again begin to divide and ultimately give

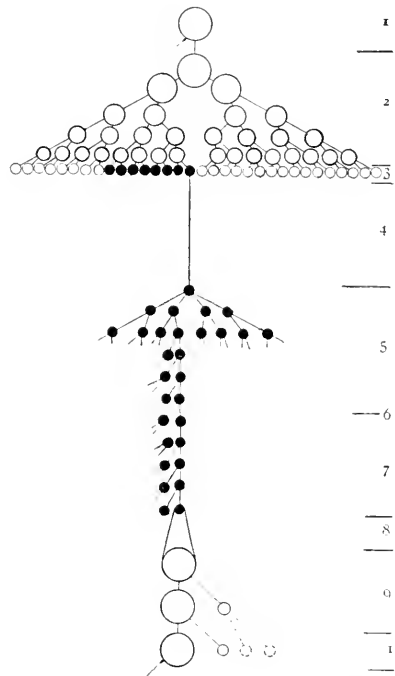


FIG. 13. HISTORY OF THE REPRODUCTIVE CELLS IN CYMATOGASTER, FROM THE BEGINNING OF ONE GENERATION TO THE BEGINNING OF THE NEXT. 1 Fertilization of the egg. 2. Segmentation of the egg. 3. Segregation of the reproductive cells. 4. Period of inactivity. 5. Multiplication of the cells originally segregated. 6. Time of the differentiation of the sexes. 7. Continued multiplication of the cells in the female. 8. Period of growth of the individual cells. 9. Period of maturation.

rise to the reproductive cells of the new individual. Not all reach this fate; a certain number are apparently lost in their migrations, and their late history could not be followed. So much seems certain—that none of the cells which became segregated from the rest so early ever became anything but reproductive cells, and that in no case do other cells ever become reproductive cells. The shortest route observed between reproductive cells in the new individual and the egg from which it developed did not exceed fifteen cell divisions. If the divisions had been continuous at the rate of division frequently seen in fish eggs all of them could have taken place in a day or two. Since the last generation of cells are really part of the new generation of individuals the time between the beginning of development and the completion of provisions for the next might have been but one or two days.

Into the question of the origin of heredity and the hereditary power of the reproductive cells I can not go at this time. Suffice it to say that I consider the hereditary power of the reproductive cells the result of a division of labor, just as the high contractile powers of the muscle cells is the result of a division of labor.\*

It is evident from what has gone before that we can not say that the individual became alive at any given point. Each individual is part and parcel of many individuals who struggled and fought and aspired, who lived, and, above all, succeeded. The fact that he is, is proof positive that, as far as his ancestry is concerned, he deserves to be. He has always been alive since the creation of his remotest ancestor. There has never been a death in the direct line of his ancestry, and he forms a link in a chain that is potentially endless and, in so far he is, through his offspring, physically potentially immortal.

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\* That the reproductive cells never develop into anything but reproductive cells ought not to confuse us, in the face of the fact that nerve cells, for instance, never give rise to any other kind of cells and other cells are never converted into nerve cells. Even in the regeneration of a lost arm only those sorts of cells are regenerated which have representatives at the cut surface.

## CHILDREN'S VOCABULARIES.

BY M. C. AND H. GALE,  
UNIVERSITY OF MINNESOTA.

THE philological legend that the vocabulary of a workingman is only about 300 words\* should show proof why it should not go the way of all legends when it is found that a child of two and a half or even two years uses by actual count from 600 to 800 different words in one day. Has anybody really estimated or counted the words used by a workingman; if so, what method has been used? A physician and father was asked to guess how many different words were used by our three children up to two and a half years of age, either in common or by any one of them. He gave vent to emphatic protests of incredulity when his guess of 'about 200' was met by the actual number of 2,170. And we ourselves have found several times that, after following a child about all day with pad and pencil and taking down all his talk for a waking day till we were almost exhausted, when we then tried to make an estimate of the words used we have only come to within a quarter to a half of the right number. This illusive underestimation of a child's vocabulary is so universal that it can only be corrected by cataloguing, indexing and actually counting the words thus recorded for a whole day. In the following table are given the different words and the total number of words used by two of our children on the day they were each two and a half years old:

	Different words.		Total words.	
	2 (boy).	3 (girl).	2 (boy).	3 (girl).
Nouns	369	307	3367	2168
Verbs	189	165	2200	2048
Adjectives	83	79	729	1327
Adverbs	42	38	1314	1031
Interjections	8	8	113	198
Pronouns	27	15	678	761
Prepositions	21	14	636	405
Articles and Conjunctions	14	3	253	54
Totals	751	629	9290	8992

It is interesting to find from the complete tables† that of the 751

\* See e. g. Max Müller: 'Science of Language,' First Series, 1870. "Now we are told on good authority, by a country clergyman, that some of the laborers in this parish had not 300 words in their vocabulary" (p. 226).

† See the authors' complete vocabularies, tables and discussion in their article 'The vocabularies of three children in one family to two and a half years of age,' 'Psychological Studies,' edited by Harlow Gale.

different words used by 2 (b.), 479 or 64 per cent. were used in the first five hours or half of the day.

Such a record does not by any means include all the words which it would be possible for a child to use in one day, could it come into contact with its entire little world of experience by playing all its plays, looking at all its books, going on all its occasional visits, seeing all its acquaintances, living through all the days of the week and seasons of the year—that would involve almost its entire vocabulary up to that date. These two children had used respectively, up to two and a half years, 1,432 and 1,308 different words, almost all of which constituted their still usable vocabulary. So that on these days they used only about half of the words they might have used. When a child's world of named things is smaller it will naturally use a larger proportion of its vocabulary on any one day. For instance, the eighty different words used by 3 (g.) at the beginning of the twentieth month were 96 per cent. of the vocabulary up to that day, but by the next month this proportion had dropped to 60 per cent. and in subsequent months varied from 54 per cent. to 43 per cent.

These children we believe to be but slightly, if at all, above the average child in the use of language. As an example of what a reputedly talkative child can do, we took the words used on his second birthday by Carl Andrist (whose father was instructor in French in the University of Minnesota); he used 803 different words.

Most of the records of children's vocabularies hitherto published have been gross underestimates, chiefly, we think, from two causes. In the first place, the estimate has almost always been made on the first or only child; for the enthusiasm for child study or psychology usually breaks out with the advent of the wonderful first child and lessens as this novelty wears away and heavier domestic cares with the second child discourage scientific ardor. But the later children have an advantage in learning much from contact with the older child. Thus our first child used only 400 words at two years, and 769 at two and a half years, that is, about half as many as the second or third child. Of three other published records of two children in the same family, two cases show a much slighter increase while one shows a decrease.

The second cause of the underestimation of a child's vocabulary is the use of unreliable methods. Even the almost constant presence of the mother with the child, and her daily noting of the new words it uses from the beginning of speech to the two or two and a half year limit, we found insufficient. For when in the case of the second child we also followed the child about and made a complete record, we found that the former method had failed to note many of the commonest words. We followed the third child through eight complete days, on the first of months 20, 21, 22, 23, 24, 25, 28 and 31; and, on checking

these words off with the daily noted new words, we found we should have missed some 250 words had we used only the method of noting new words. Thus any attempt to write out a child's vocabulary from memory or from spasmodic observations is utterly untrustworthy. So in spite of the extreme cases of children's use of words (from 25 to 1,100 at two years in the published cases), the average of 257 for the dozen children reported in Tracy's 'Psychology of Childhood,' pp. 142-144, seems only from a half to a third of the correct amount. For, even if we allow these to have been all cases of first children, the absence of any description of the method makes it probable that the easier and less complete methods were used. For the average of the first eight summaries of vocabularies at two years in Preyer ('Seele des Kindes,' 4te Aufl. 1895, S., 378) is 419, to which our first child's record corresponds. The child studied by Prof. Humphrey's thorough, though in some ways questionable, dictionary method had a vocabulary of 1,121 words. The child studied by G. Deville's method had a vocabulary of 739 words, which corresponds almost exactly with our younger children's records of 729 and 741. If then an average child at two years uses from 400 to 800 words, can we believe without some real evidence that any adult uses only the fabled 300?

The total number of words used on one day is to many people even more astonishing than the number of different words. For the child's energy represented in the production of 8,992 or 9,290 words is something relatively enormous. Would that this child energy could be expressed in figures! But here again some idea of what a speech 'record' is, can be obtained from the case of the above Carl A., who used on his second birthday—*i. e.*, when six months younger than our children—a total of 10,507 words!

In the number of repetitions of a single word one gets a measure, too, of the energy used: as on finding that our 2 (b.) used his own name 'Sammy' 1,057 times on one day (as subject, object and possessive, in place of the personal pronouns); while 3 (g.) used her favorite 'little' 660 times, 'that' 609 times and the aggressive ego words, 'I,' 'me' and 'my' 970 times.

Sammy,	1057	want,	204	some,	134
Papa,	350	see,	128	no,	292
Mama,	193	going,	124	yes,	104
Dick,	148	don't,	123	now,	151
Hilde,	62	go,	97	there,	134
boy,	45	get,	88	down,	105
bed,	42	put,	86	here,	100
house,	41	will,	79	that,	226
water,	34	did,	66	this,	116
		was,	61	in,	145
		have,	56	to,	147
		take.	55		

These comparative frequencies in the words used are an interesting index of the interests of the child, as well as of its energy. The preceding list gives those used most often by 2 (b.) on his two and a half year day:

Such a list shows the child's interests centered egoistically, and naturally, too, around his primitive struggle for existence. The aggressive want, go, get, put, will, have and take; the offensive don't, 'the everlasting no,' always taking precedence of the submissive yes; the demonstrating that, this, there, here, in and to—all show the natural pleasure-pain life in its immediate expression in ceaseless activity and in its conflict with the environment. The social instincts, however, appear in the more frequent use of his parents and sisters' names than of those of novel objects or objects for play; sympathy and approbation are shown by the use of see and some.

The important rôle played by the great activity of the child has been pointed out by Tracy (*ibid.*, pp. 146-148) in the child's use of a much larger proportion of verbs than the adult. The full record of a child's talk for a day gives a vivid and fascinating picture of this intense activity; the following scenes give fair samples. In her first play for the day with her doll, about three quarters of an hour after waking and before breakfast, 3 (g.) kept up the following stream:

"My little baby, my little baby. Momsie, Momsie, jiggle my little baby. jiggle my little baby. Please put that little pillow in, put that little pillow in—little pillow in. I did put. Just little tiny bit, little tiny bit,—little, little, little. Going take nightgown off. Safety pin, safety pin. Put that on bed. Going put that on, going put little pillow way. Please help me put my little baby's sleeves in. I call that my little baby. Why I—I—I? Try pin. Can't pin. Why write that way? Don't want my pillow,—want that pillow,—want—. Where that little baby sleep on my pillow? (Repeated) Why do just like that way? That bed spread lie on. (Repeated) Little baby,—cover legs. (Sings) Sweet little baby, sweet little baby,—Oh little baby, Oh little baby, Oh little baby, Oh little baby. Put that,—that bed spread little baby lie on,—have bed spread. Go right off. I going put my hands on that. Try make that stick together,—stick together; try make that stick together,—go together all nice. My little baby can't lie. What?—what? I used my—away back on Mamma's bed. Can't tell Hilsie that. My baby got two little shoes, two little stockings on. (Repeated) Can't take off. My poor little baby got go bed, got stay in bed. Got little neck, little neck, cunning little neck,—little neck. Please unpin that safety-pin, Momsie. My little baby not very well,—have stay in bed. No,—my little baby's nightgown,—that Grandma made (latter four times)—other Mama made me,—that Emma made me, that Emma made me. That Mama crochet, Mama crochet other one—other one. Hasie have that one (repeated twice)—that one. My little baby have sleep on,—where my little pillow? Got little chin. Why do that way? Got no nightgown. Play with little safety pin." (She then changed off to another doll.)

Of course the above was interrupted by some talk from other members of the family, but we tried to leave the child to its own activity



and spontaneous talk as much as possible. The following extract shows some of the different interests and activities due to sex. After his dinner at noon 2 (b.) began thus:

"Papa come upstairs and build with Sammy. Fix Sammy big fid(dle). S. will fix big one. S. want only—S. want Mama, one lady and one man. Oh Anna, S. see Bannie (made-up word). No, no, S. going to build little house for children. No wood—build with stone ones. No, S. want these. Put those in closet. S. want new (blocks). P. get some. Little P. get little S. Want some. No, S. will let S. S. going make pretty nice fairy houses. This going be little house down here, so can't get out. This tiny one can't get out,—get out. and get in. And that down there,—that there down beside and that, that side-arch. S. going to build nice, nice fairy house. Mama, when P. was little P. did hump, hump (laughing). Yes. S. thought he was Bannie, Bannie. (Pause playing with stone blocks alone). S. has to finish with these blocks. S. need old block—S. need old block. No, no, no, that little boy,—little boy. He going to go thro here. That S. mat. This does take all block. There P. big fid. S. don't see P. big fid. S. have to play,—have to play. S. have to put P. big fid,—P. Fiedelbogen. Yes. What this? S. want,—Hilde, H. H. (the four months' sister getting into his things). This little boy S. will give H. S. want that whip. S. going to get green Decke. Don't put Dick baby on (repeated). Little boy,—No, No,—S. want that little boy. H. did take little boy. Is'n't something to eat, H. No, No, but S. want,—H., H., H., want. Take H. H. don't want. This for H. S. can suck. Oh, there baby,—is'n't down on floor. Take H.,—take H. Don't take,—here boy, here boy. Oh, some (nonsense syllables). Yes. Mama now S. Oh, here was hat. S. found hat,—S. found boy hat. Shan't we, P.? No, S. won't come up till P. come up. S. got block lean over. P. now come up. M., don't get on S. block. S. got blocks lean over. P. build with S. P. build fountain-house. S. have to build. P. long one, P. Now P. build with S. P., now S. P. know those go down there,—belong. No, S. will put arch up there. P. build with those. Put other arch up there. P. build with S. Now take this block and build down there,—now put across there. H.,—why, why, H! Take that H. P. now take this. P. now, —Oh, build P. No, No, No, that arch down here. No, No,—Oh, S. will give H. rubber doll. There H. Now P. sit down,—H. got rubber doll."

It is astonishing how this activity keeps up to the end of the day and how the child struggles against fatigue and sleepiness. After having looked at his Brownie book in bed awhile S. was laid down by his mother to be sung to sleep as usual and the gas was turned down. Whereat he said:

"S. can't see—S. can't see. P. now give S. some more paper to write on, two more and that will be all. Sammylein, Hildelein, Mamalein, Dicklein, and that will be all. S. can't see. (Repeated five times and seven Nos.) Yes, S. want drink. Now P. drink some,—now S. want 'nother drink. Now don't write M. S. is'n't getting tired, This Water Baby. Why? Go way up to that corner. S. don't want to. S. is'n't sleepy. S. got jelly glass at S. house. M., don't turn down gas, don't, don't don't. Where P. go? No, No. (Finally weakening he says) S. want go S. bed. S. want green Decke. S. want S. pictures. M. sing some Schub(ert). Was this right way? No, this was wrong way. M., this right way? (Adjusting his beloved green Decke) This

right,—Yes. M., S. want those two pieces paper,—give S. some paper. S. have to roll up. M. cover S. Where P.? Where P.? M., where P.? M. sing loud. M. lie down on P. bed,”

when the Männlein suddenly fell off to sleep.

How considerably the range of a child's interests can vary even in substantially the same environment can be seen by a comparison of the entire vocabularies of our three children. For out of the 2,170 different words used by some one of the three up to two and a half years of age, less than a quarter, 489, were used by all; while 2 (b.) used 480 and 3 (g.) used 586 words that were not used by either of the other children. The varying interests in these cases are partly due to the difference in sex. But in the case of Professor Holden's two girls, whom he expressly says were exposed to surroundings as similar as was possible, we find at two years of age 246 words in common, while the older had used 241 and the younger 154 exclusively.\* These wide individual differences in the stock of words children use seem to us on examining the complete vocabularies in chronological order to be much better accounted for by the varying pleasure-pains or interests of the children than by the oft-quoted law of the ease of utterance.†

For though the stock in common is on the whole the easier and the individual variations are toward the harder, yet the short words with their easier initial or imitative sounds seem to be used because of their necessity or interest to the child's life, as, *e. g.*, the early words baby, cow, Papa, Mama, book, horse, dog, bottle, water, doll, pin, mittens; burn, see, take, want, eat, wash; pretty, hot, dirty, warm, broken, clean, sticky, another, there, off, away, quickly; good-bye, hurrah, peek-a-boo, etc., etc. The growth of language in the race has brought it about that the words most necessary to the child's life are the shorter and easier sounds. Thus the child uses them first because of their interest and serviceableness, and not because of their ease. So glancing down the chronological columns of our children's vocabularies,

\* Holden: 'On the Vocabularies of Children under Two Years of Age,' *Trans. Amer. Philological Assn.*, Vol. 8, 1877, pp. 58-68.

† See Schultze, 'Die Sprache des Kindes' (1880), S. 27, for the use of this principle in the sounds used by the child for words. But Holden had already applied this principle to the words which the child successively used and thus made up his vocabulary. "I am inclined to take it as a result of my inquiry that the ease of pronunciation, far more than the complexity of the idea, determines the adoption of the word" (*ibid.* p. 60). But of this principle Humphrey said: "Although it had some influence before the child was one year old, when she was two, it had ceased to have any effect whatever. She had, by that time, adopted certain substitutes for letters which she could not pronounce, and words containing these letters she employed as freely as if the substitutes had been the correct sounds" (*ibid.*, p. 7). For Preyer's arguments against the principle in both its applications to the sounds and to the real words see his pp. 367, 373 and 374.

one can see how the compound words came into use later on together with the finer specialization, shown also in the more exact adverbs, prepositions, conjunctions, etc.

Thus, too, many equally easy words come to be used much later when they become useful or interesting, as *mat*, *muff*, *people*, *joke*, *note*, *lace*, *veil*, *care*, *screw*, *bone*, *gas*, *glue*, *guess*, *give*, *fill*, *feed*, *tell*, *buy*, *shine*, *scrub*, *sure*, *like* and *soft*. On the other hand, long hard words are used when the child's interests need them, used, however, in the modified shape of the nearest imitative sound the child can make or of some original substitute word. Thus they associated some sound which served as a word for *nigger-book*, *handkerchief*, *petticoat*, *toboggan*, *umbrella*, *Brille*, *hammock*, *Brightwood*, *university*, *perfumery*, *Bauchknopf*, *apple-sauce*, *rocking-chair*, *dein ist mein Herz*, *chimney-sweep*, *Pantoffeln*, *peppermint-candy*, *waste-paper basket*, *Miss Haversham*, *David Copperfield*, *Thomas Orchestra*, *Beethoven*, *Brahms*, *button-hole scissors*, *magnifying glass*, *Kohlpechrabenschwarzermohr* (in which 2 (b.) only left out the two syllables *en* and *er*); *telephone*, *vaccinate*, *be reposed*, *collapse*, *Headerei* (to be carried on one's shoulders, originated themselves from *Washerei*), *kitzeln*, *remembér*, *disturb*; *comfortable*, *precious*, *old-fashioned*; *day after to-morrow*, *guten Morgen*, *guten Abend*, *auf Wiedersehen*.

We believe then that the acquisition of words by a child is mainly accounted for by the psychological laws of pleasure-pain, viz.: (1) the biological law that whatever is favorable or more immediately beneficial to our organism is pleasurable and that the harmful is painful; (2) between these extreme limits things are further differentiated as pleasurable or painful by being associated with things already differentiated by the biological law, and this principle of association comes indirectly under (1); (3) by the habit or custom principle whereby we come to have pleasure in anything long-continued about us—supposing it is not so immediately harmful as to kill us in the process of adaptation.

Words then are simply the tools whereby the child gets more pleasures and avoids more pains. And the number of these words is normally limited only by the pleasure-pains which are of sufficient intensity to make the motor connections for speaking the words. We have many observations showing how this association of the sound with the thing was made without any apparent attention to the sound; so that when the child's pleasure-pain interest in the thing was enough for it to want to use the word, out it popped without any previous trial or practice. If the child merely lives in an environment where the words are heard or—later on—seen in books, the words get themselves ready for use when needed.

## MESCAL: A STUDY OF A DIVINE PLANT.

BY HAVELOCK ELLIS.

## I.

MESCAL (*Anhalonium Lewinii*) belongs to the group of plants which in various parts of the world have been intimately connected with religion and have received the honors due to divine beings. This group may indeed be said to be large, but mescal—on account of the special appeal to the supernatural which its peculiar properties make—belongs to the innermost circle of such plants. It is or has been venerated by the Indians of many tribes over a very large region in Northern, Central and Eastern Mexico, in New Mexico, in Texas and in Indian Territory, each tribe having its own name for the plant—mescal, hikori, peyote, kamaba, etc.\* Botanically it is a cactus, belonging to the special and little known group of the Melocactæ; there are in the group some six or seven *Anhalonia*; they all grow in inaccessible spots on high and rocky peaks, and have only in recent years become known to science. The plant most nearly allied to the *Anhalonium Lewinii* is the *A. Williamsii*, from which is obtained the alkaloid pelletin, lately found of therapeutic value as a hypnotic. Mescal buttons (as from their shape the dried tops of *A. Lewinii* are locally known) are somewhat brittle discs some two or three centimeters in diameter and partially covered by a hairy cushion. Lewin and Henning in 1885 first described this cactus and made experiments on animals with it, from which Lewin concluded that it is 'intensely poisonous,' resembling strychnine in its action, and by its lethal action standing apart from all other *Cactæa*. This opinion probably rendered investigators of mescal cautious, and little further progress was made in our knowledge until 1894, when Mr. John Mooney, agent among the Indians, who had read a paper on this subject before the Washington Anthropological Society three years earlier, brought to the United States Bureau of Ethnology a large supply of mescal buttons which were entrusted to Professor Prentiss and Dr. Morgan, of Columbian University for physiological investigation.

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\* I retain the name mescal by which the plant first became known. It has, however, the disadvantage of being identical with the name of an intoxicating drink, prepared from one or more species of *Agave*, with which it has no connection whatever.

## II.

At this point it may be interesting to consider briefly the sacred rites with which the Indians have surrounded the mescal plant. These rites have been vaguely known for a very long time and were referred to by early travelers, like Hernandez and Sahagun. Father Ortega, on account of its hallucinatory properties, named it *Raiz diabolica*, devil's root.

The first reliable account of its use in modern times was given by Mr. Mooney from his experience of the Kiowa Indians on the Kiowa Reservation in Indian Territory. The religious ceremonies of these Indians usually take place on Saturday night; the men, having obtained a supply of the drug which is brought by traders from Mexico, seat themselves in a circle round a large camp fire within the tent. After prayer, the leader hands each man four buttons. One of these, freed from the tuft of hairs, is put into the mouth, thoroughly softened, ejected into the palm of the hand, rolled into a bolus and swallowed. Ten or twelve buttons are thus taken at intervals between sundown and 3 A.M., with the accompaniment of occasional prayers and rites. Throughout the ceremony the camp-fire is kept burning brightly and attendants maintain a continual beating of drums. The Indians sit quietly throughout, from sundown to noon of the next day, and as the effect wears off they get up and go about their work, without experiencing depression or unpleasant after-effects. On the day following they abstain, from ritual reasons, from using salt with their food. These and similar rites have become the chief religion of the tribes of the southern plain, to such an extent that the Christian missionaries, unable to grapple with the mescal cult by spiritual weapons, fell back on the secular arm and induced the government authorities at Washington to prohibit mescal under severe penalties. Nevertheless its use still persists.

Although the propaganda of the mescal cult among the Indians of the United States has thus been highly successful, it is fairly clear that much of its primitive religious significance has here been lost. We may understand how this is when we know that the Kiowa Indians are immigrants from the south; they come from the Rio Grande, and it is from the Rio Grande that they still obtain their mescal. Mexico is the chief home alike of the mescal plant and of the mescal rites in their primitive purity. It is to Mexico that we have to turn to realize their primitive significance.

As used by the Indians of the Nayarit Sierra in the province of Xalisco, mescal (or peyote, as it is here commonly called) has been described by Diguët.\* Mescal is regarded by these Indians as a food of

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\* Léon Diguët, *Nouvelles archives des missions scientifiques*, Vol. IX., 1899, pp. 621-625.

even higher order than maize, for while maize is merely the food of the body, mescal is the food of the soul. It is indeed the supreme food, and on that account is offered to the gods. Like maize, mescal has tutelary deities and a special goddess. Its psychic manifestations are considered a supernatural grace bringing man into relation with the gods; while in moderation it enables men to face the greatest fatigues and to bear hunger and thirst for five days, that is during the fast prescribed by the laws of Majakuagy. It is said that when Majakuagy was engaged in preaching his doctrines he and his disciples had to flee from persecution. In the course of his flight he broke his food vessels near San Luis Potosi, and the gods in mercy changed the fragments into mescal. The Indians only gather it in October, just before the dry season; it is said that it is only at this time that it contains its active properties. The third maize feast, which takes place at the beginning of October, is regarded as a prelude to the mescal festival and dances. An expedition is organized to the spot near San Luis Potosi, where the prophet's utensils were transformed into mescal, to gather the sacred plant. This expedition takes a month; those who lead it march in front, reciting or chanting prayers; the others follow with the pack-animals to carry the harvest. A few days before reaching the holy spot the members of the expedition practise a rigorous fast. They also perform a sort of public penance with expiation. As they return, there is great rejoicing in all the villages through which they pass, and mescal is offered on the altars and fragments given to every person met. Sufficient is reserved for the great festivals, and the rest is sold to those who took no part in the expedition.

The Huichol Indians, who occupy part of the territory covered by Digue't's investigations, have been carefully investigated as regards their religious symbolism by Dr. Lumbholtz, who touches on the mescal (or, as it is here called, hikuli) cult.\* He states that the expedition to obtain the plant goes to a place near the mining town of Real Catorce in October, but that the great festival only takes place in January. Abstinence from sexual intercourse is part of the cult, and it is noted that the use of the plant temporarily removes all sexual desire. The balance of the body is said to be maintained better than usual, and under its influence men walk fearlessly on the edge of precipices, and endure hunger, thirst and fatigue to an incredible extent. Lumbholtz states that the festival is connected with the god of fire. We may account for this by the luminous nature of the visions caused by mescal and by the influence of a blazing fire in stimulating those visions.

The same author, in the course of an account of 'Tarahumari Dances and Plant-Worship' † has described the cult of mescal among

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\* Carl Lumbholtz, *Memoirs of the American Museum of Natural History*, Vol. III., Anthropology, II., 1900.

† *Scribner's Magazine*, Oct., 1894.

an allied Indian tribe who call it hikori and worship it as a god. This account furnishes a few supplementary details to Diguët's narrative of the expedition. We are told that as the Indians approach the plants they display every sign of veneration, uncovering their heads. Before gathering them they cense themselves with copal incense. They dig out the cactus with great care, so as not to hurt it, and women and boys are not allowed to approach the god. The plants are kept in jars in caves, and offerings of food and drink made to them. Even Chiutian Indians regard hikori as coequal with their own divinity and make the sign of the cross in its presence. At all important festivals hikori is made into a drink and consumed by the medicine men, and certain selected Indians partake of it, singing invocations to hikori to grant a 'beautiful intoxication.' A rasping noise is made with sticks, while men and women dance, the sexes separately, a picturesque and fantastic dance, the women in white petticoats and tunics, before those who are under the influence of the god.

### III.

We have now to consider what are those special virtues which have caused this insignificant little cactus, hidden away among almost inaccessible rocks, to be surrounded by so splendid a halo of veneration.

The first really scientific attempt to ascertain the nature of the peculiar effects of this drug on the human organism was made by Professor Prentiss and Dr. Morgan in their investigation, already mentioned,\* of the mescal buttons obtained by Mr. Mooney among the Kiowa Indians. These observers administered the drug, in what I should consider extremely large doses (in one case as many as seven buttons), to several subjects whose symptoms were noted and their color visions briefly described. These investigators made no observations on themselves. In the following year, however, Dr. Weir Mitchell, attracted by their account of the effect of the drug, obtained some of the extract from them and made an experiment on himself, taking a large dose. Dr. Weir Mitchell describes himself as a good subject for visions, and his vivid and elaborate account of his experiences, as read before the American Neurological Society,† furnished the first really full and instructive description of the artificial paradise of mescal. In the early part of the next year, having been greatly interested by Dr. Weir Mitchell's experience, and thinking that this drug might help to throw light on various matters which I was trying to account for, I succeeded in obtaining a supply of mescal buttons in England and experimented on myself. As these observations, the first made outside America on the psychic effects of mescal, covered the same ground as Dr. Weir Mitchell's, while at the same time revealing new classes of

\* *Therapeutic Gazette*, September 16, 1895.

† Reprinted in the *British Medical Journal*, December 5, 1896.

phenomena which had not been noted by previous observers, it may be worth while to record them in full, as fairly typical of those vision-producing properties which procured for this plant its divine honors.\*

The experiment took place on Good Friday, 1897, when I was entirely alone in quiet chambers in the Temple, the most peaceful spot in central London. I made a double infusion or decoction of three mescal buttons (a single infusion is inert) and drank this, in three doses, at intervals of an hour, beginning at 2:30 P.M., two hours after a light lunch. I had not touched alcohol or smoked during the day. The following notes are reproduced, with trifling omissions, exactly as written, during the course of the experiment.

“The most noteworthy, almost immediate, result of the first dose was that a headache which for some hours had shown a tendency to aggravation was somewhat relieved. At 3 began to feel drowsy. At 3:30 took another third of the infusion. My headache was speedily still further lightened, and I now felt a certain consciousness of energy and intellectual power. No color or other visual phenomena appeared, however, even when eyes were closed for several minutes. No obvious increase of knee-jerk, though I seemed to be conscious of a certain heightening of muscular irritability as when one has been without sleep for an unusual time. Some gastric discomfort now made itself felt, but was relieved (at 4 o'clock) by eating a few biscuits. At this time, for the first time, there was a distinct lowering of pulse by some 6 or 8 beats. At 4:30 took the remaining portion of the infusion. At this period, except for a very slight frontal headache and a faint sensation of nausea, no abnormal phenomena had yet appeared, and I was feeling on the whole better than before I began the experiment. At 5 I felt slightly faint, so that it was difficult to concentrate my attention while reading and I lay down on a couch; the pulse was still lower (48) but no visual phenomena could be detected. At 5:45 while lying down reading I noticed (what Weir Mitchell noticed) that a pale violet shadow floated over the page around the point on which my eyes were fixed. Some little time earlier I had noticed that objects not in the direct line of vision, such as my hand holding the book, frequently tended to become obtrusive, and as it were heightened in color, monstrous and enlarged. At 6 the prevailing feeling was one of slight faintness with some muscular unsteadiness; there was no marked discomfort (except slight nausea); the headache had almost gone. No

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\* I published a somewhat briefer account of this experiment in 'Mescal: a New Artificial Paradise,' *Contemporary Review*, January, 1898. This paper also contains the interesting results of an experiment on an artist friend; further remarks were published in 'A Note on Mescal Intoxication,' *Lancet*, June 5, 1897. These papers attracted the attention of Dr. Walter Dixon, who made many experiments on himself and has published the results in an interesting article in the *Journal of Physiology*, September, 1899.



further visual phenomena except that it seemed that on closing the eyes after-images were marked and persistent. It may also be said that for some time previously, although no color visions came, the play of light and shade always seen with closed eyes seemed more marked than usual, and *suggested* pictures which were not really seen.

"6:15. I should take more buttons in solid form, but refrain from doing so in consequence of the faintness which makes me disinclined to do more than make these notes. Also the thought of taking more of the drug and the sight of the glass produces a feeling of nausea. The blue-black color of the ink as I write seems unusually brilliant and the shadows on my left on the verge of the visual field seem unusually violet.

"6:40. Pulse now, lying down, is about 60. When lying with eyes closed I am more conscious than before of visions on the curtain of the eyelid; but they are vague and confused, the whole of the field seeming crowded with them, and even when definite images are seen they are not recognizable, but are of the same character as the images produced by the kaleidoscope—symmetrical groupings of spiked objects. Violet shadows are still conspicuous, and now also I see what some little time earlier I seemed faintly to see—occasional distinct green shadows on the outskirts of the visual field, while a green-toned newspaper lying on the floor, whenever I glanced at it, always seems unusually green.

"7:00. It is now dark, and chancing to glance out at the window for a moment and then close my eyes I was surprised at the astonishingly bright vision of light left in my eyes, a positive after-image. All objects seen not in the direct line of vision have a tendency to look startlingly large and prominent.

"Before 7:30, when lying with closed eyes, the visions had become much distincter, but still quite indescribable, mostly a vast field of golden jewels studded with red and green stones and ever changing and full of delight. And moreover all the air round me seemed at one moment to be flushed with vague perfume—producing with the visions a delicious effect. All feelings of discomfort have now quite vanished, except only a slight feeling of faintness showing itself by tremors in hands, etc.

"8.00. The chief character of the visions is their indescribability; sometimes, however, they are like clusters of jewels—some bright and sparkling, others with a dull rich brilliance. Again they resemble a vast collection of the glistening, iridescent, fibrous wings of gorgeous insects. But the main impression is that they are constantly approaching and constantly eluding the semblance of known things. The human face is the only known form that is sometimes momentarily caught, or perhaps merely suggested.

"8:30. [*Written with pencil.*] Pulse now much higher (72 in

sitting position). Muscular incoordination is so considerable that it is very difficult to use a pen, but still easy to write with a pencil.

"I find that it is easily possible to see the visions when lying down in a dark room with open eyes. (Weir Mitchell could not do this.) Sometimes the vision seems to be of a vast hollow vessel into the polished interior of which one gazes while the hue rapidly changes on its mother-of-pearl surface. The objects seen are very often extremely definite; the remarkable point is that they are always novel. There has been all along apparent hyperæsthesia to all sensory impressions.

"9:10. I had to break off as I cannot write for long at a time. The visions continue as brilliantly as ever: I think I see them better in a room lighted by fire than in a dark room. I have seen thick glorious fields of jewels which spring into forms like flowers beneath my view and then seem to turn into gorgeous butterfly-like forms. When I speak my voice seems strange to me and certainly sounds hoarse.

"As I write (by electric light) vague thin color washes seem to lie on the paper, especially a golden yellow, and even the pencil seems to make somewhat golden-tinged marks. My hands seen in indirect vision seem strange, bronzed, scaled, flushed with red. Except for slight nausea I am feeling well, my head perfectly well, though when watching the visions I once noticed slight right frontal pain. The chief inconvenience is decidedly the motor incoordination. It involves inability to fix attention long; but otherwise intellect is perfectly clear.

"9:40. [*Written with pen.*] I am now going to bed. Visions continue; I feel well, except for slight nausea when I move and the motor weakness. [*What follows was written on the next morning.*] Before going to bed I drank some hot water with a little wine in it, but took nothing to eat. On undressing I was struck by the red, scaly, bronzed or pigmented appearance of my feet, hands and limbs when I was not directly looking at them. After going to bed the nausea entirely disappeared, not to reappear, and except for thoracic oppression and occasional sighing there was no discomfort. But there was not the slightest drowsiness. I think, however, that the visions might easily have blended into dream visions but that I was kept awake by a certain consciousness of faintness and by auditory hyperæsthesia. I was keenly receptive—as I had been all along—to sounds, and whenever I seemed about to fall asleep I was startled either by the exaggerated reverberation in my head of some distant street sound or else by the mental image (not hallucination) of a loud sound. At a later stage there was some ringing in the ear. There were also some slight twitchings of the larger muscles of the limbs. Before going to bed I had ascertained that there was marked exaggeration of the knee-jerk, and the pupils were dilated. I felt hot; the skin was dry, the kidneys active.

"Meanwhile the visions continued with but little diminution of

brilliancy, and the same perpetual novelty. Some new kind of effect was perpetually appearing in the field of vision; sometimes there was swift movement, sometimes dull somber richness of color, sometimes glitter and sparkle, once a startling rush of flashes that seemed to approach me. Usually there was a combination of rich dark color with jewel-like spots of brilliant color. Every conceivable color and tint seemed to appear at one time or another (Weir Mitchell never saw blue). Sometimes the different varieties of one color, as of red, would spring up in turn—scarlet, crimson, pink, etc. But, in spite of the immense profusion of objects, there was always a certain parsimony and esthetic value in the colors presented. They were always associated with form, and seldom appeared in large masses of color; if they did the color was of very delicate tone. I was struck not only by the brilliancy, delicacy and variety of the colors, but by the great variety and loveliness of texture which they presented—fibrous, waxen, polished, dull, glowing, veined, semi-transparent, etc. The glowing (jewel-like) and the fibrous (insect-wing) textures were perhaps the most prevalent. Although the effects were novel, they often vaguely recalled known objects—exquisite porcelain, elaborate sweetmeats, Maori architecture, Moorish windows. But in all these cases the objects grew and changed beneath my gaze without any reference to the characteristics of those real things of which they vaguely reminded me. I tried to influence their course but with very little success. It seemed that colors could to some extent be called forth but I could not evoke the simplest image by an act of will.

“On the whole, if I had to describe the visions in one word, I should say that they were living arabesques. There was generally a certain incomplete tendency to symmetry, the effect being somewhat as if the underlying mechanism consisted of a large number of polished facets acting as mirrors. It constantly happened that the same image was repeated over a large part of the field, though this holds good mainly of the forms, for in the colors there would still remain all sorts of delicious varieties. Thus at a moment when uniformly jewelled flowers seemed to be springing up and extending all over the field of vision, the flowers still showed every variety of delicate tone and tint.

“Unlike Weir Mitchell, who could not see the visions with open eyes even in the darkest room, I could see them in the dark with almost equal facility when my eyes were open, though they were not of equal brilliancy. After observing them in the dark for some hours, I became a little tired of them and turned on the gas. I then found that I was able to study a new aspect of these visual phenomena. The gas jet (a common flickering burner) seemed to burn with great brilliancy, sending out waves of light which expanded and contracted enormously. I was even more impressed by the shadows which were in

all directions heightened by flushes of red, green and especially violet. The whole place became vivid and beautiful and the tone and texture of the whitewashed but not very white ceiling was immensely improved. The difference between the room as I saw it then and the appearance it usually presents was the difference one may often observe between the picture of a room and the actual room. The shadows I saw were the shadows that the artist put in, and that are not visible in the actual object under ordinary conditions of casual inspection. At the same time shadows chased each other across the walls, never becoming actual visions.

“I wished to ascertain how the subdued and steady electric light could influence the phenomena, and passed into the next room. Here the rich shadows which were evidently largely due to the stimulus of the flickering light were not obtrusive. But I observed that whatever I gazed at seem to show a tendency to wave or pulsate. If I looked at the matting on the floor it showed a singular richness of texture, thick and felted, with a tendency to rise in little waves. These effects were apparently due to the play of heightened shadows on the outskirts of the visual field. In the same way a closed door seemed to be ajar, from the heightening of the shadows in the interspaces.

“I returned to bed still experiencing the same phenomena though in a less degree, and now for the first time there was a tendency for human figures to appear, fantastic and Chinese in character. There were vague hallucinations of smell, sometimes distinct recurrence of the freshly prepared mescal infusion; these olfactory impressions were pleasurable, I think because they involved deep inspirations, and thus relieved the respiratory oppression.

“At 3:30 A.M. I felt that the phenomena were diminishing and was able to settle down to sleep. When I awoke two hours later, after a peaceful and dreamless sleep, there was a slight headache and the visions were still present with closed eyes, though they were now in somber colors, brown and black. I slept again for an hour or so and rose at the usual time feeling by no means tired, and with an excellent appetite; except for a slight headache which passed off in the course of the morning, I felt none the worse but rather the better for my experiment. The only after-effect was a slightly hyperæsthetic vision for colored objects (as at the beginning of the experiment), lasting for a day or so, and more especially noticeable as regards blue, so that a familiar notice-board in the Strand with dark-blue background was much more conspicuous and intensely blue than usual.”

#### IV.

The experiment just described may be regarded as fairly typical of the effects of mescal in an ordinarily healthy subject, so far as my

observations extend. There are, however, very wide individual variations in the effects of the drug, as have been made clear by subsequent experiments which I have made on other persons. It may, therefore, be of interest to present another experiment for the sake of comparison. In this case the subject was not under my own immediate observation; I should not myself, indeed, have given him mescol at all, knowing that in such a case the experience would certainly not be altogether pleasant. The subject was an art-student, 26 years of age and 6 feet in height, a Highlander on the father's side, and a Lowlander on the mother's, presenting the type of the red-haired, beak-nosed Highlander. Though never ill, he is never in good condition, muscles flabby, skin clammy, pulse liable to be weak and intermittent, without reserve of mental or physical energy. He had severe rheumatism ten years previously. He is lazy and drinks and smokes to excess. He gives the impression of a man of splendid physical race, who has somehow not reached the perfection of his type. Altogether, so far as mescol is concerned, I should regard him as an unlikely subject for what the Indian would call a 'beautiful intoxication.' But the experiment which I give in the words of the very good observer who conducted it is not on that account the less interesting.

"The first dose was administered, after a fair meal, at 4:30 P.M. No nausea was at any time experienced. Pulse 96.

"5:00 P.M. The pulse was 86.

"5:30 P.M. The pulse was 62, flaccid and compressible, with a perceptible second beat, and rather intermittent. The subject had been lying in the veranda of the bungalow since 4:30 P.M. The second dose was now given.

"5:45 P.M. The pulse was 60, and remained at 60, except during exertion, for the next twenty hours. The pulsations were now occurring in a strongly staccato fashion. There was no perceptible second beat, and the pulse was not so compressible.

"6:00 P.M. The pulse was no longer staccato, but distinctly intermittent. It was, however, stronger, and but little affected by holding the wrist above the head.

"6:30 P.M. The third dose was given at 6:30, and the subject came indoors, and was wrapped up in a chair facing the open door, and looking out to sea. A deep sudden breath now caused a marked acceleration in the heart's action, and rising from a lying to a sitting posture sent up the pulse from 60 to 80, for a space of ten seconds or so.

"6:45 P.M. A feeling, neither pleasant nor unpleasant, of general lassitude and indifference, and a slight sensation of rigidity in the backs of the fingers when extended. The same feeling was present in a less degree all over the body, giving the subject the impression that the motor nerves were becoming partially paralyzed. Otherwise the subject was perfectly comfortable, though somewhat weak and lethargic.

"7:00 P.M. The pulse was alarmingly intermittent. There was often a pause of two seconds between beats. However, the subject was quite unaware of the fact, and perfectly comfortable.

"8:00 P.M. The subject complained of difficulty in breathing, as though a tight bandage were tied over the left side. The pulse was now almost, and sometimes quite, imperceptible. The arms became weak; in a few minutes they became absolutely paralyzed. The subject began to be a little scared. However, in about ten minutes the loss of power passed away, and he became perfectly comfortable, though disinclined to move a finger.

"8:45 P.M. The sea suddenly turned purple and tilted up to the eaves of the veranda, and instantly regained its normal aspect. The victim was not particularly excited at this sight; indeed, throughout the experiment I was struck by the very matter-of-fact way in which he received the various visions, I myself being far more keenly interested in them. The legs now became partially paralyzed for a few minutes. There was no other symptom whatever till 8:45 P.M., when very indefinite stationary spots of purple and blue-green were seen on the beach at a distance of fifteen or twenty feet. They gradually assumed the shape of rather conventionalized thistle-heads, some purple and some emerald. For a moment the shingle beach appeared to be turning into a bed of flowers, but they quickly faded away. When I went out and struck a match before the bungalow the flowers suddenly reappeared. Whenever a match was struck they became more vivid. It was now twilight and when the flowers appeared the beach became brighter.

"I now lit the lamp and placed it by the subject. The thistles had faded away. Suddenly the sea—which was gray—turned green, and became covered with symmetrically arranged spots of violet, which rotated on their axes and passed off to the right. There were three bathing-machines half way down the shingle, and the spots passed behind them.

"I now turned down the lamp. The shingle instantly became a bed of blue flowers; some unknown little plant which produced a short spire of blue blossoms, and a few green blades. I asked the subject to direct me to one spire which was higher than the others, and trod on it, when it disappeared. I turned up the lamp; the flowers disappeared.

"The subject now saw a large cutter about half a mile from shore, which sailed rapidly along and passed behind the bathing machines. He made a sketch of it as it approached, to give me the relative proportions of the cutter and the machines, and then described it as close in. As a matter of fact there was a small cutter about a mile off shore, and about one tenth the size of his sketch.

"9:25 P.M. On the beach, where the flowers had been seen before,

a head like the Cheshire Cat appeared. It was vague, except for the smile. Presently it developed a body and legs, and became a lynx, with no feet, and eyes like glowing opals. It danced gravely round in a circle. Having inquired as to its exact position, I went out and kicked it. It vanished.

"The subject now saw, in the wake of the moon, which was now shining brightly, a boat containing two men fishing, with a light. I could see the men only with the telescope. Handing the subject the telescope, he said that he saw the boat three times as large without the glass. He now came out and leaned on the rail of the veranda. A cloud over the moon appeared to him an oared galley, five times the diameter of the moon. The oars were moving at the rate of 30 strokes to the minute.

"10:15 P.M. The galley having disappeared, the subject sat down inside the door again. A creature with a pointed nose and sharp ears popped its head constantly round the corner of the door. As the pulse was again imperceptible I administered a pint of strong coffee.

"10:45 P.M. A beautiful miniature Eastern city appeared, on the beach about twelve feet away. It was lit, apparently, by the sun; there were walls, citadels, mosques, minarets, houses, etc., all white, interspersed with green foliage. It was very compact, standing high above the walls, and about six feet in diameter. After some five or ten minutes an enormous tortoise, with a Greek key pattern in metal round the periphery of the carapace, walked against the city and right through it when it disappeared, and the tortoise with it.

"Shortly afterwards a vast horde of little black woolly animals, rather like black guinea-pigs with astrachan coats and glow-worms for eyes, poured up over the pebble ridge from the sea, and disported themselves over the beach, which was quite covered with them. After pouring up for a minute or two they vanished into thin air. Their motion was like that of a swarm of maggots discovered in turning over a dead animal. This was the last vision. The subject expressed a desire for a very large meal, ate a small one, went to bed, immediately slept a dreamless sleep, and was for two days very languid and weak, with a feeble and depressed pulse, and occasional palpitation. He will on no account try the experiment again.

"The most remarkable feature of the visions was that they all had 'a local habitation and a name.' They all appeared out of doors, most of them on the ground at a distance of twelve feet or so; they did not move when the head or eyes were turned, but kept exactly in their place. The visions were seen with either eye indifferently; with the eyes closed nothing was seen. Mechanical pressure on the eye-balls had no effect. At one period of the experiment the muscles of the eyes became relaxed, so that the subject saw near objects slightly doubled."

## V.

It may be seen from the two experiments which I have described in some fullness that, in general character, the physical and psychic manifestations of mescal somewhat recall those produced by haschisch, the most famous and typical of the 'artificial Paradises' which man has found for himself. No other drug, indeed, can be said to approach so nearly to haschisch in its effects. They are alike in the variability of their effects on different individuals and in the difficulty of obtaining a reliable preparation.\* They both slow the heart, tending in some cases to produce intermittence, and both affect the respiration. They both produce muscular weakness and incoordination, exaggerate the knee-jerk and dilate the pupils. They both, moreover, possess the same vision-producing properties. I cannot speak from personal experience on this point, but one of my subjects, a poet who has paid much attention to the methods of generating visions, assures me that in his experience the virtues of the two drugs are about equal and that he has no preference for haschisch over mescal.

While there are thus marked and fundamental resemblances between mescal and haschisch, there also appear to be numerous points of difference. On the whole it may be said that mescal has a more restricted, a less generalized action than haschisch. In some of the early accounts of haschisch, which may now almost be said to be classic, great stress was laid on its exuberant motor manifestations, the uncontrollable antics, and the loss of all sense of time. These manifestations are much less conspicuous, and often do not appear at all, in the later accounts of haschisch, so that they are evidently not essential.

Under mescal, so far as I have been able to observe, they seldom appear. Mescal may at one stage produce a sense of well-being, vigor and intellectual lucidity, but there is no actual motor exhilaration, or loss of self-control, usually no mental failure at any point, except that when the influence is strongest attention may be impaired, so that one realizes when under mescal how much attention is a matter of muscular coordination. The action of mescal on the motor system is to depress, so that there is a tendency to tremulousness of the muscles which feel weak, and it seems to the subject that he must exert more than usual care

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\* Haschisch is said to vary in accordance with season, as well as with the district in which the hemp is obtained. The Indians believe that mescal is only active at one season of the year. I found one supply that reached me to be almost or quite inert, and it is possible that it was gathered out of season.

† The resemblances between haschisch and mescal come out most clearly in the latest and most reliable investigations, see, *e. g.*, W. E. Dixon, 'The Pharmacology of Cannabis Indica,' *British Medical Journal*, November 11, 1899, and E. B. Delabarre, 'Report on the Effects of Cannabis Indica,' *Psychological Review*, March, 1899. The latter is only a brief summary, but Professor Delabarre informs me that he hopes to publish a full account of his investigations.



to prevent himself from staggering and more than usual energy to perform even the simplest action. This may affect space-relations and one of my subjects found that in lifting a cup to his lips the distance traversed seemed very much more than usual; the same subject found that his ideas of time seemed to be disturbed, but on testing him with the watch his estimates were found to be fairly accurate.

The positive and active manifestations of mescal are always mainly if not entirely on the sensory side, and the motor weakness and sense of lassitude which is often present only throw the subject of mescal intoxication more absolutely at the mercy of the waves of unfamiliar sensory impetus which strike him from every side. Every sense is affected: apart from the various visionary influences, sounds become unfamiliar and abnormally acute, the sense of smell is stimulated or olfactory hallucinations may occur, the simplest food seems to possess an added relish, while there are vague skin sensations, and to the sense of touch the body seems as unfamiliar as everything else has become. I have elsewhere remarked, in illustration of the peculiar effects of this drug, that mescal seems to introduce us into the world in which Wordsworth lived or sought to live. The 'trailing clouds of glory,' the tendency to invest the very simplest things with an atmosphere of beauty, a 'light that never was on sea or land,' the new vision of even 'the simplest flower that blows,' all the special traits of Wordsworth's peculiar poetic vision correspond as exactly as possible to the actual and effortless experiences of the subject of mescal.

It should be added that a sense of well-being is not an essential part of these sensory manifestations. In this respect mescal is entirely unlike those drugs of which alcohol is the supreme type. Under the influence of a moderate dose of alcohol the specific senses are not obviously affected at all, but there is a vague and massive consciousness of emotional well-being, a sense of satisfaction tending to a conviction that 'all's well with the world.' Alcohol has a dulling influence on sensory activity and on the intellectual centers; and it may indeed be said that for the brain-worker whatever value the moderate use of alcohol may possess chiefly lies in the fact that after brain-work is over it helps to soothe undue brain-activity. Mescal, on the other hand, is not mainly emotional in its effects but mainly sensory and it leaves the intellect almost unimpaired even in large doses. It is true that at one stage of mescal intoxication, and more especially in quite healthy persons, there is a feeling of well-being, and even of beatitude, accompanied by an illusory sense of quite unusual intellectual activity; but there is no stage of maudlin emotionality; on the whole there is a condition of fairly unimpaired and alert intellect, untiringly absorbed in the contemplation of the strange world of new sensory phenomena into which the subject has been introduced.

These phenomena are above all visual, and the intellectual character of mescal intoxication as compared with perhaps any other intoxication, seems connected with the fact that it is the most intellectual of the senses that is chiefly involved. The visual effects of mescal may be of very various character, largely depending on the idiosyncrasy of the subject as well as on the degree of the intoxication. They vary from an exaggeration of the normal phenomena, producing a heightened play of light and shade and color, to visions seen on the curtain of the eyelid with closed eyes and with open eyes in the dark, up to actual localized hallucinations seen in broad daylight. It seems reasonable to suppose that the cerebral centers of vision are affected under mescal, and the occipital headache which occasionally follows supports such an assumption; a merely peripheral stimulation could scarcely suffice to account for such an orgy of vision. But at the same time I am convinced that the conditions produced in the eye itself are important factors in the production of the phenomena. Not only must we suppose that the retina, like all the sensory apparatus, has become hyperæsthetic, but the pupils are dilated, so widely dilated in one of my subjects that there was extreme photophobia. It is probably not without significance that in the other chief vision-producing drugs, such as haschisch and belladonna, the pupils are also dilated. It is evident that light can penetrate into the chamber of the eye with much more ease than usual. The Kiowa Indians sit round a fire during the nights on which the mescal rites are performed and I have found that the flicker of fire-light acting through the closed eyelids furnishes a very favorable condition for seeing the visions to advantage.

There is another characteristic of a large number of these visions (as indeed of many visions otherwise produced) which, it would seem, we must explain through peculiarities of the eye. I refer to what I have termed their kaleidoscopic character, the tendency to symmetrical grouping in the visual field of objects similar in shape, and harmonious, though not necessarily similar, in color, so that a kind of vision is produced such as we might attribute to an animal with faceted eyes. We might account for such a phenomenon by means of that irregular astigmatism, found more or less in normal eyes, which has been attributed to the fact that the crystalline lens is composed of many sections connected by radial sutures, or, more plausibly, with Shelford Bidwell, who has made some interesting experiments on this point, to the light passing through the coarse-meshed tissues of the eyes.\* With perhaps still greater probability we might adopt the suggestion of Zehender† who in dealing with subjective visual perceptions would explain the strikingly regular polygonal figures which arise under various con-

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\* Shelford Bidwell, 'Multiple Vision,' *Nature*, April 13, 1899.

† *Klinische Monatsblatt für Augenheilkunde*, November, 1895.

ditions to the movements and displacements of retinal pigment grains in course of chemical decomposition.

There is another visual phenomenon caused by mescal, to which my attention was particularly attracted, since it appears to have been little noticed by previous observers, and which is of considerable interest because it may be brought into line with various phenomena which occur without the intervention of drugs. I refer to the play of shadowy color, and more especially the violet halos which are seen to play around and over objects and constitute, in my own case at all events, the earliest group of color phenomena seen under mescal. I have already described my impressions of this effect, and one of my subjects who saw the same phenomenon, describes it as 'a violet fringe, surrounding objects and tending to become flower-like.' It has been observed by many when passing over snow-covered regions, and especially by Alpine climbers, that moving objects, and more especially their own hands or garments, show a violet border.\* Then we have the tendency to color vision (erythroptia or perhaps more strictly, or more usually, violet vision) to which the eye becomes liable after surgical removal of the crystalline lens. Once more there are the colors produced by the much discussed colorless 'spectrum top.' It seems to me that all these phenomena, and others that could be named, must be regarded as more or less allied. The first explanation offered for the earliest of them to be noted was that they are due to over-stimulation and exhaustion of the eye. Later inquirers have sought after a more precise mechanism for the phenomenon. Thus Dobrowolski in 1887, dealing with the erythroptia often occurring after removal of the lens, argues that a necessary condition is the dilatation of pupil produced by atropine, and that the color vision is really of the nature of a negative after-image of the rays that strike the eye. Fuchs, in 1896, who has dealt in an interesting manner with the erythroptia experienced on climbing snow-covered mountains (regarded by him as strictly a purple vision) finds that Dobrowolski's explanation is inadequate, and, while contenting himself with the theory of stimulation and fatigue for some of the phenomena, believes that the real explanation is to be found in a temporary visibility of the visual purple of the retina. Whatever the value of this explanation may be as applied to the whole group of phenomena, Fuchs more than any one helped to bring color-visions of this kind from the sphere of the pathological into the sphere of the normal. More recently still, Shelford Bidwell in 1897, when making some simple but ingenious experiments with the object of discovering the mechanism of the spectrum top, found that when a dark patch is

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\* This phenomenon was discussed in *Nature*, during May, 1897, some of those who described it assuming without question that it was an objective phenomenon.

suddenly formed upon a bright ground the patch appears to be momentarily surrounded by a blue border, and he accounts for this by the theory of a sympathetic affection of the red nerve fiber; when the light is suddenly cut off from a patch in a bright field, there occurs an insensitive reaction in the red fibers just outside the darkened patch, in virtue of which they cease for a short time to respond to the luminous stimulus, in sympathy with those inside the patch. The green and violet fibers, by continuing to respond uninterruptedly, give rise to the sensation of a blue border. Where highly competent experts fail to agree it would be rash to state any definite conclusions. It is difficult, however, not to believe that, whatever the precise retinal process may be, over-stimulation and fatigue certainly have very much to do in calling it into action. Associated with the violet halo, as we have found, there is a tendency under mescal, especially by the aid of a bright flickering light, for shadows generally to be variously colored, more especially (as in erythroptasia and allied conditions) towards the outskirts of the visual field. Any one who will sit for a few minutes with his eyes directed on a sheet of white paper illuminated by bright sunlight will soon begin to see on a small scale a faint reproduction of the colored shadows seen under the influence of mescal. Here clearly we have a fatigue phenomenon due to over-stimulation by bright light, and precisely analogous to the after-images produced by looking at any excessively bright object. Under mescal we have a similar effect produced, not through the stimulation of unusually bright light, but by the unusually hyperæsthetic condition of the visual apparatus, due in part to the dilatation of the pupil and in part to the effect of mescal on the retina.

There is one other effect of this fascinating drug to which attention may finally be called. It has been pointed out that under mescal all the peripheral sense organs become highly irritable or hyperæsthetic. Not only is this so, but they are brought in a quite unusual degree into sympathy with each other. I found that casual stimulation of the skin at once heightened the brilliancy of the visions, or produced an impression of sound. One of my subjects, an artist, had a curious sensation of tasting colors, and another found that music had a delightful influence over the visual effects. This, and the fact that the Indians keep up a continual beating of drums during the time they are under mescal, led me to plan a further experiment on myself with mescal. I arranged that when the stream of visions was in full force a friend should play to me on the piano various pieces of a more or less progressive character which were unknown to me, at all events by name. I found that these pieces, more especially those which were somewhat uniform and monotonous, not only distinctly stimulated the visions, but influenced their character; and in about half the tests there was a

real resemblance, sometimes in a striking manner, between the prevailing nature of the visions and the name of the piece. This was especially the case as regards Schumann's music. It would be worth while to carry out further experiments along this line, and on a variety of people, preferably non-musical people. It may be added that under some circumstances music itself evokes a train of visual imagery. Heine has somewhere described in detail the imagery called up when listening to Berlioz's music, and in 'Florentine Nights' he describes, in the person of his hero, the elaborate imagery evoked on hearing Paganini play, and remarks: "You know my second sight, my gift of seeing at each tone a figure equivalent to the sound, and so Paganini with each stroke of his bow brought visible forms and situations before my eyes; he told me in melodious hieroglyphics all kinds of brilliant tales; he, as it were, made a magic lantern play its colored antics before me, he himself being the chief actor." It would seem that in Heine's case music produced actual visual imagery, as under the influence of mescal. In this connection I may recall an account of visual imagery, as seen at a concert, recorded by Dr. Robert MacDougall.\*

One is tempted to ask by what process we should conceive to ourselves that the action of mescal works on the organism. I think it is not impossible to hazard such an explanation, provided that we avoid the risks attending undue precision in our explanations. We are justified, it seems to me, in supposing that mescal effects its peculiar actions by producing a kind of violent but temporary neurasthenia and cerebrasthenia. In other words, it rapidly overstimulates and exhausts the nervous and cerebral apparatus, more especially on the sensory side. It is true that such an explanation might be said to apply to the action of many drugs, including all those that are commonly called stimulants. The day has gone by when it could be supposed that a stimulant put anything into the system. It acts not by putting energy into the system but by taking it out, and so rapidly producing a state of fatigue. The careful experiments of Féré with the ergograph have lately shown that all sorts of sensory stimulants, acting on various senses and not necessarily involving the use of drugs, produce an immediate increase in the output of muscular work, but that no sensory stimulant of any kind will enable us to do a total amount of work equal to that we can achieve without stimulants, because the sudden rise of output is more than compensated by the subsequent fall. So that by the use of stimulants, so far as output of work is concerned, we not only draw on our capital,

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\* 'Music Imagery,' *Psychological Review*, September, 1898. The cases in which some definite appearance is regularly associated with the sound of each instrument belong to an allied though different class; a case of this kind is recorded in *Nature*, March 6, 1890. Here, we approach the best known group of 'secondary sensations.'

we actually dissipate and waste it. But the results of this kind of fatigue do not usually produce any condition comparable with neurasthenia; they do not, for instance, produce visions. In neurasthenic states there is, however, a tendency to visionary effects—colored vision, intolerance of light, photopsiae, persistence of retinal impressions, etc.—and, moreover, in all temporary conditions of nervous fatigue in otherwise fairly healthy people the same tendency to abnormal color effects with open eyes, and vague visions with closed eyes, is apt to show itself. I find that some persons, when very tired, see shadows as unusually violet, while kaleidoscopic visions and processions of figures and faces are also seen with closed eyes after fatiguing days. I have myself noted effects faintly recalling those produced by mescal after periods of unusual brain activity. On the border-land between sleeping and waking color-visions are also sometimes seen, and Mrs. Christine Ladd Franklin has stated that in falling asleep over a book she sees colored shadows, especially violet, floating over the page. It is noteworthy, further, that in various conditions of abnormal color-vision fatigue increases the brilliancy of the colors. The same tendency rules the association between music and visions. Heine was a somewhat neurotic subject who constantly complained of very severe headaches, and Mr. MacDougall, in describing the physical conditions under which he finds that visual imagery is liable to occur, describes a state approaching that produced by mescal: “In the earlier stages of fatigue, before the final condition has been approached, a period of cerebral excitement occurs, often accompanied by slight frontal headache, in which my mental imagery becomes more varied and concrete than normal. I feel an unusual brilliancy and fertility of suggestion; my mental scenery becomes less schematic and algebraic; comparisons and illustrations suggest themselves on every hand; thought proceeds by object images.” It may be pointed out that neurasthenia is widely regarded as a condition of depression with irritability of the higher cerebral centers. Binswanger, indeed, in his book on the pathology of neurasthenia, considers the parallel between fatigue and neurasthenia as so close that he is inclined to regard the latter as nothing else than a prolonged condition of over-fatigue. In mescal intoxication we may be said to have a neurasthenia which is very limited, but is very sudden and swift. The sensorial apparatus is allowed to run violently down, and in healthy persons the accompanying acute metabolic activity produces the pleasurable feelings which usually accompany nervous activity. It is perhaps due to the swiftness of this process, and also to the good physical condition of the subject, that no unpleasant after-effects are usually experienced. I have noticed that the pleasant or unpleasant effects and after-effects of mescal may be quite accurately foretold from a knowledge of the subject’s general health, and that the better his general

condition the less likely is he to experience any unpleasant results from taking mescal.

It was inevitable that an attempt should be made to drag mescal into the already overcrowded field of therapeutical agents. Curiously enough, the first affection which it was used to treat was neurasthenia, and the results were said to be good, but nothing further has been heard of it. In various quarters it has been suggested for use in insanity, and at Carmarthen Asylum Dr. Goodall, as he informs me, has made many trials with it, on melancholic and stuporose patients, pushing the drug eventually in large doses, but beyond dilatation of pupils and rapidity of heart action, the results were nil. I have myself never felt hopeful about mescal as a therapeutic agent, and though it is possible that of the various alkaloids obtained from it some may be found useful, it is not easy to see in what diseased conditions the crude drug itself is indicated. The fact that its best results are obtained in perfectly healthy individuals would alone counter-indicate its use as a remedial agent, and at present there seems no excuse whatever for thrusting it into the pharmacopœia.

The chief interest of mescal is for the physiologist and the psychologist.\* It may be added that for every healthy person a single experience, at all events, of what mescal has to teach would be an educational advantage of no little value. As one of my subjects, who strongly feels this educational value of mescal though he has no wish to repeat the experience, remarks: "The connection between the normal condition of my body and my intelligence had broken—my body had become in a measure a stranger to my reason—so that on reasserting itself it seemed, with reference to my reason which had remained perfectly sane and alert, for a moment sufficiently unfamiliar for me to become conscious of its individual and peculiar character. It was as if I had unexpectedly attained an objective knowledge of my own personality." Thus it is that the Indians who raised this remarkable plant to divine rank, and dedicated to it a cult, have in some measure been justified, and even in civilization there remains some place for the rites of mescal.

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\* 'What an excellent use for a medical congress,' Mr. Francis Galton writes to me, 'to put one half of the members under mescal, and to make the other half observe them.'

## INFECTIOUS DISEASES.

BY ALFRED SPRINGER, PH.D.,

CINCINNATI, OHIO.

**I**NFECTIOUS diseases have devastated more homes than all wars combined, and a check to their ravages would be the greatest boon suffering mankind can hope to achieve.

These diseases are supposed to owe their origin to the activity of ferments, enzymes, sporozoa or other ultra-microscopical organisms, consequently they must have some reactions in common with other phenomena depending upon the same agencies.

If true scientific reasoning is based upon inductive methods, namely, 'the endeavor from the much which is observable to arrive at a little which may be verified and is indubitable' then truly our knowledge of ferments is very meager—in fact practically everything we know is deduced from observing the alcoholic yeast ferments, and this for the following reasons: First, they have been employed for many ages. Second, they are larger than the other ferments. Third, they can be studied without jeopardizing fellowmen. Fourth, their chemical effects can be traced in the laboratory, qualitatively and quantitatively, and last, but not least, their study is not beset with those difficulties which immediately present themselves when effects are produced upon higher differentiated types such as man.

I shall only call attention to such properties which undoubtedly many pathogenic bacteria hold in common with them, namely, we know that these ferments multiply with exceeding rapidity—that they can withstand great ranges of temperature and many chemicals poisonous to man—that they can accommodate themselves to abnormal conditions and remain dormant until suitable conditions again arise and that by their immense numbers much organic material is destroyed. We know, on the other hand, that these ferments have their enemies which can either suppress them entirely or to such an extent as to make them harmless. We know that the introduction of other ferments in the same medium, making use of one of their essential nutrients, may cause a total cessation of their activity—we know that their own excreta or similar products act as poisons upon them. We also know that ferments and enzymes are selective in their foods, probably not from volition, but for reasons of food assimilation.

It is a well-known fact that but an imponderable quantity of a specific ferment is required to start fermentation and this, owing to



reproduction, increases in a geometrical proportion, so that in a comparatively short time the whole mass is attacked. Thus a small amount of yeast will start the dissociation of thousands of gallons of a mash—the bacteria, in a septic tank, derived from the human digestive tracts, liquefy in twelve hours all the sewage of a household, including the paper and other cellulose matter. Pathogenic germs, in media such as nutrient gelatine, agar-agar, blood serum, etc., also develop quite rapidly; nevertheless the progress of infectious diseases is comparatively slow and frequently localized.

Since many pathogenic germs are present in the air we breathe, in the water we drink, and in the soil we come in contact with, infectious diseases seemingly ought constantly prevail; this not being the case, it has been assumed that the system itself under normal conditions can withstand their attack. Predisposition, on the other hand, betokens a weakened system, *i. e.*, decreased vitality, or one in which the way for the entrance of the germs has been paved. From this it may be concluded that the so-called specific disease germs generally present are no more dangerous than the predisposing media. Immunity can be obtained either by avoiding the pathogenic germs or the predisposing cause. At present means are suggested to isolate the consumptive and destroy the intermediate-bearing host, both in malaria and yellow fever. It is not even known whether other carriers equally dangerous exist.

The destruction of the predisposing cause certainly is more humane, and the one to be sought for. Unfortunately success has been limited to but few of the many diseases known to be of an infectious nature. Probably failure is largely due to ignorance of causes producing immunity, and in fact every theory so far advanced has been badly battered by numerous failures of substantiation.

Recent experiments indicate that specific ferments can only dissociate specific foods, *i. e.*, the assimilable ones for any one class of ferments do not constitute a wide range. Furthermore, it has been proved that micro-organisms can either be antagonistic to each other, *i. e.*, one can change some nutrient essential to the other's existence, or synergetic, where one is dependent upon the other for its food—and, in some cases, they may be indifferent where the food of the one is not that of the other.

Synergetic action plainly shows how limited is the dissociating power of micro-organisms. Thus an albuminoid is first converted into an ammonia compound by one class of ferments, a second class produces nitrites and a third nitrates. In the absence of the first, neither nitrites nor nitrates can be formed, and in the absence of the second no nitrate will appear. Still more striking—most exact experiments have shown that both ferments and enzymes cannot assimilate food chem-

ically and physically the same as some of their best nutrients—save in having opposite powers of rotation.

Taking into consideration that micro-organisms can withstand temperatures and chemicals fatal to man, the slow development of infectious diseases is most probably intimately connected with an insufficiency of assimilable food. This food it may be assumed can only be obtained by symbiosis either with other micro-organisms or products of cell activity in the system itself.

It is claimed that the *Anopheles* mosquito is the intermediate host of the human malaria and the *Culex* that of the bird, but not *vice versa*. These mosquitoes undoubtedly do not select the spores of their respective parasites and avoid the others, but there must exist conditions in the system of the respective mosquito which allow of the propagation of one kind and not the other—and these conditions, I take it, are food assimilable ones.

White mice are immune to splenic fever, other mice very susceptible. Since the blood of white mice is more alkaline than that of the others—and such blood when made less alkaline becomes a good medium for the cultivation of the anthrax bacillus—it has been claimed that the alkalinity produces the immunity. On the other hand it has been found that alkalis are not particularly harmful to the anthrax bacillus—therefore, it seems to me, that alkalinity, as such, is less of a factor than its consequent effects upon the nutrients of the bacillus.

Pasteur demonstrated that micro-organisms select one of two optical isomers, and Fischer proved that it is not only a question of optical antipodes in different sugars, but amongst a great number of geometrical forms few fulfil the requirements of the cells—furthermore he is of the opinion that many chemical processes in the system are affected by molecular geometry.

The albuminoids are the most important constituents of the living cells and since they are synthetically formed from the carbohydrates of the plants, Fischer believes that the geometrical structures of their molecules, as far as asymmetry is concerned, are essentially like those of the natural hexoses. Thus it seems that configuration plays a most important rôle in making food assimilable—be it in converting inactive into active modifications or *vice versa* or the production of one optical isomer instead of the other, or some other change of configuration, the consequence would be a different behavior toward the ferments, enzymes and sporozoa.

We now come to another feature which also may be of physiological interest, namely: the fact that the alkaloids largely used for therapeutical purposes, such as quinine, cinchonine, quinicine, conchinine, strychnine, brucine and morphia can, like micro-organisms, bi-part racemic forms. Thus cinchonine separates as salt from the inactive

modification insoluble: l-Tartaric acid; d-Methoxylsuccinic acid; d-Mandelic acid. *Penicillium glaucum* destroys: d-Tartaric acid; l-Æthoxysuccinic acid; l-Mandelic acid. Lewkowitch's schizomycetes destroy: l-Tartaric acid; d-Mandelic acid. Strychnine separates: l-Lactic acid; l-Æthoxysuccinic acid. Many other examples can be cited, the principal difference being that the alkaloids separate the insoluble optical isomer and the micro-organisms make use of one of the optical isomers to build up their own structure.

The bi-partic powers of the alkaloids are as limited as those of the micro-organisms; thus strychnine can bi-part lactic acid, cinchonine malic but not lactic acid, etc., and most likely two acids bi-parted by the same base have analogous configuration.

From these arguments, I take it that predisposition and immunity are intimately connected with stereo-chemical changes, *i. e.*, where the configuration, according to Fischer, of the nutrient, on the one hand, and the ferments, enzymes, sporozoa, etc., on the other, must be to each other as lock and key. Moreover, I believe that infectious diseases are not caused by any one class of ferments, but by many acting synergetically. In line with these results it strikes me that predisposition is a condition well suited to act synergetically when the missing ferment presents itself. Immunity, on the other hand, betokens the absence of a number of active synergetic ferments, owing to lack of requisite configurations.

While this suggestion may seem to offer one hazy hypothesis for another equally hazy, it opens a broader field for investigation, it admits of better explanations of observed results, and it agrees with our ideas that the demolition of complex organic materials, such as blood and the tissues, takes place step-like and not abruptly.

Surely some day physiological chemistry will be sufficiently powerful to shed its light through the mist now surrounding the so-called vital processes—clearly define the differences between the healthy and the disease-disturbed systems—teach us how to preserve the former and counteract the latter, by other than merely empirical methods.

When that day comes, infectious diseases like tuberculosis will no longer rob the stricken patient of all hope and cause him to be a constant menace, dreaded even by those who love him most dearly. When that day comes, parents no longer need be haunted by the fear that predisposition be transmitted to their children born and unborn.

## THE PHYSIOLOGICAL EFFECTS OF ELECTRICALLY CHARGED MOLECULES.\*

BY PROFESSOR JACQUES LOEB,  
UNIVERSITY OF CHICAGO.

FIVE years ago I published a series of papers on the physiological effects of the electric current which impressed upon me the long-known fact that the galvanic current is the most universal and effective stimulus for life phenomena. This fact suggested to me the idea that it should be possible to influence life phenomena just as universally and effectively by the electrically charged molecules—the ions—as we can influence them by the electric current. From that time on the whole working force of my laboratory was devoted to the investigation of the physiological effects of ions.

My first aim was to find out whether or not it is possible to alter the physiological properties of tissues by artificially changing the proportion of ions contained in these tissues. In this way originated the investigations on the effect of ions upon the absorption of water by muscles, the effects of ions upon the rhythmical contractions of muscles, and medusæ, the heart of the turtle, and the lymph hearts of the frogs, the rôle of ions in chemotropic phenomena and the influence of ions upon embryonic development, and the development of unfertilized eggs (artificial parthenogenesis). Those who have followed my work on artificial parthenogenesis may have noticed that from the start I aimed at bringing about artificial parthenogenesis through ions. It seemed to me that I could not find any better test for my idea that the electrically charged ions influence life phenomena most effectively than by causing unfertilized eggs to develop by slightly altering the proportion of ions contained in them. I believe that all these experiments proved what I expected they would prove, namely, that by slightly changing the proportion of ions in a tissue we can alter its physiological properties.

The next step taken consisted in proving that it was indeed the electrical character of the ion that determined its specific efficiency.

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\* 'Studies on the physiological effects of the valency and possibly the electrical charges of ions': Introduction and conclusion on theoretical considerations (the footnotes being omitted) of Part I. 'The toxic and antitoxic effects of ions as a function of their valency and possibly their electrical charge,' originally printed in the *American Journal of Physiology*. From the Hull Physiological Laboratory of the University of Chicago.

I succeeded in doing this three years ago. It was known that a frog's muscle gives rise to twitchings or rhythmical contractions when immersed in certain solutions. I showed that such contractions, occurred *only in solutions of electrolytes, and not in solutions of non-conductors* (distilled water, various sugars, glycerine, urea). Soon after I showed the same to be true also for the rhythmical contractions of the medusæ. From observations made in my laboratory, the same fact was shown to hold for the turtle's heart by Mr. Lingle, and for the lymph hearts of the frog by Miss Moore. I am confident that this fact will be proved universally.

In the physiology of the heart one frequently encounters the statement that calcium is the stimulus for the contraction of the heart. I had found that a muscle is able to twitch rhythmically when immersed in the solution of salts with a monovalent kation,—I obtained contractions in Na-, Li-, Rb-, and Cs-salts,—but that the addition of a small quantity of a bivalent kation—Ca, Mg, Sr, Ba, Be, Mn, Co—inhibits these rhythmical contractions. This seemed to be a direct contradiction to the statement that calcium salts are the 'cause' of the heart-beat. The significance of the calcium had to be looked for, then, in another direction. It was soon found that the muscle, the apex of the heart, and a medusa contract rhythmically in a pure sodium chloride solution, but that they soon come to a standstill. If, however, a trace of a soluble calcium salt is added to the sodium chloride solution, the contractions continue much longer. I concluded from this that the pure sodium chloride solution acts, in the long run, as a poison—that is to say, brings about definite but at present unknown physical changes in the protoplasm—but that a trace of a calcium salt annihilates this toxic action. The amount of calcium necessary for this antitoxic effect is of course much smaller than the amount necessary to inhibit the rhythmical contractions. Soon after I succeeded in demonstrating conclusively the poisonous effect of a pure sodium chloride solution, and the annihilation of this effect by calcium. The eggs of a marine fish (*Fundulus*) develop normally in sea-water, but they can develop just as well, as I had previously found, in distilled water. The addition of ions from the outside is consequently not necessary to the development of this animal. I found, now, that, if the freshly fertilized eggs of this fish are put into a pure sodium chloride solution having a concentration equal to the concentration of the sodium chloride in the sea-water (about  $\frac{5}{8} m$ ), not a single egg can develop into an embryo. If, however, a trace of a calcium salt is added to the sodium chloride solution, as many eggs develop and in just as normal a manner as in ordinary sea-water. The calcium ions in this case undoubtedly serve the purpose of annihilating the poisonous effects of a pure sodium chloride solution.

In the meantime I had become familiar with the brilliant experiments of Hardy upon the influence of ions and the galvanic current upon colloidal solutions. They indicated to me that the next step I had to take was to see whether or not the valency and the sign of the electrical charge of an ion determine its physiological effects. I suspected that the antitoxic effect of the calcium ion in the above-mentioned experiment was due to its electrical charge and decided to investigate in a more systematic way whether or not the sign and quantity of the electrical charge influence life phenomena. My experiments carried on at Woods Hole this summer showed conclusively that this is the case for the antitoxic effects of ions and probably for the production of rhythmical contractions through ions. It seems at least possible that it is true also for artificial parthenogenesis.

#### *Theoretical Considerations.*

1. We have to attempt to answer the question, How can the electrical charges of ions produce a toxic or antitoxic effect? The answer to this question must be preceded by the answer to the more general question, How can the electrical charges of ions as well as of an electric current influence life phenomena? The basis for the answer to this question will undoubtedly be found in the work of Hardy, as well as that of Bredig, on the rôle of the electrical charges of the particles in a colloidal solution. Hardy has shown that living protoplasm is to be considered as a colloidal solution, a hydrosol. Such hydrosols are suspensions of solid particles in a fluid (water). These particles are at the highest about 1,000 to 10,000 times as large as the dimension which the kinetic theory of gases assumes for the molecules. The forces which keep these particles in solution are of an electrical nature. There exists, according to Helmholtz and Quincke, a double electrical layer at the limit between particle and surrounding water.

When the colloidal particles have a positive charge, the surrounding particles of the water have an equal negative charge. It agrees with this assumption that the colloidal particles move under the influence of an electrical current in the same way as ions. They move to the anode when they carry a negative charge, and to the kathode when they carry a positive charge. Hardy has made it probable that these charges keep the particles in solution, inasmuch as through these charges they must repel each other. Hardy has shown that as soon as these charges are taken away from them the colloidal particles will no longer be held in suspension, but either fall down or rise to the surface. In this case the hydrosol is transformed into a hydrogel. These charges can either be taken away from them through the oppositely charged electrode of a battery, or through oppositely charged ions which easily give off their charge. Solutions whose colloidal

particles have a negative charge can be caused to coagulate (go into the gel stage) by one of two means: either by positively charged ions, or by the positive electrode of a battery. The coagulating effect of ions increases with their valency, and much more rapidly than the valency. The most valuable among Hardy's discoveries is the fact that in a solution of white of egg the colloidal particles can be rendered either positively or negatively electric by the addition of hydrogen or hydroxyl ions. When the neutral or isoelectric point is reached, the slightest change—one feels almost inclined to use the word 'stimulus'—is sufficient to transform the solution into a gel.

But long before the critical point of a colloidal solution is reached the variation in the charge of the colloidal particles alters their physical properties. An increase in their charge has the same effect as if the viscosity of the liquid were increased.

The bulk of our protoplasm consists of colloidal material, and the physical manifestations of life, such as muscular contractions and protoplasmic motions, and the innervations, are due to changes of the condition of these colloidal solutions. We now may be able to understand why the electrical current is the universal form of stimulation. The reason may be that the particles in colloidal solutions are electrically charged, and that every alteration of the charge of the particles will result in a process of innervation or a contraction or protoplasmic motion, etc. We likewise understand why the ions, on account of their electrical charges, are equally well capable of altering the physiological properties of the tissues, as the galvanic current.

But how can the ions cause toxic and antitoxic effects through their electrical charges? In my preliminary notice on these experiments which appeared in Pflüger's *Archiv* in November, 1901, I pointed out the possible relation of the electrical charges to the viscosity of the protoplasm. Phenomena of cell division are, as I believe with Bütschli and Quincke, phenomena of protoplasmic streaming. Such phenomena require, as Quincke has shown, a definite degree of viscosity. If the viscosity is too great, no protoplasmic motion is possible, and the same is true if the viscosity is too small. It may be possible that the toxic charges—presumably the negative one in the case of sodium salts—alter the viscosity of the protoplasm by either making it too liquid or too viscous, thus preventing the protoplasmic motions necessary for cell division or the muscular contraction. Small quantities of oppositely charged ions with a higher valency, which give off their charge sufficiently readily, will act as antitoxic substances.

2. The thermodynamical theory of life phenomena has utterly failed to show how the thermal energy produced through the splitting up and oxidation of foodstuffs can lead to muscular contraction. Engelmann's well-known attempt at an explanation is based on a physical impossi-

bility, in view of the fact that some muscles, especially those of the wings of insects, are capable of relaxing and contracting a large number of times in a second. The facts mentioned at the beginning of this paper point distinctly towards the possibility that part of the chemical energy in our body is transformed into electrical energy, or, in other terms, the ions formed in metabolism seem to play a rôle in the dynamics of life phenomena. From the facts mentioned in this paper we can see that these ions, or rather, their electrical charges, may be responsible for such physical manifestations of life as the muscular contractions and others. It remains to be explained how the electrical energy of the ions may be transformed into the mechanical energy produced by the contracting muscle. This will be discussed in the second paper, but I will point out here that I believe that the electrical energy of the ions is transformed into surface energy. It will now become necessary to pay more attention to the production of ions in metabolism than has been done before. The  $\text{CO}_3$  and  $\text{PO}_4$  ions, as well as the H ions, can no longer be considered as mere waste products of metabolism.

3. The fact that ions may act toxically through their electrical charges, and that ions with the opposite charge may act antitoxically, may open a new and very fertile field for pathology and therapeutics. As I have stated in previous papers, especially certain neuroses, and perhaps certain mental diseases, may now find their explanation. Two years ago I pointed out that we must realize the existence of physiologically balanced salt solutions, that means salt solutions in which the ions are so combined that the toxic effects of the one are counteracted by the antitoxic effects of some other ion. Any disturbance in the right proportion of monovalent ions and ions of higher valency must lead to more or less pronounced modifications of the life phenomena.



AN AFTERNOON AT CHELLES AND THE EARLIEST EVIDENCES OF HUMAN INDUSTRY IN FRANCE.

BY PROFESSOR A. S. PACKARD, LL.D.,  
BROWN UNIVERSITY.

THE earliest traces of human occupation in France and on the European continent occur at Chelles, near Paris. We have said the oldest on the continent, for apparently still older flint implements occur in England. We refer to the so-called 'Eoliths,' or plateau implements, found by Harrison, Prestwich and others in southern England.

The Chellean flint axes are still taken out of a bed of preglacial gravel in the sand pits of Chelles resting directly on the Eocene Tertiary clays. This deposit is overlaid by later paleolithic beds, containing worked flints of the age of the earlier cave-dwellers of Le Moustier, in the Dordogne, and called the Moustierian epoch. Directly above this layer, just below the surface of the soil, occur polished stone axes of the later or recent (Neolithic) Stone Age, and other remains of human industry of the time of the Swiss lake-dwellers, while in the swamps and loam are occasionally found Gallo-Roman antiquities, such as Gallic coins, serpentine axes, and bronzes of the time of the Antonines.

Relics of the French who immediately succeeded the Romans in France are also occasionally dug up. Clovis I. and Clovis II. built villas here, and the site of one of them still preserves the name of 'the royal palace.' The queens of these two Merovingian kings, Ste. Clotilde and Ste. Bathilde, founded a monastery near the royal villa.

Thus a single glance at the walls of the gravel pits near the town shows the successive steps in the history of the region—the different stages in Paleolithic times, as well as the Neolithic or recent Stone Age; so that here are revealed, as perhaps nowhere else so clearly, the overlap of prehistoric on historic times.

It is to be observed that the relics or traces of human occupation also occur in geological strata or beds of definite age, not in caves of somewhat uncertain age, and they are associated with the bones and teeth of quadrupeds, such as the elephant, rhinoceros, horse, deer, the cave bear, etc., all of extinct species.

Hence a visit to this classical locality on a serene though hot July afternoon, in a most attractive region and in most delightful company, was both interesting and memorable.

The pleasant town of Chelles with its outlying villas, gardens and  
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modest parks lies on the north bank of the Marne about twelve miles east of Paris. It is built on the southern slope of a low eminence, with a southern exposure.

Alighting from the train, and accompanied by Professor Paul Barbier, we drove to the house of the Abbé Alfred Bonno, to whom we had been referred as distinguished by his knowledge of the prehistoric archeology of Chelles and its neighborhood. We were most cordially met by the Abbé, and before accompanying us to the quarries he invited us to examine the large collection of prehistoric remains which was stored in the attic of his house. It comprised very full series of stone implements from the bottom to the top of the paleolithic, including



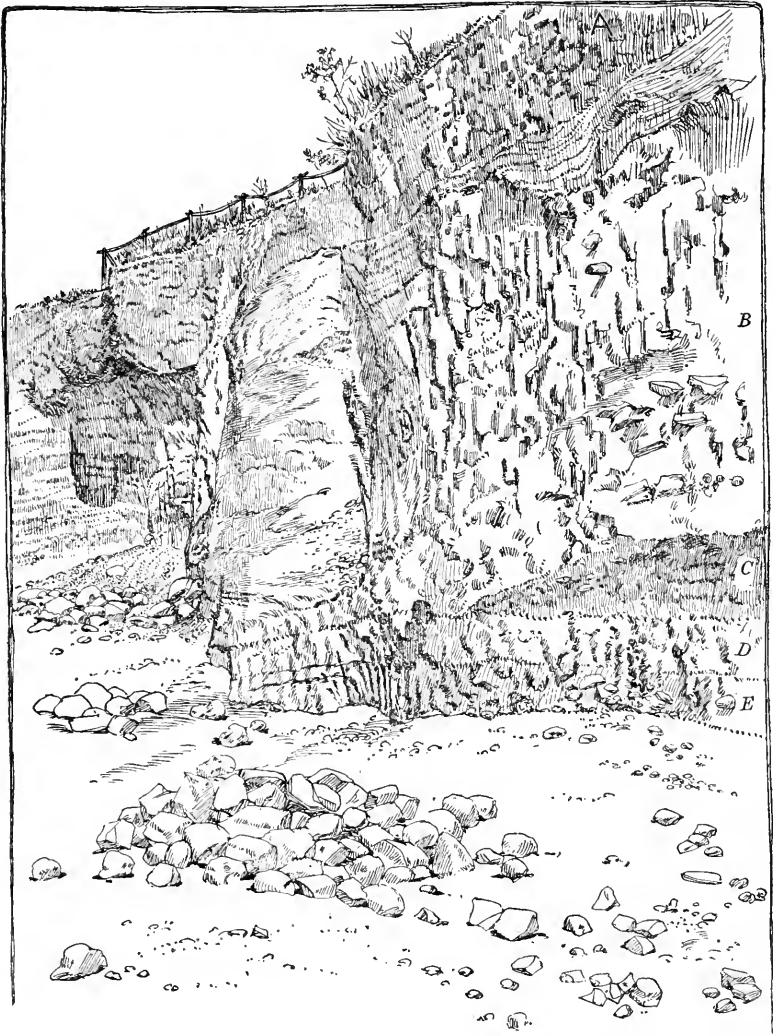
THE SAND-PITS NEAR CHELLES.

not only the Chellean and Acheulean, but also those of Moustierian age, up to the Magdalenian subdivisions, with some Solutrian lance-points. There were also numerous polished stone axes taken from the loam about the town, as well as Gallo-Roman bronze spear-heads, and finally iron weapons of war, as Chelles was once the center of the Merovingian kingdom. There were also fine knives of flint dug up from the gravels of the Fontainebleau forest. An examination, even if a hasty one, of such a rich local collection was the best possible preparation for our visit to the quarries.

We then drove to the neighborhood of the sand pits, walking to them from the end of the road, through the fields and by a shaded path, until we came out into an open space to the edge of the pits.

The accompanying figure gives a clear idea of the sequence of beds drawn from a photograph which we owe to the kindness of the Abbé Bonno.

These gravel quarries are excavated in the Pleistocene or Quaternary gravels and are situated on a plain between 125 and 140 feet in height



THE BEDS AT CHELLES, CONTAINING PREHISTORIC FLINTS, ETC.

above the sea, extending from Chelles eastward to the neighboring village of Brou. The strata underlying the fresh water or river-gravels are greenish clays or marls of marine origin and of Eocene Tertiary age. This marl contains gypsum or plaster of Paris, with crystals of

selenite, besides bones and teeth of the Eocene deer-like *Anoplotherium*, and of *Dinotherium*, an early forerunner of the elephant.

Upon this lower Tertiary marine bed rest the fresh water Quaternary beds, the series beginning with the lowest Pleistocene beds, passing through beds of supposed glacial origin containing transported pebbles, up into postglacial strata containing Neolithic implements.

The transition from the Tertiary formation is sudden. When the lowest Quaternary beds were deposited, the Eocene marl beds had been elevated, become dry land and exposed to the erosive action of the winds and rains. A long interval passed between the time of deposition of the Tertiary beds and the Pleistocene deposits which now cap them. It is to be observed that the later Tertiary formations (Oligocene, Miocene and Pliocene) are absent.

The Quaternary deposits at Chelles are divided into four distinct fresh water beds, each differing in age and in their materials, and as exposed by the workmen the whole series appears to be about 25 to 30 feet in thickness. They are as follows:

*D, E.* The lowest bed, that directly overlying the Eocene marl, consists of rolled pebbles and grayish sand, the mass being often cemented by calcareous infiltrations. This bed contains the Chellean implements. (What is apparently an upper division of this bed (*D*) is what the Abbé Bonno calls the Acheulean, and from it have been taken axes like those found at St. Acheul near Amiens.) In this lowest bed also occur the remains of *Elephas antiquus*, *Rhinoceros merckii*, etc.

*C.* A deposit, not forming a continuous bed, and only seen in places, of water worn coarse gravel and small pebbles derived from Tertiary gravels, and called by Bonno '*sables moyens*.' This is the red drift, '*diluvium rouge*,' of Ameghino. It abounds in rolled, broken, sometimes entire, Tertiary marine shells which have been brought by fresh-water streams probably from Lizy-sur-Ourcq and from Etrépilly a few miles to the northeastward, or perhaps from Soissons to the north (Bonno).

*B.* A second layer of drift or rolled and transported gravel, containing flint implements of the Moustierian epoch, and bones of the mammoth.

*A.* A thin bed of gray clay of the age of the Swiss Lake-dwellers, in which occur polished stone axes.

The chief center of interest is of course the lowest bed (*D, E*), that containing the worked flints. These are the celebrated Chellean axes, which are of various sizes, no two exactly alike, which were worked out by chipping from flint nodules, the flint being derived from the chalk deposits. These crude weapons were probably used in the chase or in battle, and were not mounted, but held in the hand. Almond-shaped, in the form of a '*coup de poing*,' they were worked on both sides or

faces, showing a set of primary and secondary chippings or flakings. Their edges are sharp, not water-worn, and, as Ameghino states, they were evidently shaped by the early paleolithic workmen on the bed where they occur. Probably several hundred of these axes have been taken from these pits. Ameghino states that he possessed over a hundred of them.

With these axes sometimes occur long rude flakes ('lames'), knife-like, sharp on one edge, struck off from the flint core by percussion. No skin-scrapers (*racloirs* and *grattoirs*) or rude spear-points have ever occurred in these beds. No human bones or teeth have ever been found in these deposits, either here or at St. Acheul, and apparently nowhere else, unless we except the human molars claimed by Nehring to be of Chellean type. These are two very large molar teeth resembling in some respects those of the chimpanzee and found in the mid-Pleistocene drift of Taubach near Weimar.

At all events man as man lived here, and what manner of beasts were his contemporaries? They were in nearly every case representatives of species now extinct. Bones and teeth of the straight-tusked elephant (*Elephas antiquus*) and of the megarhine or big-nosed rhinoceros, are not infrequent: we obtained fragments from the workmen, and picked up some in the débris at the bottom of the pit.

The remains of other mammals are less common. Ameghino enumerates besides those mentioned, the bones and teeth of the hippopotamus, of a beaver-like rodent (*Trogotherium*, also found in the preglacial beds of St. Prest, Durfort, etc.), of an ox, of a horse (perhaps *Equus stenorhis*), and an extinct deer different from the reindeer. This deer is probably the same as *Cervus belgrandi* found in beds of the same age and nature at Montreuil, where its bones are associated with the straight-tusked elephant (*E. antiquus*) and *Rhinoceros merckii*. Ameghino also found at Chelles two canine teeth of the cave bear. As to the numerous molars of the horse (we found two) Ameghino states that they differ from those of the modern horse (*Equus caballus*) frequently occurring in the later Quaternary and are allied to the Tertiary species called *Equus stenorhis*. Since the date when his paper appeared Steno's horse has been referred to the lower Pleistocene, a time of transition to the Pliocene Tertiary, and most probably, according to Osborn, represented by the forest beds of Norfolk, England, and the equivalent beds of St. Prest, Durfort, and other localities in France. In fresh-water beds of this horizon occur also remains of the cave-bear, cave-hyaena, saber-toothed tiger, musk ox, *Hippopotamus*, *Rhinoceros etruscus*, *Trogotherium cuvieri*, of an otter, and of two species of elephant, *Elephas meridionalis*, supposed to have been the ancestor of the mammoth (*E. primigenius*) and *Elephas antiquus*.

These details may be dry enough to our readers, but they are of prime importance in relation with the question whether man originated before the Quaternary, either in France, or, as is perhaps more probable, migrated there from some Asiatic or African region in company with the hippopotamus, rhinoceros and other tropical forms which were his contemporaries.

Here might be mentioned the equivalent beds exposed in the sand-pits at Montreuil, which is nearer Paris, and just north of Vincennes. As stated by Ameghino, the deposits at this place are the same as at Chelles. The lowest beds are gray sands, without boulders, and rich in mammalian bones. Above lies a bed of large rounded pebbles, but it is sterile, or destitute of any but mere fragments; directly above is a bed of sand, this being capped by the red drift with boulders. The lowest beds present the same traces of denudation and of ancient erosion as observed in the corresponding beds at Chelles. No Chellean axes have been found at this quarry, at least the workmen were unacquainted with them, but Ameghino himself found in the lowest or preglacial bed two flint flakes, with a very pronounced bulb of percussion (*'concoide'*) which prove the former presence of man.

In the third bed (*B*), *i. e.*, that lying beneath, occur the true Moustierian implements which are entirely different in shape from the Chellean axe, being broadly triangular or pointed in outline, and only worked on one face, being flat on one side and convex on the other. In this interglacial bed occur the bones and teeth of the mammoth (*Elephas primigenius*) and this is the age of the cave-dwellers of the Spy or Neanderthal race, the age of the mammoth, of the *Rhinoceros tichorhinus*, the reindeer, musk ox, etc. With the Moustierian points occur flint knives, and also two new forms, the skin-scraper (*racloir*) and lance points. We see here traces of the immigration of subarctic mammals, showing that the climate was cooler than in the Chellean epoch, while the human race had either become modified, or had migrated hither from elsewhere, though these peculiar broad points do not, so far as we know, exist beyond the limits of France.

The same sequence is shown in the lowest beds at St. Acheul, near Amiens. The basal deposits, rich in Chellean almond-shaped implements contain at or below the depth of seven meters the remains of *Elephas antiquus*; at or below five meters *Hippopotamus amphibius*, while in the higher beds the straight-tusked elephant is succeeded by the mammoth, whose remains do not occur below the depth of three meters (Osborn).

Ameghino calls attention to a circumstance worthy of mention. As we have seen, flint axes of excellent workmanship occur in considerable numbers at the base of the lowest Quaternary beds lying directly upon the eroded surface of the Eocene Tertiary greenish marls.

So well are these implements made that we are forced to believe that this industry extended back to a still earlier period than the age of the beds in which these axes occur, and as he says, this fact 'constitutes for me the most weighty arguments that we can invoke in favor of the existence of man during the end of the Tertiary period.' Exhibiting to the members of the Anthropological Society the flints and teeth he had found, he showed that their edges were not water-worn, and that the flint axes had been abandoned by men where they were found. "Man, then, lived on the spot, and the instruments, at least in part, have also been worked out on the same ground. What proves this is that the little nuclei, like the two I exhibit, were found in the same bed. The teeth and bones of the mammals present no trace of having been water-worn. On the other hand, as the mammalian remains and the evidences of human workmanship are found at all the horizons of this lower bed, we are obliged to conclude that man inhabited this region almost continuously, or at least with very brief interruptions."\*

Remains of man have been discovered in Kent County, England, and in Dorset in the high-level gravels, which are certainly preglacial, as they contain remains of *Elephas meridionalis* in beds regarded by Lyell as 'a patch of Pliocene gravel.' These beds were afterwards referred by Prestwich to the early Pleistocene. As Prestwich states, the base-line between the Pliocene and the lowest Pleistocene is somewhat arbitrary, and the two periods in England gradually merged into each other.

These beds were afterwards referred by Prestwich, certainly the best authority then living, to the early Pleistocene. As he claimed, the base line between the Pliocene and the lowest Pleistocene is somewhat indefinite, and the two periods in England gradually merged into each other. The beds in question, namely those in Kent and Dorset counties, England, were regarded by Prestwich as the English equivalent of the St. Prest (Eure et Loire) beds, situated about fifty miles southwest of Paris, and also of the so-called Pliocene beds of the Val d'Arno in Italy. These beds, as well as those at other places in France, *i. e.*, Durfort in Gard, and Malbattu and Peyrolles in the Auvergne (Puy-de-Dome), which also contain remains of *Elephas meridionalis*, are now regarded as 'transitional between Pliocene and Pleistocene with prevailing affinities on the latter side.† The climate of this transitional preglacial epoch, when the plateau man of Southern England chased the tropical or meridional elephant, and other beasts, such as tigers, hyaenas, rhinoceros and the hippopotamus, a mixed assemblage of

\* 'Sur le gisement de Chelles,' *Bulletins de la Société d'Anthropologie* (3), iv., 1881, pp. 96-101.

† H. F. Osborn, 'Correlation between Tertiary Mammal Horizons of Europe and America,' *Annals New York Academy of Sciences*, xiii., 1900, pp. 1-72.

Asiatic and African forms, was mild, though somewhat cooler than that of the later Pliocene. It grew colder at the end when the glacial period was ushered in.

While of course the remains of man, or his flint tools, are to be looked for in the Pliocene beds of Europe, it is still possible that he was an immigrant from southeastern Asia, and shared in the migration of animal life which reached Europe from that region at the beginning of the Quaternary or Pleistocene.

It is now generally recognized that the 'missing link' or half ape, half man creature (*Pithecanthropus erectus*) of Java, whose skull (calvarium), femur and three molar teeth were discovered by Dubois in beds shown by him to be of Pliocene age, was the immediate precursor of man.

In the absence of any traces of man in the Tertiary beds of Europe may he not have, geologically speaking, suddenly appeared in Western Europe in company with *Elephas meridionalis*?

In his 'History of the European Fauna,' Scharff states that the genus *Elephas* makes its first appearance in the Upper Miocene of India.

"Our European *E. antiquus* is, according to Professor Zittel, probably identical with *E. armeniacus* of Asia Minor, while *E. meridionalis* agrees in all essential characters with the Indian *E. hysudricus*. The Indian and European species of fossil elephants altogether are very closely related, and the supposition that they all have had their original homes in the Oriental region offers, I think, no serious obstacle. The view of the European origin of the mammoth especially is open to very serious objections. It does not occur in any European Pliocene deposits, and could not therefore have originated in our continent until Pleistocene times."

It may be here stated that the mammoth (*Elephas primigenius*) is believed to be a descendant of *Elephas meridionalis*.

We may, then, provisionally at least, venture to suppose that the human descendants of the Java ape-man shared in this great wave of migration of tropical beasts, birds, insects, shells, etc., which at the end of the Pliocene or beginning of the Quaternary passed by way of Asia Minor and Greece into Europe, and peopled the plains and roamed through the forest lands of western Europe.

This view is supported by the fact that after the many years of research in the upper tertiary beds of Europe, no indubitable trace of flint tools of human workmanship or any other traces of human occupation have yet been discovered, while thousands of them, we speak within bounds, have been taken from the preglacial gravel beds of France and of England, which lie next above the Tertiary strata.



## THE PROGRESS OF SCIENCE.

## THE WILL OF CECIL RHODES.

THE bequest of Cecil Rhodes for education and the promotion of a good understanding between Great Britain and the United States follows very closely upon Mr. Carnegie's endowments of education in Scotland and of research in the United States. These three gifts, each of \$10,000,000, are of such magnitude that they not only assure the accomplishment of vast plans for the general good, but also attract public attention and mold opinion in a way that is perhaps as beneficent as the direct results. Mr. Rhodes was misunderstood during his lifetime—he was called the 'Diamond King of South Africa,' a promoter of stock companies and an adventurer. Now his will is misunderstood in some quarters; it is said on the one hand to aim to aggrandize England at the cost of other nations, and, on the other hand, to be chimerical—a chapter from Rousseau's *Emile*. Rhodes almost ranks with Napoleon and Bismarck in his masterful personality, and in a certain straightforward lack of scrupulousness. While Napoleon subordinated all to his personal ambition and Bismarck was chiefly concerned with the aggrandizement of a dynasty, Rhodes devoted himself to building an empire, including in his projects, as his life in part and his will fully indicate, the welfare first of the British Empire, then of the Anglo-Saxon race, then of the Germanic nations and finally of the whole world. Both in his life and in the provisions of his will he was a dreamer and an idealist. But in his life he proved that he was a seer who could turn his visions into facts, and there is every reason to be-

lieve that his plans for the disposition of his fortune will actually accomplish the ends he had in view.

It was certainly a fine dream to bring together at Oxford young men from the colonies, from the United States and from Germany, selected for intellect and character, learning to esteem each other, carrying to all parts of the world common interests and a common culture. It would be intolerable if all our universities were Oxfords, but there is room in the world for one place that shall fully represent the traditional culture of the past, and Oxford possesses a unique fascination that seems to adapt it to the purpose planned. The more Oklahomian the young man sent to Oxford, the more will he profit and the more will Oxford itself profit. The students from the United States who have studied in Germany have brought the two countries close together, and the hundred American boys constantly at Oxford will surely make more intimate and cordial the relations between the two great Anglo-Saxon races.

Oxford is not a university for research, but a place for culture: the boys who are awarded the scholarships should be just from school, as Mr. Rhodes intended. His provisions for selecting them deserve quotation. The qualifications are to be:

First—His literary and scholastic attainments.

Second—His fondness for or success in many outdoor sports, such as cricket, football, and the like.

Third—His qualities of manhood, such as truth, courage, devotion to duty, sympathy for and protection of the weak, kindliness, unselfishness and fellowship.

Fourth—His exhibition during school days of moral force of character and

instincts to lead and take interest in his schoolmates, for these latter attributes will likely in after life guide him to esteem the performance of public duties as his highest aim.

Marks for these four qualifications should be awarded somewhat in the following proportions: Four-tenths for the first, one-tenth for the second, three-tenths for the third and two-tenths for the fourth.

Marks for the several qualifications should be awarded independently—that is to say, marks for the first qualification by examination; for the second and third qualifications, respectively, by the ballot of fellow-students of the candidates, and for the fourth qualification by the headmasters of the schools, and the result of the awards, that is to say the marks obtained by each candidate for each qualification, should be added together and the successful student be the one who received the greatest number of marks, giving him the highest all-round qualification.

#### THE AMERICAN UNIVERSITY.

THE great educational endowments created by Mr. Rhodes, Mr. Carnegie and others naturally direct attention to our universities, and the question as to what they are accomplishing is asked on many sides. An optimistic answer is given in the last number of the *North American Review* by President Harper, of the University of Chicago, and a pessimistic answer in the last and preceding number of the *Forum* by Professor Ladd, of Yale University. Dr. Harper points out that the library and the laboratory occupy the places of honor in the university. He tells us that the laboratory for a single science should 'cost more than the entire college plant of the last generation.' The largeness of the cost of a modern university is rather attractive than otherwise to him: he has spoken of the need of a university with an endowment of fifty million dollars; and this does not, as a matter of fact, appear to be extravagant at a time when a manufacturing corporation may have a capital of a thousand million dollars.

The making of men and the advancement of knowledge is after all a more important industry than the manufacture of steel. Dr. Harper is certainly right in maintaining that professional schools should be part of the university, and is probably right in urging the affiliation of colleges with one another and with the university. But he seems to be unduly optimistic and perhaps locally influenced in professing faith in the future of the denominational university. He says: "Whatever the state may do, the obligation which rests upon the churches is as strong and as serious as it has ever been in the past." But the church can never permanently compete with the state; the future belongs to the state university. Baptists may endow a university, but no one should endow a Baptist university.

The cheerful if somewhat material optimism of President Harper is preferable to the complaining tone adopted by Professor Ladd. He gives correctly the functions of a university: "(1) The highest mental and moral culture of its own students; (2) the advancement, by research and discovery, of science, scholarship and philosophy; (3) the diffusion, as from a center of light and influence, of the benefits of a liberal, genial and elevating culture"; but he thinks that "the institutions of the higher education in this country are worth all that they are costing . . . only if they are to be prepared to exercise all these three functions in a much more intelligent and effective fashion than at present." Now every one hopes that the American University will continually improve its methods of teaching, will increasingly contribute to the advancement of knowledge, and will more and more become the intellectual and moral center of the community; but it seems odd that a university professor should doubt whether a university is at present worth what it costs. All our universities together do not cost one tenth

as much as the sugar we eat, the beer we drink or the tobacco we smoke. The education of a single man who makes a scientific discovery with industrial applications pays back to the community the entire cost of his university since its establishment. And surely the moral and intellectual influence of the university is entirely incommensurate with its cost. But Professor Ladd believes that our political leaders 'are as good as the people who tolerate them deserve,' and that in general we are in a condition of 'degradation, social and moral,' so it is perhaps no wonder that he does not altogether approve of our universities.

THE AMERICAN PHILOSOPHICAL  
SOCIETY AND THE AMERICAN  
PHILOSOPHICAL  
ASSOCIATION.

It is somewhat interesting to notice that at almost the same time last month, the American Philosophical Society, established in 1743, held a general meeting in Philadelphia, and a newly established American Philosophical Association held its first meeting in New York City. A hundred and fifty years ago all the sciences were parts of philosophy, and it was natural for a society established primarily for the promotion of useful knowledge to call itself a philosophical society. Now we have some twenty sciences, each maintaining a separate national society. The last of all the groups of special students to organize themselves is that of students of philosophy, and they not unnaturally take the name in which the American Philosophical Society has historic rights.

As a matter of fact students of philosophy have for some years met as a branch of the American Psychological Association, and it is gratifying that nearly a hundred teachers of philosophy in our colleges and universities have found it possible to organize a national society. It is also worthy of note that the Philosophical Association will meet

next winter at Washington, in conjunction with the American Association for the Advancement of Science and its affiliated societies, thus indicating its intention to be a truly scientific society. There has certainly been a tendency for a branch of knowledge, when it became reasonably definite, to split off from philosophy, leaving to that discipline those subjects regarding which agreement is impossible. But students of philosophy are now finding a definite field that can be cultivated by scientific methods, whereas students of the special sciences discover the need of examining certain presuppositions that properly belong to philosophy. There is undoubtedly at present a *rapprochement* between philosophy and the sciences, of which the newly established Philosophical Association is a sign and to which it will contribute. The first meeting, held at Columbia University, was decidedly successful. Over forty members were present and some twenty papers were presented and discussed. Professor J. E. Creighton, of Cornell University, presided, and is succeeded in the chair by Professor A. T. Ormond, of Princeton University.

In the March issue of this Journal we published an article on the American Philosophical Society, established by Franklin and 'held in Philadelphia for the promotion of useful knowledge.' The oldest of American societies, it has for more than a century and a half maintained its activity and usefulness. The general meeting held last month in the old hall of the society brought together members from all parts of the country and a large and interesting program. There may be some question as to whether the Philosophical Society should undertake to retain the national character which it very properly assumed when first established, or whether the time has not now gone by when special papers on all the sciences can to advantage be presented on one program, but it is certain that the

social and other arrangements made in Philadelphia could scarcely be equalled in any other city. Philadelphia must share with Washington, New York, Boston, Chicago and other cities the honor of being one of our chief scientific centers, but its Philosophical Society still retains a certain preeminence.

#### *SOCIETIES FOR THE SCIENTIFIC STUDY OF EDUCATION.*

THE backwardness of education as a science is borne witness to by the lack of professional societies such as exist for other sciences. It is a sign of progress, therefore, that at the last meeting of the British Association an educational section was established and that the first meeting of an 'American Society for the Scientific Study of Education' met recently in connection with the meeting of the Department of Superintendence of the National Educational Association. At the same time and place there was held a conference of teachers of education in American colleges who considered steps toward formal organization and elected as chairman, Professor John Dewey, of Chicago University, and as secretary, Professor M. V. O'Shea, of the University of Wisconsin. Both these organizations seem likely to become more and more societies of experts in the scientific treatment of educational problems rather than of men of practical influence in the management of school systems, and may seek affiliation with other scientific societies in the American Association. Next year, however, the Society for the Scientific Study of Education, and probably also the conference of college instructors, will meet with the Department of Superintendence of the National Educational Association. One of the functions of such societies is to judge as a jury of peers the value of the discoveries and hypotheses made by its members. To the lack of any association of sufficient weight to perform this service is due in part the sufferance of educational fads

and the paucity of serious investigations of the facts of school life. The impulse to research is dependent upon emulation, pride and practical wants, and the direction it takes depends still more upon social considerations. Publicity and esteem for intellectual work are among the agencies that assist progress in any field of thought. Organizations composed of experts in the study of education might also cooperate with other learned and scientific societies in important ways. The men now engaged in the promotion of knowledge through research and through the training of advanced students exert but slight influence in improving the teaching of the millions of children in the schools, and they will rarely be fit to do so directly. But a society formed of students of education who were their university associates might make use of both the knowledge and the reputation of these experts, and at the same time amend their recommendations to suit the actual conditions of school work. The recommendation of the British Association for the Advancement of Science has been thus used to support measures of reform in the teaching of geometry in Great Britain. In our own country such a formal organization of expert students of education might have led the National Educational Association to insist that the teaching of physiology be put beyond the reach of politics and one-sided enthusiasts.

#### *BIOGRAPHIES OF EMINENT CHEMISTS.*

IN our notice of the biography of the Swiss chemist Schönbein, in the *POPULAR SCIENCE MONTHLY* for April, we followed custom in giving him credit for discovering the passivity of iron, but the peculiar behavior of this metal induced by nitric acid had actually been observed forty-five years before by the English chemical manufacturer, James Keir. In his paper on the 'Dissolution of Metals in Acids,'

read to the Royal Society on May 20, 1790, Keir described quite fully many of the phenomena due to 'altered' iron, as he called it, and this property was afterwards known to many chemists; nevertheless, Schönbein first used the term *passivity*, and the discovery of the phenomena is commonly ascribed to him.

The 'Sketch of the Life of James Keir' is one of the rarest of the biographies of chemists, having been printed for private circulation, and edited by his grandson, James Keir Moilliet (London, 1868). Keir, who was born in 1735, was educated as a physician, but entered the army, and on retiring became a successful man of business, associated at one time with Boulton and Watt; he was an intimate friend of Erasmus Darwin and of Joseph Priestley, whose phlogistic views he shared in spite of the clear demonstrations of Lavoisier. In a letter to Darwin, dated 1790, Keir wrote: "I neither believe in phlogiston nor in oxygene, nor in any other of Lavoisier's metaphysical principles. . . . What I dislike in the anti-phlogistians is their pedantry and presumption; in the old system there is one assumed matter, whereas in Lavoisier's there are oxygene, hydrogene, calorique and carbone, all of which are imaginary, or at least hypothetical beings." Keir was a member of the social club known as the Lunar Society, which was founded in Birmingham in 1766, and lasted nearly forty years.

All that is known of this private society, its founders, its membership and its meetings is found in another privately printed volume, 'Scientific Correspondence of Joseph Priestley,' by Henry Carrington Bolton (New York, 1892); this contains ninety-seven letters of the eminent chemist who discovered oxygen, accompanied by historical and bibliographic notes. The book is illustrated by portraits of Priestley and of his friend Wedgwood, to whom many of the letters are

addressed; they cover the period from 1780 to 1804, the last being written by Thomas Cooper to Dr. Benjamin Rush to announce the death of Priestley, which had occurred that morning (February 6). Some letters written in 1783 concerning Watts' experiments throw light on his share in the discovery of the composition of water. Priestley, as is well known, adhered throughout his life to the theory of phlogiston, and never accepted the doctrines of his contemporary Lavoisier. The life of this great French chemist was edited by Edouard Grimaux, in a handsome, well-illustrated volume (Paris, 1888). This contains besides the story of his grand discoveries, of his government positions and his domestic concerns, many official documents, supplying the historical proofs; the events associated with his arrest, imprisonment and unhappy and tragic end, are of painful interest.

Charles William Scheele, the poor apothecary of an obscure town in remote Sweden, made twenty-five prime discoveries, any one of which would have sufficed to make him famous; his 'Letters and Drawings,' edited by A. E. Nordenskiöld were published in a handsome octavo, illustrated with plates and fac-similes. The hundred and thirty-three letters extend from 1767 to 1781, and are addressed to Gahn, Bergman, Hjelm and others; the editor endeavors to prove from Scheele's manuscripts that he isolated oxygen more than a year earlier than Priestley. Books printed outside of Sweden were hardly accessible to Scheele. In 1777 he wrote to Gahn: "Priestley's book I have not yet seen. If it were in French I should like to read it. Here I am in great darkness as respects literature, a deprivation that is very unfortunate." Those seeking details of the life and labors of Scheele must consult this authoritative work, which appears in two editions, Swedish and German (Stockholm, 1892). Scheele wrote in both these languages

indifferently, but he used Latin and symbols taken from alchemical manuscripts to designate chemical substances.

#### THE CONDITIONS OF CHEMICAL ACTION.

It has long been known that the presence of water is necessary in order that many chemical reactions shall take place, and that substances which ordinarily unite with great violence have no action upon each other when thoroughly dried. It has even been found possible to distil phosphorus in an atmosphere of oxygen, provided that the phosphorus and oxygen are both perfectly free from any trace of the vapor of water. It has, however, been found by a number of experimenters that hydrogen and oxygen will unite with each other when heated, even if dried. This exception seemed to be due to the fact that when the two gases unite, water is formed, but theoretically the first particles of the gases could not unite unless a trace of water were present. This led Professor Brereton Baker, of Dulwich College, who has done much work along this line, to the idea that the gases used might not be perfectly pure. The oxygen and hydrogen for the experiment are generally formed by the electrolytic decomposition of dilute sulfuric acid or caustic potash. But several years ago Professor Morley, of Cleveland, pointed out that the gases from these sources contain traces of impurities. By electrolyzing highly purified barium hydroxid, Professor Baker was enabled to avoid previous errors and obtain absolutely pure gases. The mixed hydrogen and oxygen were thoroughly dried (over phosphorus pentoxid) and sealed in glass tubes. After ten days' drying the tubes were heated to 600 degrees Centigrade and remained perfectly unchanged, while companion tubes, similarly prepared, except as to the drying, exploded in every instance. In tubes which had been dried only two days, the

hydrogen and oxygen united slowly to form water, but did not explode. In order to test the effect of higher temperatures, tubes were prepared with a silver spiral attached to platinum wires which were sealed into the glass. The spiral was heated until the silver melted, but no explosion took place and no hydrogen was formed. When, however, a platinum spiral was substituted the tubes did explode, probably owing to the catalytic action of the platinum. From the experiment with the silver wires it is evident that when perfectly dry, hydrogen and oxygen do not combine with each other, even at 1,000 degrees Centigrade, the melting point of silver.

The experiment with the partially dried gases seems to lend confirmation to the theory of Dr. Armstrong that without an electrolyte no chemical action is possible; for though water is but slowly formed, it is present in far greater quantity than is necessary to bring about the action, yet no explosion follows. It may be assumed here that the water formed by the union of very pure gases is itself very pure, and since pure water is not an electrolyte, this water should not cause an explosion of the gases.

#### THE PERIODICITY OF SOLAR PHENOMENA.

In the *Astronomische Nachrichten* (Numbers 3,723-24) F. Hahn has propounded a new theory to explain the periodicity of solar phenomena. The various theories, which have been advanced hitherto in explanation of the periodic phenomena which occur at the sun, have failed to take into account the so-called solar atmosphere, the light and heat absorbing envelope which surrounds the photosphere. The importance of this atmosphere, in connection with its influence on the radiant energy of the sun, has never been properly appreciated, although attention was called to it by Langley, who showed that the sun, if deprived

of its atmosphere, would radiate into space twice as much energy as at the present time. He also showed that an increase of 25 per cent. in the absorption by the solar envelope would lower the surface temperature of the earth by 100°F. Langley's attention was directed chiefly to the earth, and not to the reflex action on the sun itself, which such an atmosphere must exert. A decrease in the outside radiation of energy, caused by any change in the enclosing solar envelope, means an increase in the energy contained in the sun. It is reasonable to assume that changes in the absorptive power of the atmosphere must arise, and Mr. Hahn presents the query: What becomes of the energy which is prevented from escaping into space by the solar envelope? He endeavors to show that there may occur in the atmosphere changes sufficient to lead to alterations in the thermal conditions of the sun's mass and attempts to decide how far such changes may lead to the known variations in the phenomena at the surface of the sun. Astronomers are generally agreed in accepting the theory of Helmholtz, which accounts for the generation of the sun's heat by the contraction of its mass. This theory, while it explains the generation of heat in any star, does not in itself give information as to whether the amount of heat thus formed is just sufficient to balance that which is lost by radiation. As a fact, there are doubtless suns, as indicated by the spectroscope, which are increasing, and others which are decreasing, in temperature, and in the life of each sun there is, probably, a period of increasing, and later one of decreasing, temperature. Our sun is perhaps an example of those stars in which the heat lost by radiation is greater than that gained by contraction. With this assumption the layer of maximum incandescence and radiation will be shifted nearer and nearer toward the sun's center. The result will be that, due to the increased

absorption of the denser envelope, the solar radiation will be decreased, which will tend to raise the temperature of the inner layers of the sun itself. By this overheating the vertical temperature-gradient will become so steep that mechanical equilibrium will be impossible. Although retarded by the powerful convection currents which prevail, disturbances will sooner or later ensue as a result of these strained conditions of the internal overheating, and solar outbursts will occur. Mr. Hahn then proceeds to an analytical demonstration.

The problem consists in determining the changes in the amount of the outside radiation, caused by increased or decreased absorption. The method is an application of the Bouguer-Lambert formula for the extinction of light and heat in an absorbing medium. Formulas have been derived for the energy of radiation from the upper limits of the atmosphere, for the changes in the radiating power, and for the frequency of eruptions and spots. The results thus obtained appear to be in close agreement with observation. The object of the article is to give an abstract of the main principles upon which is built a new solar theory. In a paper which is to appear in the *Annals* of the Edinburgh Royal Observatory the author will enter more in detail into the various applications of the theory to periodic phenomena at the sun's surface. This theory differs from the views generally accepted, in that it involves the assumption that an increase in the dynamical forces at the surface of the sun indicates a decrease in the heat and light radiation, but here also the author believes that his theory accords well with the facts of observation.

#### SCIENTIFIC ITEMS.

THE National Academy of Sciences held its annual stated session at Washington, beginning on April 15.—The spring meeting of the Council of the

American Association for the Advancement of Science was held on April 17. The annual meeting will be held at Pittsburgh, beginning on June 30.

THE portrait of Benjamin Franklin, executed by Gainsborough at the time of the signing of the Treaty of Paris, and lately given to the University of Pennsylvania by the class of 1852, has been hung in the University Library.—A memorial bronze tablet has been placed on the Albany (N. Y.) Academy in memory of Joseph Henry, stating that his experiments in electricity were made in that building while he was acting as professor of mathematics.

THE British National Physical Laboratory was formally opened on March 19. Sir William Huggins, president of the Royal Society, presided, and addresses were made by the Prince of Wales, Lord Rayleigh, Lord Kelvin and others.—Professor Emil v. Behring (Marburg) will give the amount of the Nobel prize recently awarded him (\$40,000) to the Prussian State for the permanent endowment of the Institute of Experimental Therapeutics founded by him in the University of Marburg. The gift is to be devoted to the prosecution on a large scale of the researches

on serum initiated by Professor Behring.—Lord Walsingham has given to the British Museum (Natural History) his collection of butterflies and moths. This collection of microlepidoptera contains over 200,000 specimens, and is probably the largest and most valuable in the world. It includes the Zellar, Hoffman, Christoph and other collections, and contains many type specimens. Lord Walsingham has himself published numerous monographs on the microlepidoptera.—An anonymous gift of \$20,000, for the benefit of the Harvard College Observatory, has been received from a friend of the director, Professor Edward C. Pickering.

MR. ALEXANDER AGASSIZ and his party have returned to America, from their exploration of the Maldives. The principal work done was the sounding of the channels between the lagoons and the development of the plateau on which the atolls of the Maldives have been formed.—Dr. D. T. MacDougal has returned from Arizona and Sonora with an extensive collection of giant cacti and other large xerophytic plants, which are being installed in the horticultural houses of the New York Botanical Garden.







LORD KELVIN.

# THE POPULAR SCIENCE MONTHLY.

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ON THE DEFINITION OF SOME MODERN SCIENCES.\*

BY PROFESSOR W. H. DALL,  
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## INTRODUCTION.

IN the early days of this Society, as some of you may remember, it comprised those workers in science resident in Washington who were most eminent in varied branches of research. While in our Society, as in the firmament, one star differed from another star in glory, yet among those ready to contribute to the program or discussion, we might then count many of those reckoned as authorities in their special lines of work and in many different fields.

As the body of scientific men in government service, or local educational institutions, increased with the increasing importance of scientific method and the evolution of the sciences themselves, new bodies sprang into existence, aiming to exploit special provinces of the realm of science. To these naturally gravitated the members of the Philosophical Society chiefly concerned, and in the numerous flourishing organizations now existing in this city the original members of the parent association recognize its intellectual progeny.

With the differentiation of the avenues of communicating thought, it naturally came about that the chief papers in certain branches would be read in the society devoted to those specialties, and the programs of the Philosophical Society thus became less varied. But we have rather prided ourselves, and trust to the younger members to carry on the tradition, in still holding the doors open, so that any communica-

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\* Discussion before the Philosophical Society of Washington, March 15, 1902.

tion bearing on the increase or diffusion of knowledge is still as cordially welcome and as appropriately delivered before our Society as in the former time. It was frequently observed by the older members that among the benefits which they derived from our meetings none was greater than the opportunity of each to learn from the lips of a competent associate the conclusions formed in lines of research otherwise unfamiliar to the listener. Thus the mental horizon of each was broadened and the capacity for wider generalization and more philosophical views was duly enlarged.

As, by the operation of the causes already alluded to, the membership of the society has come to be devoted to fewer lines of research, it has still been possible to preserve our reputation for catholicity in science and its beneficial consequences, by calling from time to time on those eminent in particular branches, who may not be members of our body, to favor us with some account of the researches to which they are devoted, or of the present state of opinion as to the progress actually made.

To-night is one of those occasions: and I feel that I am only voicing the unuttered sentiments of all our members when I express our cordial appreciation of the courtesy our guests have shown us in their willingness to contribute to our program.

In considering the general subject of the evening, I was led to look up the definitions of science and law, as such, in the oldest available dictionaries of our language. The earliest noted is that of Phillips, in 1720, who tells us that science is 'knowledge founded upon or gained by certain clear and self-evident principles,' and Bailey, in 1737, holds it to be 'a framed system of any branch of knowledge comprehending the doctrine, reason or theory of the thing, without any immediate application of it to any uses or offices of life.' A study of other and subsequent definitions shows that the early lexicographers at least regarded science as a theoretical system divorced from practice.

Law, on the other hand, appears to have been regarded chiefly as a rule or measure imposed by some external authority on the subject of it. While the words used in defining these entities may have a modern meaning injected into them, it is practically certain that the minds which framed these definitions possessed no such comprehension of them.

For our purposes science is: exact knowledge of facts and their inter-relations, and, by an extension common to the language, the methods used in attaining this knowledge and the systematic statement of it when attained are included under the same name.

No better definition of law than that of Blackstone appears anywhere. He calls 'A rule of action.' We now amplify this definition by discriminating under the single name two classes of law, namely,

those imposed by authority human or divine; and the observed constant sequence of events which we codify as the 'Laws of Nature.'

As our possession of unclassified facts increases, the need of systematizing them becomes greater until of necessity a new science is framed to cover those categories not previously dealt with.

We hope to-night to learn something of some of the relatively new or modern sciences of which our program speaks.

The rapid development of what were a few years ago merely twigs of the tree of science into stout and fruitful branches is the most remarkable phenomenon of our times.

The majority of our grandfathers were content to declare that 'figures cannot lie,' a proverb which our fathers came to understand needed much qualification before it could be accepted. To-night we may hope to learn from a master in the science, something of the precautions by which the perversity of figures must be fenced about, in order to confine them to their useful and appropriate field.

It is not so long since eminent workers in economic questions believed it the duty of government to leave the operation of commercial forces to natural processes, the then unnamed 'Survival of the Fittest.' The bitter cry of ill-paid labor, the unreasoning fury of the strike riot, and the realization that in its essence civilization is the reversal of the processes of nature 'red in tooth and claw,' these, aided by an ever-growing consciousness of the brotherhood of man, were required to develop into a science the study of the wonderfully complex forces of economic civilization. Of this new science something will be told to us to-night.

For unnumbered centuries mankind has been slowly eliminating from the ranks of the hypernatural, phase after phase of the aspects of nature which he could come to understand. Slow indeed was the flow of grist from the mills of the goddess of wisdom unceasingly grinding. How should man account for that which was spiritual and impalpable, yet obvious, when he knew not the alphabet of that which was physical and material? Step by step must the stairway be laid on imperishable foundations before man might hope to ascend to the temple of knowledge. Thread by thread must the wires be spun and stretched from the verge of the known to the pillars of truth beyond the abyss of ignorance. What wonder if, even now, the great mass of mankind will hardly follow the investigator across the slender path of assured footing trembling in the higher air? Are not magicians, fortune tellers, mediums, all the phantasmagoria of magic and the occult still represented in our literature and life, and by hereditary transmission more or less imprinted on our instincts? The new science of psychology, still in the flush of youth, is pressing forward to lay these phantoms of the dusk and sweep the fogs away.

As for the last and most inclusive of all sciences, that which considers the interrelations which alone make civilization, science and progress possible; some of whose laws even the lowly ant and bee have unconsciously learned and applied; I must leave our guest of the evening to speak as one having authority. That man is a unit in a certain sense; that every individual carries with him determining atoms of his entire hereditary line, the unbroken continuity of which is the first condition of his existence; is a truism. That in another sense mankind is also a unit and that no member of the entire congregation can suffer or enjoy without effect upon the mass, is equally true if hard to realize. Once realized by the generality of mankind it seems conceivable that the flame of a genuine fraternity would illuminate the darker mysteries of life and labor, of good and evil, among us, as if from the refulgence of that shining city, not built with hands, of which the prophets tell.

#### STATISTICS.

BY THE HON. CARROLL D. WRIGHT,  
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**G**OTTFRIED ACHENWALL, who was born in 1719 and died in 1772, and was a professor of philosophy at Göttingen in 1750, is reported to have originated the modern statistical method. Undoubtedly others used it before Professor Achenwall, but it is as well to attribute the first specific use of the method in the modern sense to him as to any other.

The word 'statistics' is from the French 'statistique,' from the Greek 'statos,' meaning fixed or settled, from the stem 'sta,' to stand. Hence statistics means a method by which fixed or settled conditions can be determined. According to definition, statistics is first a collection of facts relating to a part or the whole of a country or people, or of facts relating to a class of individuals or interests and different countries, especially those facts which illustrate physical, social, moral, intellectual, political, industrial and economic condition or changes of condition, and which admit of numerical statement and arrangement in tabular or graphic form. Second, it is that department of political science which classifies, arranges and discusses statistical data.

As we understand it, one of the most essential primary objects of statistics is to secure a simple, concrete statement of a mass of facts the essence of which could not otherwise be expressed except by means of long and tedious descriptive language, and even by the use of such language no concrete and clearly-defined conclusion could be reached. There is no method of expressing certain things except through the statistical method. This is true when we understand that statistics

belongs to the historical or comparative method of study. The German historian, Schlosser, said that history is statistics ever advancing, and statistics is stationary history. Looking beneath the words of Schlosser, one must conclude that he meant that the constant accumulation of statistical data from period to period or from epoch to epoch—that is, statistics ever in motion—creates history, history being made up of the ever-advancing events of life which are shown through statistical methods. But that statistics of one epoch constitutes the permanent history thereof.

So the statistician, in the truest historical and comparative sense, writes history, but he writes it in the most crystallized form which can be adopted. He uses symbols, but with them he unlocks the facts of his own period so that they may be made plain to all students coming after him. He tells the story of our present state in such a way that when the age we live in becomes the past that story shall be found to exist in true and just proportions. The word 'statistics,' illustrating fixed and settled conditions, indicates the soundness of the German writer's thought and the true spirit in which the statistician should work.

The use of the statistical method in a scientific way is practically modern. In ancient times there were counts of the people, but no scientific use of the results that would warrant the application of the name statistics. These 'counts' were largely to ascertain military strength and divisions of geographical sections. David, you will remember, undertook to number the people. This effort on his part caused him a great deal of difficulty, and, so far as the history of the world is concerned, every man since David's time who has undertaken to number the people has met more or less opposition and had more or less trouble. All through history we read of counts or, as we say now, enumerations, but they were crude in the extreme and cannot be considered as statistical efforts.

Under our modern systems there are three kinds of statistics—I mean by 'kinds' methods which involve different systems to secure results. These are, first, statistics secured by the continuous record of official acts, as, for instance, the returns from the custom houses; those returns relating to imports and exports, immigration and other affairs are the results of a continuous record of events and are reported to a central office, tabulated and classified. School statistics, the returns of births, deaths and marriages—these come under this classification. They belong more clearly to the domain of bookkeeping, although statistical genius is essential in the classification and analysis of the entries.

The second class of statistics are those secured by actual enumeration, like census statistics, where aggregates are essential to the in-

tegrity of results. We must know the number of all the people, the total value of products and of capital, the aggregate wages paid in manufactures, and various other data where there would be little or no value unless all are included in the results. This class of statistics demands higher statistical qualifications, both in preparing for the enumeration and in the tabulation, classification and analysis of the results.

The third kind of statistics are those secured through a special investigation of certain representative facts. For instance if it is desired to learn the cost of producing iron and steel, it is not necessary, as in the previous case, to secure data for all the establishments engaged in such production. A few representative works offer ample information for determining cost of production. So, in endeavoring to ascertain the course of wages and prices, it is not essential to secure aggregates or data relating to all prices or to the wages paid to all the people employed.

The practical work of official statistical offices is divided into three parts also—first, the collection of data, which involves the preparation of schedules and instructions; second, the tabulation and the presentation of the results obtained, and, third, the analysis. No statistical table should ever be used without consulting carefully all textual treatment thereof, the accompanying notes and the analysis.

Facts may be presented in two ways—in tables, comparative and otherwise, and by the graphical method. The latter is popular and very effective in displaying proportions. The difficulty with it is that one cannot in a speech or in an article quote the diagrams, but it has a very important place in scientific statistics. The graphical method is carried to an absurd degree at times, but it nevertheless offers to a certain class of minds the very best method of determining results. In the final reflections upon statistics, however, one is drawn to the figures themselves.

With these preliminary statements, the general subject for discussion to-night brings us to the question: Is statistics a science or a method? It is not a matter of much consequence whether statistics constitutes a science or is simply a method. English writers on statistics generally consider it a method; continental writers, a science. American students often lean to the continental view. It is true that statistical research can be called a scientific method of determining facts and for studying various phenomena from which laws relating to life, production, distribution, consumption, etc., etc., can be drawn; and the method must be considered scientific, because by it the facts can be clearly stated, classified and analyzed, elements which make science in every department.

We speak of the science of botany, for one reason because all the



facts relating to botany can be classified, and so, as to other departments of human knowledge, classification or the lack of it may determine the scientific character of the knowledge. Science demands a classification of facts so rigid that all men will consent to its use and to the conclusions to which it may point.

Notwithstanding statistics is a science or a scientific method, its use is often empirical, deceptive, illusory and dishonest, and because of these things the method itself is often condemned. No one thinks, however, of condemning anaesthetics because the burglar chloroforms his victim, or the elementary features of arithmetic, the means by which all honest accounts are kept, simply because dishonest accounts are made possible by the same means. So many instances of the lying use of honest statistics meet one's observation that it is not remarkable that many make surprising denunciation of statistics and the assertion that anything can be proved by it is made to belittle the importance and value of the method.

It is true that one so disposed can, by dropping an essential element of a table, show the exact reverse of the truth, just as the foolish man said he could prove by the Bible itself there was no God, referring to the statement 'there is no God,' leaving out part of the whole statement, which is 'The fool hath said in his heart, there is no God.' So writers and speakers who have a particular economic theory to sustain will drop out of the statistical presentation of the facts the elements which work against them, using the others as the whole truth. This is seen very often in political speeches. The attempt to make comparison between the percentage of growth of population and the percentage of growth in the expenditures of the Federal Government, using no facts relative to the great increase in mechanical production and of wealth, is a vicious use of statistical data. Such showings are the results of the work of the statistical mechanic, the man who constructs statistical tables to order.

Statistics really take the place of observation. The latter is not trustworthy. Enumerations, counts, or records of continuous events are essential to establish accurate knowledge. But statistical science in this direction differs from the exact sciences. A few experiments may establish the fact that water freezes at a certain point or that the intermingling of two chemical agents will produce certain results, and the conclusion is that the same results will always be secured when the same elements are brought in contact: but the phenomena of life conditions and productions may not so easily be ascertained. Statistical work is full of fallacious details. Fallacies are found in the ordinary practice of striking averages. These things add to the disturbing influences resulting from any great enumeration, to perplexing differences among international trade accounts and to miscalculation by individual inquirers.

M. Quetelet, who was the first to use statistics in moral directions, explained the principles which ought to guide us in the matter of averages. He pointed out that an average may indicate two different things. For instance, one measures Nelson's monument ten times, and always with a slightly different result, and then adds the measurements together and divides the same by ten, the quotient, it is alleged, being an average or mean. So one may accurately measure the Duke of York's Pillar, the Parisian Obelisk and the Column Vendome, add the measurements together, divide the sum by three, and declare the quotient to be the average or mean height of those monuments. Quetelet contended, and very properly, that the results in the two instances are of such different significance as to require two separate names. He would limit the average or mean to cases represented by the first illustration—repeated measurements of one monument—and he would apply the term 'arithmetical mean' to cases represented by the second illustration—the measurement of several monuments. The repeated measurings of one monument result in a mean approximation to something actually existing, and this is an excellent definition of an average. The measurings and calculations having reference to a number of monuments result in no knowledge of anything existing; they simply and only indicate a relation among things actually existing.

This difficulty often appears in reporting average wages. Take, for instance, a works employing 20 men at \$1 per day, 40 men at \$2 per day, and 60 men at \$3 per day. The ordinary bookkeeper in a counting room would add these rates together—\$1, \$2 and \$3—making a total of \$6 as the result of the different rates. He would divide 6 by 3, the number of rates, and declare that the average wages in his works was \$2 per day. This is an arithmetical mean. The true average is to be obtained by a more elaborate calculation. Twenty men at \$1 earn \$20, 40 men at \$2 earn \$80 and 60 men at \$3 earn \$180 per day. Thus, 120 men earn \$280 per day. Dividing \$280 by 120, we have the true average, which is \$2.33 instead of \$2, the arithmetical mean. So also there are many fallacious calculations drawn from the use of percentages.

Some amusing incidents happen from this method. A writer recently declared that 300 per cent. of the Turks in the city of Washington were criminals. On investigation it appeared that there was one Turk in the city, and he had been convicted three times. So of the young student who took for his thesis the assertion that women in co-educational colleges more frequently married during their college course than men in the same institution. He found a college in which there were 100 men and 2 women. One of the men married one of the women. Hence he sustained his conclusion that 1 per cent. of the men married, while 50 per cent. of the women married. Thorold Rogers'

work 'Six Centuries of Work and Wages' contains several instances of this pernicious use of percentages. So, also, many are constantly using the unscientific conclusions drawn from concomitants—because one thing exists another logically exists contemporaneously.

These illustrations show the necessity of making statistics, the statistical method, thoroughly scientific in all directions, but this scientific conception of statistics does not warrant statisticians in using algebraic formula or in resorting to the calculus to secure results. The results under such methods rarely vary from those secured by the simple common-sense method of statistics; on the other hand, they disturb the reader and the common mind cannot understand them. All statistics should be simple, straightforward and clear, and any confusing element which disturbs this clearness is detrimental to the real purpose of the statistical method. While there are very many illustrations going to show the misuse of the method, nevertheless all right-minded men understand that, in economic questions especially, the comparative and historical method of study is the correct one, and the concrete, historical and comparative method is best carried on through the scientific use of statistics.

#### POLITICAL ECONOMY.

BY ROLAND P. FALKNER,

LIBRARY OF CONGRESS.

THE problem of definitions is a perplexing one, and some of the most distinguished writers on political economy make no attempt to introduce their treatment by a definition. Marshall, for instance, tells us 'Political economy is a study of man's actions in the ordinary business of life; it inquires how he gets his income and how he uses it.' A definition is, at the best, but a guide-post whose accuracy cannot be tested until the path has been tried. Its principal service is as a preliminary line of demarkation in comparison with other things supposed to be more familiar than the field to be entered upon. One definition which has become commonplace is that political economy is the science of wealth, and if we abstain from any discussion of what constitutes a science and what constitutes wealth, it may be deemed measurably satisfactory.

After all, the phraseology of a definition is far less important than the matter which follows it, and while economists, in common with the devotees of other studies, have not been lacking in verbal controversies as to the definition of their subject, the subject matter of their discussions, apart from mere questions of emphasis, has been in the main identical. The question of definition resolves itself, therefore, into an

inquiry as to the scope of political economy and the methods which it pursues.

The division between the various fields of human knowledge is largely a matter of convenience, a sort of intellectual division of labor. This is particularly the case with those subjects which deal with the various aspects of human relations, especially political science, political economy and sociology. Human activities are so interlaced that it is comparatively easy, from whatever standpoint we begin their investigation, to extend the field of inquiry so as to embrace them all. There has been therefore, respecting these three subjects, much unprofitable controversy as to which should be deemed the dominant or master science and to which priority should be given. If, however, the study of each of these aspects of human society calls for peculiar aptitudes on the part of the investigator, it would seem that the best results should be obtained when each laborer cultivated his own patch without indulging in border controversies with his neighbors.

Political economy, the science of wealth, deals with man's relation to nature in the satisfaction of his material wants. Since nature does not shower its bounties abundantly, man's wants cannot be satisfied without human effort. Economics seeks to discover the general rules which govern man in this effort. Certain of the conditions of this activity are axiomatic and fundamental, while others are dependent upon time, place and circumstance.

Primary conditions are nature's limits and man's wants, and both have hitherto been accepted without inquiry. Of late years, however, economists have sought to measure man's wants, to determine their direction and intensity, and to thus ascertain their effects as molding forces in the economic activities which result from them. This has given us an analysis of demand which has been useful in pointing out the subjective elements in our economic activities, though it has led its adherents to trench closely upon the domain of psychology and has exposed them to the criticism that they have been digging in other men's gardens with inefficient instruments. The results of this analysis have been extremely interesting, and despite the protest of the psychologists, promise a restatement of economic theory based upon a more exact formulation of the laws of demand. Yet it can hardly be said that these views and the treatment which follows from them have become commonplaces of economic reasoning, and as it is the general consensus of opinion with which we are concerned, we may pass them over.

It was not until the economic processes became somewhat differentiated that the necessity for an explanation of them was felt. When men awoke to the idea that the affairs of every-day life were subject to rules and order, they observed that the processes involved were by no means simple. They saw men cooperating in the production of

goods, the fruits of this cooperation divided among the participants, the products themselves change hands from one person to another before they were used directly for the satisfaction of desire. In other words, they saw the economic sequence of production, exchange, distribution and consumption, and it became the object of political economy to discover the conditions and rules under which these phenomena were enacted in the daily affairs of men. As parts of one sequence they had relations one to another in which were enmeshed the relations of the human beings who conducted them. Upon what principle do the latter act?

Observation that to most men labor is irksome led to the axiom that in all economic activity men sought the maximum result with the minimum effort. This homely psychological generalization is as fundamental to the interpretation of economic phenomena as the equally homely physical generalization that nature's wants, with reference to man's desires, are limited. It has appeared in various guises, of which perhaps the most obnoxious is the concept of the economic man, who in all his doings follows the precepts of an enlightened self-interest—a being unknown to actual observation, who has merited the scorn which has been heaped upon him. Man in his economic dealings follows his self-interest according to the measure of his enlightenment, but it cannot be denied that very frequently the light which is in him is darkness. The economic man is an ideal towards which, solely in their economic dealings and without reference to other activities, the men of every-day life strive. No adequate explanation of the affairs of life can be made on any other assumption than that men follow their rational interests so far as they perceive them and that foremost among them is the desire to obtain the largest result with the least expenditure of effort.

Thus understood, the economic man is the key by which the economist seeks to interpret the affairs of every-day life. It is simply the key, and not the subject matter to be interpreted. This the economist finds around him, varying at different stages of the world's progress with the growth of knowledge, the order of society and the diffusion of wealth.

These elementary considerations of the scope of political economy have briefly indicated the nature of its method. With a few simple generalizations it seeks to interpret the composite phenomena which it observes. Observation, therefore, and deduction are inextricably combined in it. If the concrete basis upon which it rests is forgotten and observation is thrown into the background, the result is a strongly deductive analysis which applies a few simple conditions to the successive phenomena of the economic sequence to be interpreted. This is the characteristic of the classical or orthodox school of political

economy, against which in recent times there has been a strong reaction to bring to honor again the factor of observation. It insists that this observation shall not be preliminary only, but that each successive phenomenon shall be tested by it. Price, for instance, is not an abstraction, but a concrete thing, which must be studied before we can have any proper theory of price, and so with all the phenomena of every-day life. The principle of observation applied to the past is the principle of historical research, and as a knowledge of the past is the best key to the understanding of the present, so those who hold this view have engaged in considerable historical researches which have given to their tendencies the name of the historical school. These economists have performed a notable service in pointing out the relativity of economic laws. They have dispelled the notion that the principles of political economy were fixed and immutable and that their activity was necessary to quicken the germ of development which was hidden in the older and more deductive economics. But it will be recognized that they introduce no new principles of investigation nor any to which, had they then been formulated, the great writers of earlier days could not have subscribed. They have enriched political economy by showing us that the phenomena to be interpreted are far richer and more complex than they appeared to the older economists, but they have not dispensed with the necessity of interpretation, for that is the life blood of the science.

#### PSYCHOLOGY.

BY PROFESSOR E. A. PACE,  
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TO define *a priori* the nature and scope of a science is always difficult; and it is especially difficult during periods of transition. Speculation as to what psychology ought to be is of course interesting and important; but its value depends largely upon the frank recognition of what psychology actually is, or perhaps what the psychologies actually are. Even the statement that psychology is the 'science of mental processes,' owes much to its elasticity; for the psychologists who accept it differ as to the meaning of the terms 'mental' and 'process.' They differ more widely as to the worth of particular methods and hypotheses: and they are by no means unanimous regarding generalizations and laws.

This situation is due in part to the fact that psychology, on taking its place in the midst of the empirical sciences, found that these, by their rapid accumulation of data, had both lightened and increased its task. If the way was open to the solution of older problems, it was also beset by new problems which belonged, on one side at least, to phys-

iology and physics. How the methods and results of these sciences could be turned to profit, without any sacrifice of its own method or autonomy, was, for psychology, not easy to determine. Fortunately, with some friendly discussion regarding metes and bounds, psychology has not only held its own, but has also rendered service to its neighbors.

It has not abandoned its traditional method. For the analysis of the various states, processes, tendencies and activities which appear in the individual consciousness, introspection cannot be dispensed with. If it is supplemented, as we nowadays say, by other methods, this implies not that self-observation of a keener sort is our prerogative, but rather that, with clearer knowledge of the conditions upon which our mental life depends, we are enabled to study each process both in itself and in its manifold relations. Comparison is thus a conspicuous and even an essential feature of modern psychological methods.

Psycho-physical research, as the name indicates, seeks to determine the relations between mental processes and physical processes. Whether this determination and its quantitative results should be called measurement, is still a subject for discussion. But there can no longer be any question as to the value for psychology of experimental methods. With the aid of these it is now possible to compare accurately changes in sensation and variations in the quality and intensity of external stimuli, to observe closely the organic modifications which accompany emotion, and to fix, within reasonable limits, the time-rate of the most complex processes. In a general way, of course, it has always been known that there was some sort of connection between the psychical and the physical; what modern psychology accomplishes is the more detailed and more exact investigation of that connection. Similarly with the phenomena of association, memory, attention, inhibition and fatigue; their importance has long been recognized, but their thorough analysis is the outcome of experimental work.

A complete solution of the problems that are offered in this portion of the field would leave on our hands the larger problem as to the development of consciousness. That mind is a growth, that its behavior in any given moment is affected by its behavior in all the past moments, all psychologists admit. But there is much to be learned regarding the successive phases of this growth. By what steps does the mind advance from the earliest impressions of childhood to the complex activities of adult life? What share in the process shall be assigned respectively to heredity, to the influence of environment, to the mind's own reaction by impulse, imitation and the growing consciousness of ends to be attained? The answer to such questions involves obviously a comparison between later forms of mental life and its simpler beginnings which may lead us far into the province of biology. Certainly no theory of evolution can afford to disregard the mental factors any

more than psychology can overlook the results established by biological research.

This becomes more evident in view of the fact that both mental and bodily life may and too often does vary from the course of normal development. Those modifications which, either suddenly or gradually, reduce the mind to chaos, have in the past been studied chiefly on their practical side. They possess none the less an interest for psychology. By contrast at least they throw light on the normal activities of mind.

It should be noted, however, that in mental pathology as in psychophysics and in the study of normal development, comparison is simply a means of getting new information concerning those processes which appear in the normal individual consciousness. To render this information available and to coordinate the multitude of facts which it contains or suggests, some sort of theory is necessary; and there is no lack of theorizing in modern psychology.

Owing, perhaps, to the predominance of comparative methods, the theory of psycho-physical parallelism is just now in vogue. It is agreed, in general, that mental processes and physical processes take place simultaneously, and to this extent the one series may be said to parallel the other. But beyond this, discussion is rife and the end is not yet. If, on the more orthodox view, it is claimed that the two series are merely parallel, *i. e.*: without any causal nexus, it is urged on the other hand, especially in these latter times, that there must be interaction, mind producing effects in the organism and *vice versa*. While, again, it is maintained that the conscious processes have causal relations of their own—a specific psychological causality; it is also asserted that the causal relation exists for the physical processes only, and that mind gets its connectedness as an accompaniment of the bodily series.

The final adjustment of these claims may depend, in a measure, upon the eventual acceptance or rejection of the hypothesis, now favorably regarded, that every conscious state has for its organic basis the passage from centripetal effects in the brain to centrifugal effects, and consequently has its efferent or motor phase as well as its afferent or sensory phase. This hypothesis, however, leaves untouched the inquiry as to the precise way in which mind acts on body and body on mind. The latter problem, in fact, is essentially metaphysical. It points at once to the remoter region in which epistemology and criticism hold sway.

More than any other science, psychology finds itself obliged to canvass its results in the light of philosophy. Of late the statement has been made quite frankly that the way to psychology has its starting-point in philosophy. Be this as it may, psychology is, for the time being, at the stage of self-examination, taking an account of its titles to existence as a science. Not that it doubts of its proper object;



the whole range of experience and of scientific thought is before it. But the question is—how can this object be laid hold of? The spontaneous, unreflecting attitude of mind is confessedly beyond the reach of investigation. And if by reflection we endeavor to describe and to explain the mental life, do we not construct for our own purposes an object which is more or less artificial?

This criticism implies no skeptical tendency. It surely will not deter psychologists from their work of investigating the more subtle elementary processes of mind, its unfolding in the individual and its relations to the complex activities of its environment.

#### SOCIOLOGY.

BY LESTER F. WARD,  
U. S. GEOLOGICAL SURVEY.

SO far as the definition of sociology is concerned, it is simply the science of society, or the science of social phenomena. All the more specific definitions that have been proposed have created more confusion than they have cleared up. What is needed in sociology is not definitions, but a clear presentation of the scientific principles underlying it. There is one such principle, failure to recognize which causes most of the difficulty in endeavoring to establish the science. This principle, however, is one that also applies to psychology, biology, and all the other sciences classed as 'complex'—to the biological sciences and the moral sciences. This principle may be formulated as follows:

*In the complex sciences the quality of exactness is only perceptible in their higher generalizations.*

Or, since exactness, *i. e.*, uniformity, invariableness, reliability, etc., is what constitutes scientific law, the same truth may be simplified and reduced to the following form:

*Scientific laws increase in generality as the sciences to which they apply increase in complexity.*

In sociology, therefore, which is the most complex of the sciences, the laws must be the most highly generalized. I shall not attempt to do more here than bring forward a few illustrations of the above propositions. It is clear that the method of sociology is essentially that of generalization, *i. e.*, of grouping phenomena and using the groups as units. Nature works by this method, for example, in chemistry, where it is believed that the higher compounds have as their units compounds of lower orders.

Social phenomena are obtrusive, ever-present, multitudinous. Their very proximity is a bar to their full comprehension. This I have called 'the illusion of the near,' and likened it to trying to see a city

or a forest while in its midst. The near is indefinite and unsymmetrical. It presents a multitude of dissimilar, heterogeneous objects. They appear to be without order. To see order in them they must be seen from a distance. Beauty is almost a synonym of order. A landscape is beautiful because distance has reduced its chaos of details into order. A mountain seen at a distance is a symmetrical object of rare beauty, but when one is climbing it the rocks and crags, the ridges and gulches, the trees and prostrate logs, the brush and briars, constitute a disordered mass to which the term beauty does not apply. It is much the same with social phenomena. They must be seen, as it were, at long range, which brings groups of facts into relief and shows their relations.

What Dr. Edward B. Tylor has called 'ethnographic parallels,' viz., the occurrence of the same or similar customs, practices, ceremonies, arts, beliefs, and even games, symbols and patterns, in peoples of nearly the same culture at widely separated regions of the globe, proves, except in a few cases of known derivation through migration, that there is a uniform law in the psychic and social development of mankind at all times and under all circumstances working the same results. The details will vary with the climate and physical conditions, but if we continue to rise in the process of generalization we shall ultimately reach a plane on which all mankind are alike.

Even in civilized races there are certain things absolutely common to all. The great primary wants are everywhere the same, and they are supplied in substantially the same way the world over. Forms of government seem greatly to differ, but all governments aim to attain the same end. Political parties are bitterly opposed, but there is much more on which all agree than on which they differ. Creeds, cults and sects multiply and seem to present the utmost heterogeneity, but there is a common basis even of belief, and on certain occasions all may and sometimes do unite in a common cause.

Not only are the common wants of men the same, but their passions are also the same, and those acts growing out of them which are regarded as destructive of the social order and are condemned by law and public opinion, are committed in the face of these restraining influences with astonishing regularity. This is not seen by the ordinary observer, and every crime or breach of order is commonly looked upon as exceptional. But when accurate statistics are brought to bear upon this class of social phenomena they prove to be quite as uniform, though not quite so frequent, as the normal operations of life.

The ordinary events of life go unnoticed, but there are certain events that are popularly regarded as extraordinary, notwithstanding the fact that the newspapers every day devote more than half their space to them. One would suppose that people would some time learn

that fires, and railroad accidents, and mine disasters, and boiler explosions, and robberies, and defalcations, and murders, and the whole list of events that make up the daily news, were normal social phenomena. Nearly every one of them has occurred nearly every day in nearly every country in the world during the lives of us all and those of our fathers and grandfathers. But this enormous mass of evidence has no effect whatever in dispelling the popular illusion that such events are extraordinary. There is nothing new in 'news' except a difference in the names. The events are always the same. All this applies equally to those larger events that make up the bulk of what is popularly understood as human history. Viewed from the standpoint of sociology, history contains nothing new. It is the continual repetition of the same thing under different names. This is what is meant by generalization. We have only to carry it far enough in order to arrive at unity. Society is a domain of law and sociology is an abstract science in the sense that it does not attend to details except as aids in arriving at the law that underlies them all.

We may call this the *sociological perspective*. It is the discovery of law in history, whether it be the history of the past or the present, and including under history social as well as political phenomena. There is nothing very new in this. It is really the oldest of all sociological conceptions. The earliest gropings after a social science consisted in a recognition of law in human affairs. The so-called precursors of sociology have been those who have perceived more or less distinctly a method or order in human events. All who have done this, however dimly, have been set down as the heralds of the new science. Such adumbrations of the idea of law in society were frequent in antiquity. They are to be found in the sayings of Socrates and the writings of Aristotle. Lucretius sparkles with them. In medieval times they were more rare, and we scarcely find them in St. Augustine, but Ibn Khaldoun, a Sarracen of Tunis, in the fourteenth century gave clear expression to this conception. His work, however, was lost sight of until recently, and Vico, who wrote at the close of the seventeenth century and beginning of the eighteenth, was long regarded as the true forerunner of Montesquieu. Still, there were many others both before and after Vico, and passages have been found reflecting this general truth in the writings of Machiavelli, Bruno, Campanella, Bacon, Hobbes, Locke, Hume, Adam Smith, Ferguson, Fontenelle, Buffon, Turgot, Condorcet, Leibnitz, Kant, Oken, etc.

The theologically inclined, when this truth was brought home to them, characterized it by the phrase 'God in history,' and saw in the order of events the divine hand guiding the acts of men toward some predestined goal. This is perhaps the most common view to-day outside of science. But science deals with phenomena. Sociology therefore

can only become a science when human events are recognized as phenomena. When we say that they are due to the *actions* of men, there lurks in the word 'actions' the ghost of the old doctrine of free will, which, in its primitive form, asserts that any one may either perform a given action or not according as he may will. From this point of view it is not supposed that any event in human history need have occurred. If the men whose actions caused it had willed otherwise it would not have occurred.

The scientific view of history is that human events are phenomena of the same general character as other natural phenomena, only more complex and difficult to study on account of the subtle psychic causes that so largely produce them. It has been seen more or less clearly by the men I have named and by many others that there must be causes, and the philosophy of history that gradually emerged from the chaos of existing history was simply an attempt to ascertain some of these causes and to show how they produced the effects. To those who make the philosophy of history coextensive with sociology this is all that sociology implies. Certainly it was the first and most essential step in the direction of establishing a science of society. The tendency at first was strong to discover in the environment the chief cause of social variation, and some authors sought to expand the term *climate* to include all this. This doctrine was of course carried too far, as shown by the saying that 'mountains make freemen while lowlands make slaves.' It was found that this was only half of the truth, that it took account only of the objective environment, while an equally potent factor is the subjective environment: *caelum non animus mutant qui trans mare currunt*. Character, however acquired, is difficult to change and must be reckoned with in any attempt to interpret human events. Thus expanded, the study of society from this point of view becomes a true science, and recently it has been given the appropriate name of *mesology*. The great influence of climate and physical conditions must be fully recognized. It reaches back into the domain of ethnology and physiology and doubtless explains the color of the skin, the character of the hair, and the general physical nature of the different races of men. The psychic effects of the environment are scarcely less important, and the qualities of courage, love of liberty, industry and thrift, ingenuity and intelligence, are all developed by contact with restraining influences adapted to stimulating them and not so severe as to check their growth.

The social effects are still more marked. We first see them in the phenomena of migration and settlement and the ways in which men adapt themselves to the conditions, resources and general character of the region they may chance to occupy. The question asked by the traditional boy in the geography class, why the large rivers all run

past the great cities, illustrates how clearly everybody sees natural law at work in society. It is the laws of society that determine the direction in which population moves. For example, in peoples at all advanced the head of navigation of rivers is usually the site of the principal towns. A short time ago, when water was more used than now as a power, there was usually combined with the advantages offered by the head of navigation (vessels being then smaller than now), the additional advantage of the fall in the stream, which is almost always greatest at the point where the piedmont plateau joins the coastal plain. As streams only reach their base level after emerging upon the coastal plain, this sudden fall almost always occurs a short distance above the head of navigation. As this is true of all the streams that drain a continent, a line may be drawn through this point on all the rivers and it will be approximately parallel to the coast. Such a line is called the 'fall line,' and it is a law of population that the first settlements of any country take place along the fall line of its rivers.

There are many laws that can be similarly illustrated, and careful observation reveals the fact that all social phenomena are the results of its laws. The one example given must suffice in the present case. But these social, or sociological, laws may themselves be grouped and generalized, and higher laws discovered. If we carry the process far enough we arrive at last at the fundamental law of everything psychic, especially of everything affected by intelligence. This is the *law of parsimony*. It has, as we shall see, its applications in biology, and its homologue in cosmology, but it was first clearly grasped by the political economists, and by many it is regarded as only an economic law. Here it is usually called the law of *greatest gain for least effort*, and is the basis of scientific economics. But it is much broader than this, and not only plays an important rôle in psychology, but becomes, in that collective psychology which constitutes so nearly the whole of sociology, the scientific corner stone of that science also.

We have seen that the quality of scientific exactness in sociology can only be clearly perceived in some of its higher generalizations, where, neglecting the smaller unities which make its phenomena so exceedingly complex, and dealing only with the large composite unities that the minor ones combine to create, we are able to handle the subject, as it were, in bulk. Here we can plainly see the relations and can be sure of their absolute uniformity and reliability. When we reach the law of parsimony we seem to have attained the maximum stage of generalization, and here we have a law as exact as any in physics or astronomy. It is, for example, perfectly safe to assume that under any and all conceivable circumstances, a sentient and rational being will always seek the greatest gain, or the maximum resultant of gain—his 'marginal' advantage.

Those who affect to be shocked by such a proposition fail to understand it in its full breadth. They think that they themselves at least are exceptions to the law, and that they do not always seek their greatest gain, and they give illustrations of actions performed that result in a loss instead of a gain. This is because they understand by gain only pecuniary gain, or only gain in temporary enjoyment or immediate satisfaction. If they could analyze their feelings they would see that they were merely sacrificing a present to a future advantage, or what they regard as a lower to what they regard as a higher satisfaction. When Henry Clay said (if he did say it) that 'every man has his price,' he may have merely stated this law in a new form. If we make the important qualification that the 'price' is not necessarily a money price, we may see that the statement contains a truth. Even in the lobby, which he probably had in mind, it is well known that downright bribery is very rarely resorted to. It is among the least effective of the lobbyist's methods. There are other far more successful as well as less expensive ways of gaining a legislator's vote. Passes on railroads and other favors of that kind are much more common, but even these are relatively coarse and transparent, and the great vested interests of a country know how to accomplish their ends by much more subtle means. It is only necessary to put those whom they desire to influence under some form of obligation, and this is usually easy of accomplishment. Among the most effective means to this end are social amenities and the establishment in apparently the most disinterested ways of a friendly *entente*, which appeals to the sense of honor and makes any man ashamed to act contrary to the known wishes of a friend. Under such imperative influences as these constituencies are easily forgotten.

But this is by no means the whole meaning of the law. It deals solely with motives, and worthy motives are as effective as unworthy ones. It is based, it is true, on interest, but interest is not always bad. It is much more frequently good. It was necessarily good, at least for the individual, in the beginning, since it had the mission to impel life- and race-preserving activities. Interest may be perverted, but this is the exception. Men feel an interest in doing good, and moral interest is as real as any other. Ratzenhofer shows that men have been profoundly moved by what he calls 'transcendental interests,' which he defines as a reaching out after the infinite, and to this he attributes the great religious movements of society. If therefore we take into account all these different kinds of interest, physical, racial, moral, social and transcendental, it becomes clear that all action is based on supposed gain of one or other of these orders.

Still, the world has never reached a stage where the physical and temporary interests have not been paramount, and it is these upon

which the economists have established their science. Self-preservation has always been the first law of nature, and that which best insures this is the greatest gain. So unerring is this law that it is easy to create a class of paupers or mendicants by simply letting it be known that food or alms will be given to those who ask. All considerations of pride or self-respect will give way to the imperious law of the greatest gain for the least effort. All ideas of justice which would prompt the giving of an equivalent vanish before it, and men will take what is proffered without thought of a return or sense of gratitude. In this respect men are like animals. In fact, this is precisely the principle that underlies the domestication of animals and the taming of wild beasts. So soon as the creature learns that it will not be injured or molested and that its wants will be supplied, it submits to the will of man and becomes a—parasite. Parasitism, indeed, throughout the organic world is only an application of the law of parsimony. Pauperism produced in the manner described is social parasitism. But parasitism always results in degeneracy, and pauperism, engendered in society by well-meaning persons ignorant of the law of parsimony, is social parasitic degeneracy.

While, therefore, in view of the number and variety of causes that combine to determine any single act, no law can be laid down as to how any individual will act under a given set of circumstances, we have a law which determines with absolute certainty how all men act under all circumstances. If there is any apparent exception to this law we may be sure that some element has been overlooked in the calculation. Just as, in the case of a heavenly body which is observed to move in a manner at variance with the established laws of gravitation and planetary motion, the astronomer does not doubt the universality of those laws, but attributes the phenomena to some undiscovered body in space of the proper size and in the proper position to cause the perturbation, and proceeds to search for that body; so in human society, if there are events that seem at variance with the fundamental sociological law of parsimony, the sociologist may safely trust the law and proceed to discover the cause of the social perturbation.

## THE COMMERCIAL VALUE OF HUMAN LIFE.

BY MARSHALL O. LEIGHTON.

ENLIGHTENED society readily grants that the lives of its members constitute its most treasured resource. Legislative authority has reserved its severest penalties for those who plot against and destroy its subjects. Along with the advancement of civilization has come a higher and higher appreciation of the inalienable right of the human organism to live its allotted time, and the most benign forms of government in the present day assume that its first duty is the preservation of the life and the comfort of its units.

Pagan history reveals a frightful waste of the resource vested in human life, and early Christian times are marked by only a slight improvement. Wanton destruction continued to be common even to a later date, and is at the present time excused under well-known and unusual circumstances. Yet the tendency has been and will ever be to preserve more and more securely bodily existence of mankind.

There are two radically distinct measures of human life. The one is purely humanitarian and considers only the divinity of man. Under such an estimate, the life of an individual must be priceless, and cannot be approximately valued in terms employed in monetary denomination. The other seeks to eliminate all sentimental considerations, and deals with the individual upon the basis of his value to the community as a productive agent, like a horse, locomotive or cotton gin. The second basis of measurement is an unpopular one, and has received so little attention that it is regarded as undeterminable by the general public. The majority of the computations set forth in the few paragraphs now available can be regarded as little more than wild, disingenuous guesses.

What, then, determines the value of human life? As eminent an authority as Rochard has stated that it is the sum "that the individual has cost his family, the community or the state, for his living, development and education. It is the loan which the individual has made from the social capital in order to reach the age when he can restore it by his labor." It is hardly probable, however, that this statement will receive permanent acceptance by a thoughtful man. A little reflection will show that it reverts to the generally discredited and socialistic theory that values are determined by cost. Under such a valuation, the resource vested in an individual grows from birth, not with his increasing powers of production and the greater certainty of



his attaining the age of self-support and becoming useful, but by reason of the fact that his maintenance is costing more and more. It would mean that the individual is most valuable at the moment before he becomes self-sustaining, and thereafter loses value until he has paid back to society the cost of his maintenance during dependent years. The time arrives when the account is balanced, and he is of no value whatsoever, even though he might be at the prime of his productive powers. On the other hand, the generally accepted meaning of value has little relation to the cost of production; it depends upon final utility. The value of a commodity depends upon its use, or its productive ability in a community, and, as we are dealing with life as a commodity, in truth, an article, these well-established economic principles must apply, even as truly as in the case of commercial products, in the market of New York. The more logical view, therefore, must be that the commercial value of a life must be measured by its general usefulness, its power of production, and the monetary returns which it makes to society.

Numerous suits for damages, in courts of law, for the wrongful deaths of individuals constitute the commonest, the most fruitful and almost the only trustworthy references available in which life values are dealt with. It has been necessary for judicial authority to consider the question to a minute degree, and if the basis of computation is applicable to the conditions found in the general social universe, it ought to provide a trustworthy source of information upon the subject.

It will be seen at once that in suits at law for compensation for death, the loss is computed from the standpoint of the surviving relatives who bring the suit; a widow prays for compensation for the loss of her means of support; or a bereaved family petitions for damages occasioned by the loss of services of a mother. The question therefore to be determined is: Does the loss to the surviving relatives represent, in any degree, the loss to society? Let us examine into the conditions governing judicial procedure in cases of this kind.

The principle generally adhered to in estimates of life values is well defined by the English court procedure, and this has been followed in spirit if not in letter by the majority of the states of our union. It is, in effect, as follows: "The jury may give such damages as they shall deem a fair and just compensation with reference to the pecuniary injury resulting from such death." In nearly every state, therefore, pecuniary loss is made the basis of damages, and exemplary or punitive damages are not permitted. This means that the damages allowed in such cases represent what are believed by such courts to be actual loss, without any suspicion of punishment for the party responsible for the destruction. Such punishment assumes a charge for premeditation or criminal negligence, and is dealt with by other methods than by civil

suit. The principle surely conforms to the basis of computation applicable to the loss to society at large.

Damages cannot be given as a solatium. It is assumed that the bereavement of a party can not be soothed by an application of the coin of the realm, and the higher courts scrutinize the work of juries in order to eliminate the results of passion upon the part of the members thereof. Sympathy for the destitute orphan can have no part in the award of damages. This principle, also, conforms to the requirements in estimating the loss to society.

Nothing can be allowed for the injury to the deceased nor for physical nor mental suffering. Again appears a conformation to the conditions demanded by the social state. The loss of a mill operative in the Commonwealth of Massachusetts is indirectly felt by the inhabitants of the State of Delaware, yet such loss is not greater by reason of the physical disfigurement of said operative nor the mental sufferings which he may have been obliged to undergo in the process.

Insurance of the life of the deceased is no mitigation of damages; this rule of the courts is absolute. It is considered that if the deceased was sufficiently productive to enable him to pay his annual insurance premiums, it is clearly in testimony of his thrift and an element in favor of his greater usefulness, therefore his greater value to the community. Here conditions in the estimation of loss to society are still further met. It matters little to the great mass of individuals whether *that* money, the measure of value, is put into circulation *via* the insurance companies or by the individual.

Standard mortuary tables are admitted in evidence, in awarding damages for wrongful death. Such tables apply to the whole community even more clearly than to the deceased. Whatever a man's station in society, his value is dependent upon, and modified by, his life expectancy. If this be short, the guarantee of his continued usefulness is less assuring than that of a man with the prospect of a longer life.

The whole matter, therefore, naturally and finally goes back to a question of fact for the jury or court, and wherever an accidental death has been effected, the deceased is measured by his productiveness. This productiveness is directly enjoyed by his family, his employer and his associates, and through them, sooner or later in an equal degree by society at large. Therefore the measure of pecuniary loss to said family becomes a measure of damage to society. It is reasonable to believe then, that awards by courts of law for death are a safe and trustworthy estimate of the pecuniary value of the life of the deceased. There are, of course, exceptions; justice has ever been perverted; but the great mass of cases taken together, forms a reasonable basis of estimation of the value of human life.

Several of the states, however, permit their juries to assess punitive damages in cases of this character. The regulation applying to such is, in effect, as follows: "The jury may give such damages, pecuniary or exemplary, as, under the circumstances of the case, may seem to them just." Again, in some states, the maximum amount of assessment is limited by law to \$5,000.00. These facts are mentioned in order to show that such damages cannot be safely included in a set of tables used for computation of values, as either the privilege of the jury, in the one case, or the statutory limitation, in the other, may prevent an award from representing a true estimate of the value of the deceased. Under the former conditions, an award of high damages may be in a large degree punitive, and only a small part of it may represent the court's estimate of the pecuniary loss. Under the latter state, an award of \$5,000.00 may mean that, in the opinion of the authorities, the life was worth more, but the best that could be done was to give the maximum award.

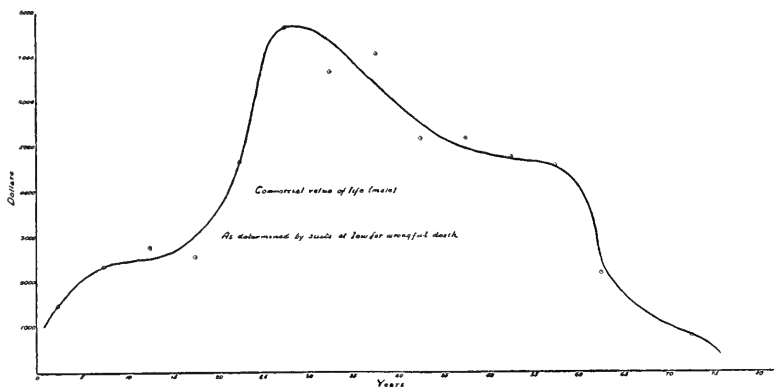
From a mass of cases which have been collected for the estimates hereinafter set forth, there have been excluded all those occurring in states in which either of the above conditions were present. Careful exclusion has also been made of cases in which there appeared unusual circumstances or conditions which rendered them non-representative of the great majority. This process has left a total of 147 cases, the decedents in which were males, of all ages, classes and conditions, some completely supporting families, and others merely contributing to the support of other persons. These cases are believed to be the result of wise judicial procedure, the awards have all been confirmed by Supreme Courts or Courts of Appeals, and they seem to form a trustworthy basis upon which to estimate.

It appears that there are not conveniently available records of suits at law, in which the decedents were females, in sufficient number to warrant the construction of a table of values for this sex. Such cases seem to be infrequent, compared with those in which the male sex figures. This is undoubtedly due to the fact that man's existence is, by reason of his occupation and inborn venturesomeness, more hazardous than woman's, and therefore presents a greater number of casualties.

Arrangement of the different cases of award for wrongful death, in the order corresponding to the age of the decedents, from the youngest to the oldest, shows a somewhat heterogeneous mass of figures, often varying considerably in the same age column. This might be expected in such an arrangement, for mankind is widely diverse. The productiveness of an individual depends upon his habits, application, thrift, mental acuteness, physical condition and many of the other personal qualities which accompany mankind. Where one indi-

vidual may possess many of these, they may be partially or altogether wanting in another, and so the judgment of juries and courts is altered to meet these conditions in the individual.

Dividing the life into age periods of five years, and combining the awards in each period, it is found that the resulting average in each period is thoroughly representative of the whole group and possesses tolerably narrow limits of probable error. Such an arrangement is shown in the accompanying diagram, in which the ordinates represent the ages of the decedents, and the abscissæ the average amount of damages awarded per case, for each age group. In this curve, it will be seen that the foci are plotted along the



center ordinate, or two and one half years away from each age-group limit. This is done in order that they may more truly represent the value of the average valuation for each five-year term, and the resulting curve may more nearly conform to the extremes, in its course from the beginning to the end of each age group.

Let us now examine this diagram and observe as closely as possible how the relative values there expressed (without regard to the actual values which they represent) conform to common observation. From the initial point, there is a rapid rise, caused by a rapidly enhancing value occasioned by the greater certainty of escape from the dangers of tender childhood. Each month and week during this period is hazardous, and as each month and year is passed in safety the risk becomes correspondingly less. Following this, is a flat portion during which the values do not change so markedly, until the age of puberty is passed. Then occurs a sharp increase, which, as it merges with the term of self-sustenance, becomes more rapid, culminating at about the age of 30 years. This is the prime of American manhood; not the period of highest productiveness, nor the age of ripest wisdom. The future is now the important feature, and there are questions of

permanence to be taken into consideration. Physical vigor usually begins to decline at this period. We are familiar with the fact that the powers of the athlete then begin to wane; champions of this age give way to younger aspirants. This means that the risk becomes greater and the confidence in future values is lowered. Therefore, even though the age of 30 is not the climax of existing usefulness, it comprises the highest combination of value and permanence.

After the age of 30, there follows a gradual decline of values until the age period 55-60 is reached, when the declivity becomes sharp, remaining so to the end. The decrease in each age group is not marked and might not be apparent when separate cases are considered, but the collective arrangement indicates with faithful accuracy all that might be expected from common observation.

#### CONCLUSIONS.

1. The pecuniary value of life is subject to the same economic laws as are applied to the more vulgar commodities.

2. In courts of law, the measure of an individual's productiveness, which is the measure of his value, receives the most careful scrutiny; therefore the decisions of such courts, where existing statutes permit, are trustworthy in determining an individual's value to his family.

3. The pecuniary value of a life to its relatives represents its pecuniary value to society.

4. Damages given for wrongful death are such that they can be represented by an average in different age groups, with only narrow limits of probable error.

5. The relation of these age-group values, one to the other, is supported by common observation and statistical reasoning.

## INSTINCT,

WITH ORIGINAL OBSERVATIONS ON YOUNG ANIMALS.\*

BY DOUGLAS A. SPALDING.

THE exquisite skill and accurate knowledge observable in the lives of the lower animals, which men generally have regarded as instinctive—born with them—have ever been subjects of wonder. In the hands of the natural theologian, whose armory has been steadily impoverished in proportion as mystery has given way before science, instinct is still a powerful weapon. When the divine expatiates on the innate wisdom and the marvelous untaught dexterity of beasts, birds, and insects, he is in little danger of being checked by the men of science. His learned enemies are dumb, when in triumph he asks the old question:

Who taught the nations of the field and wood  
 To shun their poison and to choose their food?  
 Prescient, the tides or tempests to withstand,  
 Build on the wave, or arch beneath the sand?

The very little that our psychologists have done for instinct may be told in a few words. The only theory of instinct, of the nature of an explanation, is that put forward by Mr. Herbert Spencer as part of his philosophy of evolution; but, as a theory, it is only beginning to be understood and appreciated among scientific men; while some eminent thinkers question the reality of the phenomena to be explained. Professor Bain, our other psychologist, and his able following of trained disciples, simply discredit the alleged facts of instinct. Unfortunately, however, instead of putting the matter to the test of observation and experiment, they have contented themselves with criticizing the few accidental observations that have been recorded, and with arguing against the probability of instinctive knowledge. In defending the Berkeleyian Theory of Vision, Professor Bain, in answer to the assertion that the young of the lower animals manifest an instinctive perception of distance by the eye, contends that 'there does not exist a body of careful and adequate observations on the early movements of animals.' Writing long ago on the same subject, Mr. Mill also, while admitting that 'the facts relating to the young of the lower animals have been long felt to be a real stumbling-block in the way of the theory,' maintains that 'our knowledge of the mental operations of animals is too imperfect to enable

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\* Reprinted from *Macmillan's Magazine*, February, 1873.

us to affirm positively that they have this instinct.' Denying the facts, however, was not Mr. Mill's mode of saving the theory. He was rather of opinion that the 'animals have to us an inexplicable facility both of finding and selecting the objects which their wants require.' How very inexplicable, he conceives, their mental operations may possibly be, may be gathered from the fact of his suggesting an experiment to ascertain whether a blind duckling might not find the water as readily as one having sight. The position of psychologists of the too purely analytical school, however, is not that the facts of instinct are inexplicable; but that they are incredible. This view is set out most explicitly in the article on 'instinct' in 'Chambers's Encyclopædia.' Thus:

"It is likewise said that the chick recognizes grains of corn at first sight, and can so direct its movements as to pick them up at once; being thus able to know the meaning of what it sees, to measure the distance of objects instinctively, and to graduate its movements to that knowledge—all which is, in the present state of our acquaintance with the laws of mind, wholly incredible."

And it is held that all the supposed examples of instinct may be—for anything that has yet been observed to the contrary—nothing more than cases of rapid learning, imitation or instruction.

Thus it would appear that with regard to instinct we have yet to ascertain the facts. With a view to this end, I have made many observations and experiments, mostly on chickens. The question of instinct, as opposed to acquisition, has been discussed chiefly in connection with the perceptions of distance and direction by the eye and the ear. Against the instinctive character of these perceptions it is argued, that as distance means movement, locomotion, the very essence of the idea is such as can not be taken in by the eye or ear; that what the varying sensations and feelings of sight and hearing correspond to, must be got at by moving over the ground—by experience. On the other hand, it is alleged that, though as regards man the prolonged helplessness of infancy stands in the way of the observer, we have only to look at the young of the lower animals to see that as a matter of fact they do not require to go through the process of learning the meaning of their sensations in relation to external things; that chickens, for example, run about, pick up crumbs, and follow the call of their mother *immediately* on leaving the shell. For putting this matter to the test of experiment, chickens, therefore, are most suitable and convenient subjects. I have observed and experimented on more than fifty chickens, taking them from under the hen while yet in the eggs. But of these, not one on emerging from the shell was in a condition to manifest an acquaintance with the qualities of the outer world. On leaving the shell they are wet and helpless; they struggle with their legs, wings, and necks, but are unable to stand or hold up their heads. Soon, however, they may be distinctly seen and felt pressing against and endeavoring to keep in

contact with any warm object. They advance very rapidly. I have seen them hold up their heads well, peck at objects, and attempt to dress their wings when only between four and five hours old. But there is no difficulty in conceiving that, with great spontaneity and a strong power of association, much might be learned in four or five hours. Professor Bain is of opinion, from observations of his own on a newly dropped lamb, that 'a power that the creature did not at all possess naturally, got itself matured as an acquisition in a few hours.' Accordingly, in the absence of precautions, the time that must elapse before chickens have acquired enough control over their muscles to enable them to give evidence as to their instinctive power of interpreting what they see and hear, would suffice to let in the contention that the eye and the ear may have had opportunities of being educated. To obviate this objection with respect to the eye, I had recourse to the following expedient. Taking eggs just when the little prisoners had begun to break their way out, I removed a piece of the shell, and before they had opened their eyes drew over their heads little hoods, which, being furnished with an elastic thread at the lower end, fitted close round their necks. The material of these hoods was in some cases such as to keep the wearers in total darkness; in other instances it was semi-transparent. Some of them were close at the upper end, others had a small aperture bound with an elastic thread, which held tight round the base of the bill. In this state of blindness—the blindness was very manifest—I allowed them to remain from one to three days. The conditions under which these little victims of human curiosity were first permitted to see the light were then carefully prepared. Frequently the interesting little subject was unhooded on the center of a table covered with a large sheet of white paper, on which a few small insects, dead and alive, had been placed. From that instant every movement, with the date thereof, as shown by the watch, was put on record. Never in the columns of a Court Journal were the doings of the most royal personage noted with such faithful accuracy. This experiment was performed on twenty separate chickens at different times, with the following results. Almost invariably they seemed a little stunned by the light, remained motionless for several minutes, and continued for some time less active than before they were unhooded. Their behavior, however, was in every case conclusive against the theory that the perceptions of distance and direction by the eye are the result of experience, of associations formed in the history of each individual life. Often at the end of two minutes they followed with their eyes the movements of crawling insects, turning their heads with all the precision of an old fowl. In from two to fifteen minutes they pecked at some speck or insect, showing not merely an instinctive perception of distance, but an original ability to judge, to measure distance, with something like infallible accuracy. They did not attempt to seize things beyond their



reach, as babies are said to grasp at the moon; and they may be said to have invariably hit the objects at which they struck—they never missed by more than a hair's breadth, and that, too, when the specks at which they aimed were no bigger, and less visible, than the smallest dot of an *i*. To seize between the points of the mandibles at the very instant of striking seemed a more difficult operation. I have seen a chicken seize and swallow an insect at the first attempt: most frequently, however, they struck five or six times, lifting once or twice before they succeeded in swallowing their first food. The unacquired power of following by sight was very plainly exemplified in the case of a chicken that, after being unhooded, sat complaining and motionless for six minutes, when I placed my hand on it for a few seconds. On removing my hand the chicken immediately followed it by sight backward and forward and all round the table. To take, by way of example, the observations in a single case a little in detail: A chicken that had been made the subject of experiments on hearing, was unhooded when nearly three days old. For six minutes it sat chirping and looking about it; at the end of that time it followed with its head and eyes the movements of a fly twelve inches distant; at ten minutes it made a peck at its own toes, and the next instant it made a vigorous dart at the fly, which had come within reach of its neck, and seized and swallowed it at the first stroke; for seven minutes more it sat calling and looking about it, when a hive-bee coming sufficiently near was seized at a dart and thrown some distance, much disabled. For twenty minutes it sat on the spot where its eyes had been unveiled without attempting to walk a step. It was then placed on rough ground within sight and call of a hen with a brood of its own age. After standing chirping for about a minute, it started off towards the hen, displaying as keen a perception of the qualities of the outer world as it was ever likely to possess in after life. It never required to knock its head against a stone to discover that there was 'no road that way.' It leaped over the smaller obstacles that lay in its path and ran round the larger, reaching the mother in as nearly a straight line as the nature of the ground would permit. This, let it be remembered, was the first time it had ever walked by sight.\*

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\* Since writing this article, I see it stated in Mr. Darwin's new book, 'The Expression of the Emotions in Man and Animals,' that "the wonderful power which a chicken possesses only a few hours after being hatched, of picking up small particles of food, seems to be started into action through the sense of hearing; for, with chickens hatched by artificial heat, a good observer found that 'making a noise with a fingernail against a board, in imitation of the hen-mother, first taught them to peck at their meat.'" My own observations give no countenance whatever to this view: (1) I have frequently observed chickens finally hatched in a flannel nest over a jar of hot water and left undisturbed for

It would be out of place here to attempt to indicate the full psychological bearing of these facts. But this much may be affirmed, that they put out of court all those who are prepared only to argue against the instinctive perception by the eye of the primary qualities of the external world. When stripped of all superfluous learning, the argument against this and every other alleged case of instinctive knowledge is simply that it is unscientific to assume an instinct when it is possible that the knowledge in question may have been acquired in the ordinary way. But the experiments that have been recounted are evidence that prior to experience chickens behave as if they already possessed an acquaintance with the established order of nature. A hungry chick that never tasted food is able, on seeing a fly or a spider for the first time, to bring into action muscles that were never so exercised before, and to perform a series of delicately adjusted movements that end in the capture of the insect. This I assert as the result of careful observation and experiment; and it cannot be answered but by observation and experiment at least as extensive. It is no doubt common for scientific men to discredit new facts, for no other reason than that they do not fit with theories that have been raised on too narrow foundations; but when they do this they are only geologists, or psychologists—they are not philosophers.

Before passing to the perceptions of the ear, it may be mentioned that, instead of hooding chickens, which had the advantage of enabling me to make many interesting observations on them when in a state of blindness, I occasionally put a few eggs, when just chipped, into a flannel bag made for the purpose. In this bag the hatching was completed artificially, and the chickens allowed to remain in the dark from one to three days. When placed in the light they departed themselves as regards sight in the manner already described. For the purpose

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a few hours, begin, immediately after the covering was removed, and while they still sat nestling together, to pick at each other's beaks and at specks of oatmeal when these were dropped on them, all noise being as far as possible avoided. (2) Each of the twenty chickens made subjects of the experiment described in the text, began to eat without any assistance from the sense of hearing; the greatest possible stillness being maintained and required during the experiment. (3) Chickens picked up food though rendered deaf while yet in the shell. One of these, deprived of both sight and hearing at its birth, was unhooded when three days old, and nine minutes after it vigorously pursued a large blue fly a distance of two feet, pecking at it several times: the bird proved perfectly deaf. Another with its ears similarly closed, was taken from the dark when a day and a half old, and when an experiment was being tried to ascertain whether it was perfectly deaf—which it turned out to be—it began to pick up and swallow small crumbs. What in this case really surprised me was that, the gum employed in closing its ears having also sealed up one of its eyes, it nevertheless picked up crumbs by sight of its one eye almost if not altogether as well as if it had had two.

of merely testing the perceptions of the eye or the ear this is by far the easier experiment. The hooding process requires considerable delicacy of manipulation, and the chickens are very liable to be injured.

With respect now to the space perceptions of the ear, which, in man at least, even Mr. Spencer regards as acquired by each individual. Chickens hatched and kept in the said bag for a day or two, when taken out and placed nine or ten feet from a box in which a hen with chicks were concealed, after standing for a minute or two, uniformly set off straight for the box in answer to the call of the hen, which they had never seen and never before heard. This they did, struggling through grass and over rough ground, when not yet able to stand steadily on their legs. Nine chickens were thus experimented upon, and each individual gave the same positive results, running to the box scores of times, and from every possible position. To vary the experiment I tried the effect of the mother's voice on hooded chickens. These, when left to themselves, seldom made a forward step, their movements were round and round, and backward; but when placed within five or six feet of the mother, they, in answer to her call, became much more lively, began to make little forward journeys, and soon followed her by sound alone, though, of course, blindly, keeping their heads close to the ground and knocking against everything that lay in their path. Only three chickens were made subjects of this experiment. Another experiment consisted in rendering chickens deaf for a time by sealing their ears with several folds of gum paper before they had escaped from the shell. I tried at different times to stop the ears of a good many in this way, but a number of them got the papers off, others were found not quite deaf, and only three remained perfectly indifferent to the voice of the mother when separated from them by only an inch board. These had their ears opened when between two and three days old, and on being placed within call of the mother hidden in a box, they, after turning round a few times, ran straight to the spot whence came what must have been very nearly, if not actually, the first sound they had ever heard. It seems scarcely necessary to make any comment on these facts. They are conclusive against the theory that, in the history of each life, sounds are at first but meaningless sensations; that the direction of the sounding object, together with all other facts concerning it, must be learned entirely from experience.

If now it be taken as established that in the perceptions of the eye and the ear, chickens at least manifest an instinctive knowledge of the relations and qualities of external things, the popular belief that the special knowledge, the peculiar art and skill, so marked in the various species of animals, come to them mostly without the labor of acquisition, is at once freed from all antecedent improbability. In the way of direct evidence, the little that I have been able to observe in this wide

field goes to prove that the current notions are in accordance with fact. We have seen that chickens follow the call of their mother before they have had any opportunity of associating that sound with pleasurable feelings; and one or two observations, which must be taken for what they are worth, support the general opinion that they have an equally instinctive dread of their more deadly enemies. When twelve days old one of my little *protégés*, while running about beside me, gave the peculiar chirr whereby they announce the approach of danger. I looked up, and behold a sparrow-hawk was hovering at a great height over head. Having subsequently procured a young hawk, able to take only short flights, I made it fly over a hen with her first brood, then about a week old. In the twinkling of an eye most of the chickens were hid among grass and bushes. The hen pursued, and scarcely had the hawk touched the ground, about twelve yards from where she had been sitting, when she fell upon it with such fury that it was with difficulty that I was able to rescue it from immediate death. Equally striking was the effect of the hawk's voice when heard for the first time. A young turkey, which I had adopted when chirping within the uncracked shell, was on the morning of the tenth day of its life eating a comfortable breakfast from my hand, when the young hawk, in a cupboard just beside us, gave a shrill chip, chip, chip. Like an arrow the poor turkey shot to the other side of the room, and stood there motionless and dumb with fear, until the hawk gave a second cry, when it darted out at the open door right to the extreme end of the passage, and there, silent and crouched in a corner, remained for ten minutes. Several times during the course of that day it again heard these alarming sounds, and in every instance with similar manifestations of fear. Unfortunately, my hawk coming to an untimely end, I was prevented from proceeding with observations of this class. But these few were so marked and unmistakable in their character that I have thought them worth recording.

There are instincts, however, yet to be mentioned, concerning the reality of which I have thoroughly satisfied myself. The early attention that chickens give to their toilet is a very useful instinct, about which there can be no question. Scores of times I have seen them attempt to dress their wings when only a few hours old—indeed as soon as they could hold up their heads, and even when denied the use of their eyes. The art of scraping in search of food, which, if anything, might be acquired by imitation—for a hen with chickens spends the half of her time in scratching for them—is nevertheless another indisputable case of instinct. Without any opportunities of imitation, when kept quite isolated from their kind, chickens began to scrape when from two to six days old. Generally, the condition of the ground was suggestive; but I have several times seen the first attempt, which consists of a sort

of nervous dance, made on a smooth table. As an example of unacquired dexterity, I may mention that on placing four ducklings a day old in the open air for the first time, one of them almost immediately snapped at and caught a fly on the wing. More interesting, however, is the deliberate art of catching flies practised by the turkey. When not a day and a half old I observed the young turkey already spoken of slowly pointing its beak at flies and other small insects without actually pecking at them. In doing this, its head could be seen to shake like a hand that is attempted to be held steady by a visible effort. This I observed and recorded when I did not understand its meaning. For it was not until after, that I found it to be the invariable habit of the turkey, when it sees a fly settled on any object, to steal on the unwary insect with slow and measured step until sufficiently near, when it advances its head very slowly and steadily till within an inch or so of its prey, which is then seized by a sudden dart. If all this can be proved to be instinct, few, I think, will care to maintain that *anything* that can be learned from experience *may* not also appear as an intuition. The evidence I have in this case, though not so abundant as could be wished, may yet, perhaps, be held sufficient. I have mentioned that this masterpiece of turkey cleverness when first observed was in the incipient stage, and, like the nervous dance that precedes the actual scraping, ended in nothing. I noted it simply as an odd performance that I did not understand. The turkey, however, which was never out of my sight except when in its flannel bag, persisted in its whimsical pointing at flies, until before many days I was delighted to discover that there was more in it than my philosophy had dreamt of. I went at once to the flock of its own age. They were following a common hen, which had brought them out; and as there were no other turkeys about the place, they could not possibly learn by imitation. As the result, however, of their more abundant opportunities, I found them already in the full and perfect exercise of an art—a cunning and skilful adjusting of means to an end—bearing conspicuously the stamp of experience. But the circumstances under which these observations were made left me no room for the opinion that the experience, so visible in their admirable method of catching flies, was original, was the experience, the acquisition of those individual birds. To read what another has observed is not, however, so convincing as to see for oneself, and to establish a case so decisive more observation may reasonably be desired; at the same time, it can scarcely be attempted to set aside the evidence adduced, on the ground of improbability, for the *fact* of instinct: all that is involved in this more striking example has, we venture to think, been sufficiently attested.

A few manifestations of instinct still remain to be briefly spoken of. Chickens as soon as they are able to walk will follow any moving object.

And, when guided by sight alone, they seem to have no more disposition to follow a hen than to follow a duck, or a human being. Unreflecting on-lookers, when they saw chickens a day old running after me, and older ones following me miles and answering to my whistle, imagined that I must have some occult power over the creatures, whereas I simply allowed them to follow me from the first. There is the instinct to follow; and, as we have seen, their ear prior to experience attaches them to the right object. The advantage of this arrangement is obvious. But instincts are not conferred on any principle of supplying animals with arts very essential to them, and which they could not very well learn for themselves. If there is anything that experience would be sure to teach chickens, it would be to take care when they had got a piece of food not to let their fellows take it from them, and from the very first they may be seen to run off with a worm, pursued by all their companions. But this has been so stamped in their nature that, when they have never seen one of their kind, nor ever been disturbed in the enjoyment of a morsel, they nevertheless, when they get something larger than can be swallowed at once, turn round and run off with it.

Another suggestive class of phenomena that fell under my notice may be described as imperfect instincts. When a week old my turkey came on a bee right in its path—the first, I believe, it had ever seen. It gave the danger chirr, stood for a few seconds with outstretched neck and marked expression of fear, then turned off in another direction. On this hint I made a vast number of experiments with chickens and bees. In the great majority of instances the chickens gave evidence of instinctive fear of these sting-bearing insects; but the results were not uniform, and perhaps the most accurate general statement I can give is, that they were uncertain, shy and suspicious. Of course to be stung once was enough to confirm their misgivings forever. Pretty much in the same way did they avoid ants, especially when swarming in great numbers.

Probably enough has been said to leave no doubt in minds free from any bias on the subject, that in the more important concerns of their lives the animals are in great part guided by knowledge that they individually have not gathered from experience. But equally certain is it that they do learn a great deal, and exactly in the way that we are generally supposed to acquire all our knowledge. For example, every chicken, as far as my observations go, has to learn not to eat its own excrement. They made this mistake invariably; but they did not repeat it oftener than once or twice. Many times they arrested themselves when in the very act, and went off shaking their heads in disgust, though they had not actually touched the obnoxious matter. It also appeared that, though thirsty, they did not recognize water by sight, except perhaps in the form of dew-drops on the grass; and they had to

some extent to learn to drink. Their first attempts were awkward; instead of dipping in their beaks, they pecked at the water, or rather at specks in the water, or at the edge of the water. All animals have a capacity to learn; each individual must learn the topography of its locality, and numerous other facts. Many dogs, horses and elephants may be able to learn more than some men. But I have no doubt that observation will bear out the popular belief that what may be called the professional knowledge of the various species—those special manifestations of practical skill, dexterity and cunning that mark them off from each other, no less clearly than do the physical differences whereon naturalists base their classifications—is instinctive, and not acquired. As we shall see, the creatures have not in a vast multitude of instances the opportunity to acquire these arts. And if they had the opportunity, they have not individually the capacity to do so, even by way of imitation. We have seen as a matter of fact that it is by instinct that the chicken, and, I may now add, the turkey, scratch the surface of the earth in search of insects; also, that the turkey has a method of catching flies so remarkably clever that it cannot be witnessed without astonishment. Now, chickens like flies no less than turkeys, and, though with less success, often try to catch them. But it is a significant fact that they do not copy the superior art. To give every opportunity for imitation, I placed a newly-hatched chicken with my turkey, when the latter was eleven days old. The two followed me about for several weeks, and when I deserted them they remained close companions throughout the summer, neither of them ever associating with the other poultry. But the chicken never caught the knowing trick of its companion—seemed, indeed, wholly blind to the useful art that was for months practised before its eyes.

Before passing to the theory of instinct, it may be worthy of remark that, unlooked for, I met with in the course of my experiments some very suggestive, but not yet sufficiently observed, phenomena; which, however, have led me to the opinion that not only do the animals learn, but they can also forget—and very soon—that which they never practised. Further, it would seem that any early interference with the established course of their lives may completely derange their mental constitution, and give rise to an order of manifestations perhaps totally and unaccountably different from what would have appeared under normal conditions. Hence I am inclined to think that students of animal psychology should endeavor to observe the unfolding of the powers of their subjects in as nearly as possible the ordinary circumstances of their lives. And perhaps it may be because they have not all been sufficiently on their guard in this matter, that some experiments have seemed to tell against the reality of instinct. Without attempting to prove the above propositions, one or two facts may be mentioned. Untaught, the new-born

babe can suck—a reflex action; and Mr. Herbert Spencer describes all instinct as ‘compound reflex action’; but it seems to be well known that if spoon-fed, and not put to the breast, it soon loses the power of drawing milk. Similarly a chicken that has not heard the call of the mother until eight or ten days old then hears it as if it heard it not. I regret to find that on this point my notes are not so full as I could wish, or as they might have been. There is, however, an account of one chicken that could not be returned to the mother when ten days old. The hen followed it, and tried to entice it in every way; still it continually left her and ran to the house or to any person of whom it caught sight. This it persisted in doing, though beaten back with a small branch dozens of times, and indeed cruelly maltreated. It was also placed under the mother at night, but it again left her in the morning. Something more curious, and of a different kind, came to light in the case of three chickens that I kept hooded until nearly four days old—a longer time than any I have yet spoken of. Each of these on being unhooded evinced the greatest horror of me, dashing off in the opposite direction whenever I sought to approach it. The table on which they were unhooded stood before a window, and each in its turn beat against the glass like a wild bird. One of them darted behind some books, and squeezing itself into a corner, remained cowering for a length of time. We might guess at the meaning of this strange and exceptional wildness; but the odd fact is enough for my present purpose. Whatever might have been the meaning of this marked change in their mental constitution—had they been unhooded on the previous day they would have run to me instead of from me—it could not have been the effect of experience; it must have resulted wholly from changes in their own organization.

The only theory in explanation of the phenomena of instinct that has an air of science about it, is Mr. Spencer’s doctrine of Inherited Acquisition. The laws of association explain our intellectual operations, and enable us to understand how all our knowledge may be derived from experience. A chicken comes on a bee, and imagining it has found a dainty morsel, seizes the insect, but is stung, and suffers badly. Henceforth bees are avoided; they can be neither seen nor heard without a shudder of fear. Now, if we can realize how such an association as this—how what one individual learns by experience may, in any degree, be transmitted to the progeny of that individual—we have a key to the mystery of instinct. Instinct in the present generation is the product of the accumulated experiences of past generations. The plausibility of this hypothesis, however, is not appreciated by the majority of even the educated portion of the community. But the reason is not far to seek. Educated men, even materialists—their own positive statements to the contrary notwithstanding—have not yet quite escaped from the habit



of regarding mind as independent of bodily organization. Hence it is, that while familiar with the idea of physical peculiarities passing by inheritance from one generation to another, they find it difficult to conceive how anything so impalpable as fear at the sight of a bee should be transmitted in the same way. Obviously, this difficulty is not consistent with a thorough belief in the intimate and invariable dependence of all kinds of mental facts on nervous organization. Let us, if possible, make this clear. The facts of mind that make up the stream of an individual life differ from material things in this important respect, that whereas the latter can be stored up, volitions, thoughts, and feelings, as such, cannot. Facts of consciousness cannot be thought of as packed away like books in a library. They have to be forever produced, created, one after another; and when gone they are out of existence. Whatever associations may be formed among these, must depend for their permanence on the corresponding impress given to the nervous organism; and why should not this, which is purely physical, be subject to the law of heredity? Look at a friend as he lies in unconscious sleep. His sovereigns are in his pocket, but where is his stock of ideas? Where is all that he has learned from experience? You have simply a living machine; but such a machine that it can wake and exhibit all the phenomena of what we call a well-informed and cultivated mind. Suppose, now, that while you stand by, another organism, the same in every particle and fiber, is by some mysterious process formed direct from its elements. Outwardly you cannot tell the one from the other; but wake them and how will it be? Even then, will not the one being recognize you, and then be as completely and indistinguishably your friend as the other? Will not the newly created man, by virtue of his identical material organization, possess the mind and character, the knowledge and feelings, the past, in a word, the personal identity of the other? I have made this extreme supposition in order that no doubt may be entertained as to the shape in which I hold the doctrine that for every fact of mind there is a corresponding fact of matter, and that, given the material fact, whether produced by repeated experiences in the life history of the individual, or inherited from parents, the corresponding mental fact will be the same. If this view be admitted, there can be no difficulty in conceiving how entrance into life on the part of the animals may be a waking up in a world with which they are, in greater or less degree, already acquainted! Instinct, looked at from its physical side, may be conceived to be, like memory, a turning on of the 'nerve currents' on already established tracks: for no reason, we presume, can be suggested why those modifications of brain matter that, enduring from hour to hour and from day to day, render acquisition possible, should not, like any other physical peculiarity, be transmitted from parent to offspring. That they are so transmitted is all but proved by

the facts of instinct, while these in their turn receive their only rational explanation in this theory of inherited acquisition. But the difficulty of the undisciplined mind lies, as we have said, in an inability to grasp the full significance of the doctrine that, in an individual life, it is the physical part alone that endures from day to day; that, strictly speaking, we cannot feel the same feeling or think the same thought twice over; that only as by pulling the bell-cord to-day we can, in the language of ordinary discourse, produce the sound we heard yesterday, can we, while the established connections among the nerves and nerve centers hold, live our experiences over again.

This doctrine of inherited acquisition, then, is, to say the least, a good working hypothesis in explanation of all those facts of instinct that may be conceived as built up, compounded out of, the accumulated experiences of innumerable generations. So far good. But it will occur to every reader that the peculiar depths of animal psychology are not yet explored. Two classes of phenomena still lie in the dark. First, there are the many extraordinary and exceptional feats of dogs and other animals, which seem to be constantly falling under the observation of everybody except the few that are interested in these matters. Second, all the more wonderful instincts, especially those of insects, are such that it is hard, if at all possible, to conceive how they ever could have been derived from experience.

With regard to the first, it is not desirable to say much. Though volumes of marvelous stories have been written, I am not aware that any careful experiments have been tried, and, as the performances in question are of an exceptional character, it is perhaps but scientific caution not as yet to put too much stress on them. For my own part, though I have been very intimate with dogs, I have been singularly unfortunate in having never witnessed any of their more incomprehensible clairvoyant-like achievements. I have known them to do many surprising things, but I have always found that they had, or might have had, something to go upon—enough, coupled with quick intelligence, to account for their exploits. What may be said in this connection, if, indeed, it be prudent to say anything, is that, while we certainly cannot have all the data of experience from without of all the vastly different living things which people the earth, the air, and the ocean—while we certainly can have no trace of many feelings that arise from changes in the organisms of the different creatures, and which, instinctively interpreted, start them on lines of action—a host of statements, generally accepted as fact, suggest the opinion that even such animals as dogs, are alive to, conscious, sensible of influences that scarcely affect us, or wholly escape our cognition. If this be so, they have a basis of experience from which to start in their calculations that we want, and, if so, well may their actions seem to us, as Mr. Mill said, hopelessly inexpli-

cable. Take, not the most remarkable, but the best authenticated example of this class—the frequently alleged fact of dogs and other animals returning in a straight line, or by the most direct routes, through districts they had never before traversed, to places from which they had been taken by devious tracks, and even shut up in close boxes. To most people this is a phenomenon sufficiently incomprehensible. They are certain they themselves could do nothing at all like it. But there is in some men what may be just a hint of this faculty. Most people that have lived only in cities are very soon lost in a strange and trackless district, and still sooner in a pathless wood; in the one case, after wandering this way and that for a few hours, in the other, after merely turning round a few times, they can tell nothing of the direction whence they came. But all men are not so easily lost; some, without consciously making notes, retain, after long wandering in such situations, a strong and often accurate impression, not of the ground they have gone over, but of the direction in which lies the place whence they started. Without attempting to throw any light on the mental chemistry of this perception, we would submit that in it may perhaps be found a clue to the mystery of those astonishing home-journeys of dogs, sheep, cats, pigeons, bees, etc., of which hundreds are on record.

It is, however, with the other dark enigma that we are more specially concerned. We do not think it necessary to examine the proof of the actuality of such marvelous instincts as those of bees and wasps. But for the too fond love of a theory we venture to think none would doubt the reality, or the instinctive character, of their “far-sighted,” or, more correctly, blind provisions for the future. The problem before us is not whether, for example, the male of the fish *Arius* does, and by instinct, hatch the eggs of the female in his mouth, but how such a singular mode of incubation ever had a beginning? Perhaps the most widely known instance of this class of instincts is the provision of the solitary wasp for the worm that will issue from her egg after her own death. She brings grubs—food that as a wasp she never tasted—and deposits them over the egg, ready for the larva she will never see. The life history of every insect exhibits instincts of this perplexing description. Witness the caterpillar, how at the proper time it selects a suitable situation and spins for itself a silken cocoon. It may be admitted at once that the creatures, as *we behold them*, never could have lived to acquire such instincts by any process of experience and inheritance of which we can conceive. Nor let it be supposed that it is only in the insect world, where all is so strange, that instincts are to be met with so essential to lives of the individuals or their progeny that without them the creatures in their present shape could never have existed. Of this kind are the first movements observable in the life of a bird, and which take place within the shell. I have often observed the self-delivery

of the chicken. The prison wall is not burst in pieces by spontaneous, random struggles. By a regular series of strokes the shell is cut in two—chipped right round in a perfect circle, some distance from the great end. Moreover, the bird has a special instrument for this work, a hard, sharp horn on the top of the upper mandible, which being required for no other purpose disappears in a few days. Obviously each individual bird no more acquires the art of breaking its way out than it furnishes itself with the little pick-hammer used in the operation; and it is equally clear that a bird could have never escaped from the egg without this instinct. Again, how were eggs hatched before birds had acquired the instinct to sit upon them? Or who will throw light on the process of such an acquisition? Nor are the subsequent phenomena easier of explanation. A fowl that never before willingly shared a crumb with a companion, will now starve herself to feed her chickens, which she calls by a language she never before used—may have never even heard—but which they are born to understand. Once more, it is clearly because she cannot do otherwise that a she-rabbit, when with her first young, digs a hole in the earth away from her ordinary habitation, and there builds a nest of soft grass, lined with fur stripped from her own body. But how as to the origin of this habit?

We need not accumulate examples of seemingly unfathomable instincts. And it may be confessed at once that in the present state of our knowledge it would be hopeless to attempt to guess at the kinds of experiences that may have originally, when the creatures wore different shapes and lived different lives, wrought changes in their nervous systems that, enduring and being modified through many changes of form, have given to the living races the physical organizations of which these wonderful instincts are the corresponding mental facts. Nor, perhaps, can it be confidently asserted that in experience and heredity we have all the terms of the problem. The little we can say is that though in the dark we need not consider ourselves more in the dark as to the origin of those strange instincts than we are concerning the origin of those wonderful organs of astonishing and exquisite mechanism that, especially among the insects, are the instruments of those instincts. Nay, more, if the view we have put forward concerning the connection between mental manifestations and bodily organization be correct, the question of the origin of these mysterious instincts is not more difficult than, or different from, but is the same with, the problem of the origin of the physical structure of the creatures; for, however they may have come by their bodies, they cannot fail to have the minds that correspond thereto. When, as by a miracle, the lovely butterfly bursts from the chrysalis full-winged and perfect, and flutters off a thing of soft and gorgeous beauty, it but wakes to a higher life, to a new mode of existence, in which, strange though it may sound, it

has, for the most part, nothing to learn; *because* its little life flows from its organization like melody from a music box. But we need not enlarge on this a second time.

In seeking to understand the phenomena of instinct we of course get the full benefit of the law of Natural Science, which though it throws no light on the origin of anything, mental or physical—for, as Mr. Darwin says, it ‘has no relation whatever to the primary cause of any modification of structure’—nevertheless helps us to understand the existence of instincts far removed from the circumstances or conditions of life under which they could have been acquired. Suppose a Robinson Crusoe to take, soon after his landing, a couple of parrots, and to teach them to say in very good English, “How do you do, sir?”—that the young of these birds are also taught by Mr. Crusoe and their parents to say, “How do you do, sir?”—and that Mr. Crusoe, having little else to do, sets to work to prove the doctrine of Inherited Association by direct experiment. He continues his teaching, and every year breeds from the birds of the last and previous years that say “How do you do sir?” most frequently and with the best accent. After a sufficient number of generations his young parrots, continually hearing their parents and a hundred other birds saying “How do you do, sir?” begin to repeat these words so soon that an experiment is needed to decide whether it is by instinct or imitation; and perhaps it is part of both. Eventually, however, the instinct is established. And though now Mr. Crusoe dies, and leaves no record of his work, the instinct will not die, not for a long time at least; and if the parrots themselves have acquired a taste for good English the best speakers will be sexually selected, and the instinct will certainly endure to astonish and perplex mankind, though in truth we may as well wonder at the crowing of the cock or the song of the skylark. Again, turkeys have an instinctive art of catching flies, which, it is manifest, the creatures in their present shape may have acquired by experience. But suppose the circumstances of their life to change; flies steadily become more abundant, and other kinds of food scarcer: the best fly-catchers are now the fittest to live, and each generation they are naturally selected. This process goes on, experience probably adding to the instinct in ways that we need not attempt to conceive, until a variety or species is produced that feeds on flies alone. To look at, this new bird will differ considerably from its turkey ancestors; for change in food and in habits of life will have affected its physical conformation, and every useful modification of structure will have been preserved by natural selection. My point however is, that thus, by no inconceivable steps, would be produced a race of birds depending for all their food on an instinctive art, which they, as then constituted, could never have acquired, because they never could have existed without it.

No doubt, to the many, who love more to gaze and marvel than to question and reflect, all this will seem miserably inadequate as a clue to one of the greatest mysteries of life. But enough, if I have indicated my view of how the most inexplicable of instincts may have had their origin; or rather, if I have shown how our utter inability to trace them back to their origin tells nothing against the probability that they all came into existence in accordance with those laws of acquisition and heredity that we now see operating before our eyes. We cannot tell how the pupa of the dragon-fly came by the instinct that prompts it to leave the water and hang itself up to dry. But we may be able to explain this quite as soon as to unveil the origin of the hooks by which it hangs itself up. And if ever human intelligence should so trace the evolution of living forms as to be able to say, "Thus was developed the bill-scale wherewith birds now break their way out of the shells," it will probably be able to add, "and these were the experiences to which we must trace the instinct that makes every little bird its own skilful accoucheur."

EDUCATIONAL VALUE OF PHOTOMICROGRAPHY.

BY ARTHUR CURTIS SCOTT,  
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THE part of the universe which the penetrating power of the microscope reveals to the student of nature, though concerned with the infinitesimal, equals the macroscopic portion in magnitude and significance.

Modern scientific consideration recognizes the fact that no more accurate method of research can be concentrated on the question of origin, cyclic changes in development and existing structure of various forms of matter, both organic and inorganic, than that of their minute examination under the microscope. It is a familiar fact that early investigators with this instrument, as well as many at the present time, exhibit as results of their work drawings of the objects examined. While these pictures made with the camera lucida may be reasonably exact when drawn by a careful investigator under the best conditions, it is true that they are frequently inaccurate under ordinary circumstances, and when numerous reproductions are desired the photomicrograph is largely superseding the laborious work of the draftsman.

It is probable that the application of photography to the reproduction of microscopic structure has largely been due to the demand for unmodified and unprejudiced exactness of detail. Again the photographic plate is more sensitive and more efficient than the retina, for not only is the human eye easily fatigued, but it is quite unable to regard slight differences of illumination, or to differentiate the most minute characteristics of specimens. While it is a fact that the plate is most sensitive to light of a certain color and intensity, it is also true that the requirements can be readily obtained, and that the silver salt is able to indicate the action of light that fails to stimulate the sense of vision. The existence of funiculi in the coma-bacilli of Asiatic cholera, for example, was proved by the aid of photography after repeated failures to discover them by other means.

The middle of the nineteenth century marks the beginning of attention to photomicrography when Mayer of Frankfort devised apparatus for this work. Since that time wonderful advance has been made both in photography and microscopy, and we now may obtain not only extremely rapid and color sensitive plates, with readily modified developers that allow a considerable latitude of exposure, but micro-

scopes of the highest perfection mechanically, and closely approaching that standard, optically. It may be said in this connection also that though apparatus of excellent quality is thus readily obtained, yet a reasonably accurate knowledge of the optical principles involved and of photographic manipulation is quite necessary to insure satisfactory results. In fact it is the writer's conclusion, after some years' experience connected with the various branches of scientific photography, that no more difficult problem has presented itself than the production of a thoroughly satisfactory photomicrograph of a specimen magnified to 2,000 diameters.

Probably many failures in the work are directly traceable to the use of inferior microscopes, and a few points noticed here may be interesting and possibly instructive.

It would seem hardly necessary to mention the elementary principle in optics, that the spectrum resulting from the resolution of white light is divided into three more or less distinct parts, according to wave length and effect upon matter. Beginning with the longest wave length, we have the infra red and red, or heat portion; then the yellow and green, or light (visual) portion; and finally the blue and violet, or chemical portion. Simple lenses, being of prismatic origin in manufacture, refract white light in such a way as to resolve it into its component colors, and the wave length of the red being greater, it suffers less refraction than the yellow, which in turn is refracted less than the blue; and thus the converging rays do not focus at the same point as a whole, and chromatic aberration results. Further, the fact that for any given lens there is a decrease in thickness from center to circumference, results in unequal refraction of the light as a whole and spherical aberration results, which practically means distortion of the image of an object. Both these defects, chromatic and spherical aberration, are reduced to a minimum by the combination of crown and flint glass to correct the former, and a reduction of aperture or multiplicity of lenses to overcome the latter.

It is a well-known fact, however, that the ordinary microscope objectives have what may be called residual chromatic aberration which focuses the light rays a trifle nearer the lens than the chemical rays, and thus when the image is perfectly sharp upon the ground glass of the camera, the chemical rays, which alone are active upon the photographic plate, do not accurately delineate the object. Fraunhofer has shown, that when the portion of the spectrum of greatest intensity upon the retina, that between the yellow and green is expressed by 1,000, the part between the blue and violet is only 31, so the difficulty in focusing the chemical rays is obvious. It actually amounts to focusing carefully the image, and then moving the objective toward the object an indefinite distance,



in order to obtain the desired result. Of course with low power objectives one may do this after repeated trials with some accuracy, but the chief difficulty is found in determining whether an indistinct negative is due to improper manipulation, or imperfect resolving power in the objective. For this reason, even for elementary work, such apparatus is not economical and is quite unsatisfactory.

A consideration of the apochromatic objectives of Professor Abbe and Professor Hastings, which are readily obtained with either the Zeiss or Bausch & Lomb Optical Co.'s instruments, is therefore important. These objectives having a uniform correction for spherical aberration, correct also for three colors, resulting in a better concentration of image rays and greater resolving power; this improvement in objectives brings the photographer's work nearer perfection, though there is, with high power objectives, an error which thus far remains uncorrected. This defect is balanced, however, by over-corrected eyepieces known as compensating oculars, which are designed for use with these objectives. Thus for photographic work neither an apochromatic objective with the ordinary Huyghenian eyepiece, nor the achromatic objective with compensating eyepiece is satisfactory.

The bulk of literature on photomicrography advises the use of the objective without any eyepiece; such advice is good with ordinary achromatic objectives, as the addition of the eyepiece would only introduce more absorbing and reflecting parts without correcting any of the defects in the objective. Where fine work is desired, however, and apochromats are used, the compensating ocular is not only necessary for the highest degree of correction of the system, but is useful in the regulation of magnifying power.

From the fact that so many different makes of objectives and oculars are in the market, accompanying their respective microscopes, the simplest method of rating in photographic work seems to be a statement of the number of diameters which the object is magnified. The magnifying power is most readily and accurately obtained by using a stage micrometer, one millimeter divided into hundredths, and measuring directly the magnification of the image upon the ground glass with an engine-divided steel rule.

The illumination of the object to be photographed is of so much importance that a few points may be briefly considered. An almost indispensable adjunct of the microscope in this connection is the Abbe sub-stage condenser, which not only condenses the light, but illuminates the object with a cone of light having an angular aperture equal to that of the objective employed. It is arranged to move with rack and pinion, thus providing a means for controlling the illumination to an important extent. Experience shows that the best illumination upon

the object in general obtains when the Abbe condenser is as far away from the microscopic slide on one side as is the objective on the other. Thus for oil immersion work a drop of oil must be placed between the condenser and slide as well as upon the objective. It frequently happens that when the proper position of the condenser is located for low power objectives the detail is somewhat obliterated because of too intense illumination, and the manipulation of the iris diaphragm connected with the condenser is necessary in order to obtain the best results.

From whatever source the light falls upon the Abbe condenser, an auxiliary condenser before it is advantageous, except when daylight is used upon the mirror beneath the stage. The use of daylight has disadvantages, however, which do not recommend it for photographic work. With diffused light falling upon the mirror it is impossible to use even moderately high power objectives and obtain sufficient light for focus-

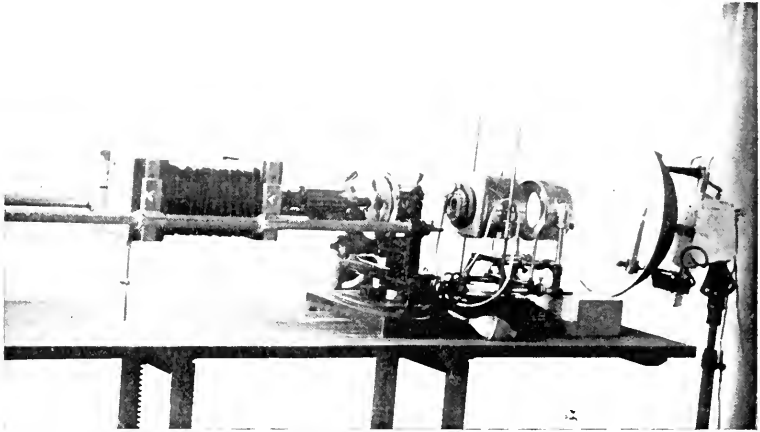


FIG. 1. CONVENIENT ARRANGEMENT OF APPARATUS FOR ORDINARY PHOTOMICROGRAPHIC WORK.

ing, while with the direct rays of the sun, unless a heliostat is used to maintain the position of the sun constant upon the mirror, one cannot obtain a photograph before the sun has changed enough to throw the image of the object off the plate. In addition to this inconvenience in general, the optical imperfections of the mirror are such as to make the production of sharp photographs difficult, and much better results are obtained with high magnifying power, by dispensing with its use and transmitting the light directly from the source through the optical system.

Photomicrographic work of low magnification has been successfully done with the various forms of artificial illuminants of low candle power. The writer, in the production of first photographs used very

successfully a series of such lights, beginning with a two-wick oil lamp behind a large Florence flask filled with water, the flask serving at once as a condenser and heat filter. Afterward, in succession, was used an argand gas lamp; a Welsbach burner; a three-wick projection lantern, burning camphorated oil; a 50-candle power incandescent lamp; and a four-burner acetylene lamp with stereopticon double condenser, to the final and most efficient light of all, an arc light which can be regulated between 1,000 and 5,000 candle power. Of course the arc light gives out a great amount of heat as well as a satisfactory quantity of light, and were the rays to fall directly upon the microscope lenses the temperature would rise high enough to endanger their mountings. To obviate this difficulty a distilled water cell two inches thick is placed in front of the stereopticon double condenser, which is directly before the arc at such a distance as to parallelize the divergent beam. It is a common idea that an alum solution is the best for absorbing heat while transmitting light. That such is not the case is proved by experiment. Melloni and others have shown that distilled water will intercept more heat rays than a solution of alum. The writer has verified that conclusion and is also able to show that distilled water transmits more light, has practically the same heat-absorbing power through a considerable range of temperature and also has the advantage of no formation of crystals in the cell. Distilled water is necessary, as with common water the air bubbles collect on the parallel faces of the cell as the temperature rises, and obstruct the passage of light.

The form of apparatus shown complete in Fig. 1, using a Zeiss microscope and Bausch & Lomb adjustable camera with automatic regulating arc light, gives excellent results for ordinary dry mounted

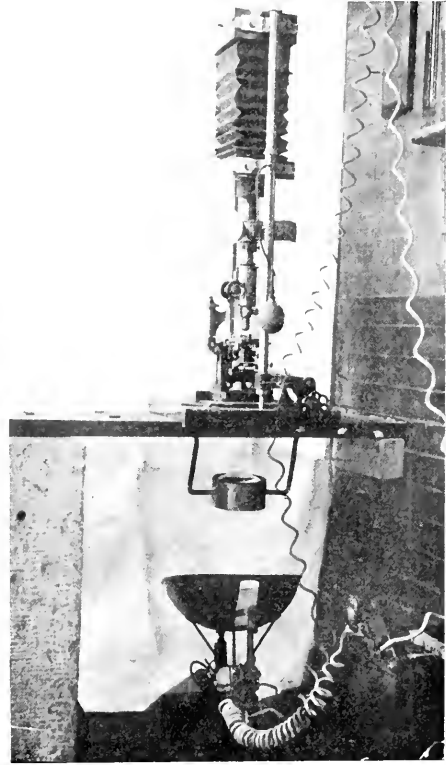


FIG. 2. APPARATUS COMPLETE FOR MAKING INSTANTANEOUS PICTURES OF LIVING MICROSCOPIC ANIMALS.

slides that may be readily photographed with the microscope in a horizontal position. A mechanical stage is of great convenience in this work as it saves much time in accurately placing a slide, especially where high power objectives are used and when focusing must be done at arm's length. In the making of photographs of rock sections, it is frequently necessary to use Nicol prisms in order to properly differentiate particular portions. The one is placed over the ocular, or between it and the objective, and the other beneath the sub-stage condenser. As the latter is free to be rotated, it is an easy matter to bring out clearly the special features desired. Fig. 2 illustrates the apparatus in a vertical position. It must be operated in this position when freshly mounted slides are used and where photomicrographs are to be made of living organisms. A special shutter devised by the writer for the photographing of living specimens, a detailed description of which will be found in the *Scientific American* of March 24, 1900, is shown in place on the draw tube of the microscope. In place of the mirror a hole is drilled through the base of the camera stand in order to make transmitted light available. With this arrangement, as illustrated, photographs have been made in  $1/50$  of a second. (see Figs. 3 and 4).

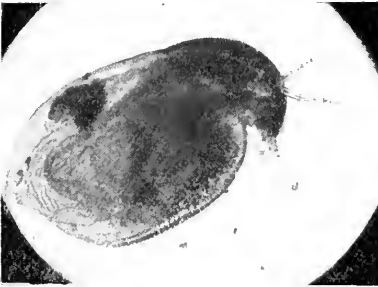


FIG. 3. PHYLLOPOD. LINE SPECIMEN.  
 $\times 250$ . EXPOSURE  $\frac{1}{50}$  SEC.

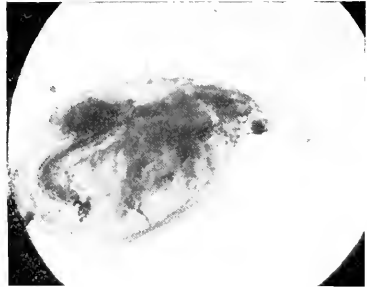


FIG. 4. DAPHNIA. LINE SPECIMEN.  $\times 150$ .  
 EXPOSURE  $\frac{1}{50}$  SEC.

The character of the plates used in connection with the work and a word as to their manipulation is worthy of notice, because ultimate results are not dependent upon first quality optical apparatus alone. With ordinary light and low power objectives, a slow plate is to be preferred, and with such conditions the Carbutt's B brand has given excellent results. Where polarized light is employed a color sensitive plate is preferable. Such light often gives the most beautiful colors with rock sections and crystal specimens, and the Cramer isochromatic plate renders the color values admirably.

The question of exposure must be decided principally by experience. The candle power of the illuminant; the character of the

light, whether ordinary or polarized; the kind of stain used upon the slide, if any; the magnifying power employed, and the rapidity of plate, all combine to determine the limiting values for exposure. There is scarcely opportunity in this paper to enter into discussion of these

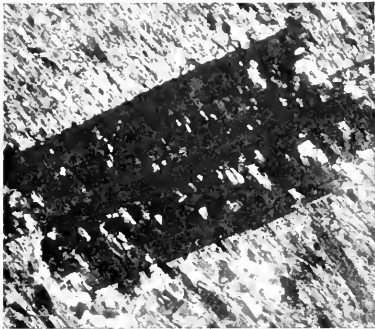


FIG. 5. CRYSTAL OF CHLORITOID IN QUARTZ.  $\times 110$  DIAMETERS. POLARIZED LIGHT.



FIG. 6. BAND OF QUARTZ CROSSED BY MICA.  $\times 100$  DIAMETERS. POLARIZED LIGHT.

factors in detail. In general, however, it may be said that the blues transmit more actinic light than they appear to do; and so there is danger of over-exposure, while with the dark yellows and reds it is quite the reverse. Other conditions remaining the same the exposure is directly proportional to magnifying power, and since frequent changes in objectives and oculars are necessary to obtain the desired magnifica-

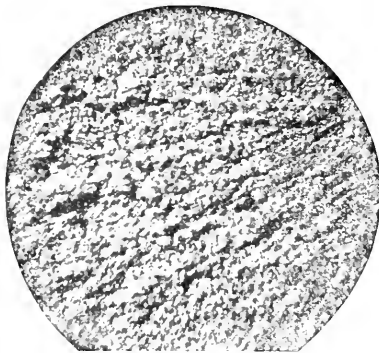


FIG. 7. SECTION OF IRON. 60 DIAMETERS.

tion of different objects, the calculation of the exposure in terms of magnification expressed in diameters simplifies the work considerably. With living organisms that are given plenty of space to move about, in order to be photographed under conditions favorable to them, the exposure must necessarily be very short, and of course only moderately high powers can be used, and the intensity of the light must be very

high. While the subject of this article can be expected to admit of only a limited discussion of photomicrographic apparatus and its manipulation, it has seemed best to thus briefly mention a few points on the modus operandi of the work that one may the better comprehend its value.

To convey an idea of the scope of photomicrography in its application to the study and subsequent presentation of the details of objects

FIG. 8.

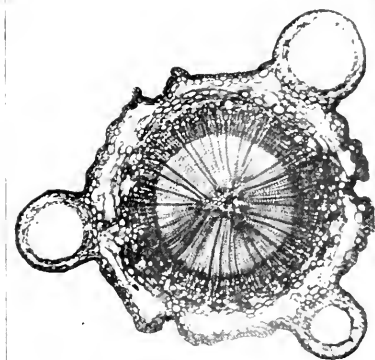


FIG. 9.

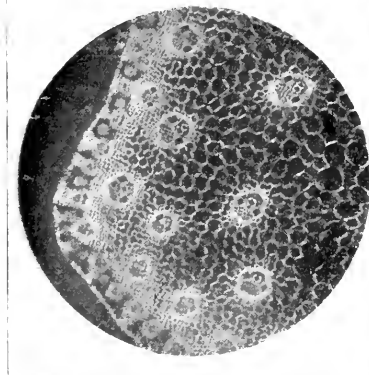
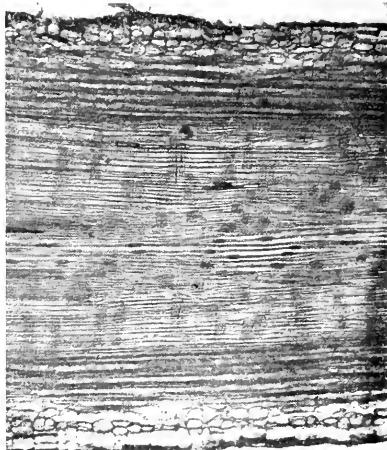


FIG. 10.



FIG. 11.

FIG. 8. CROSS SECTION OF JUNIPER STEM SHOWING THREE RESIN DUCTS.  $\times 50$  DIAMETERS.

FIG. 9. LONGITUDINAL SECTION OF LINDEN.  $\times 90$  DIAMETERS.

FIG. 10. CROSS SECTION OF SUGAR CANE.  $\times 50$  DIAMETERS. POLARIZED LIGHT.

FIG. 11. WING OF SEED OF EGGERMOCARPUS.  $\times 80$  DIAMETERS. POLARIZED LIGHT.

in nature we may well begin with the inanimate substance and finish with the living animal organism. Time was when men referred to the 'everlasting hills' as though such portions of nature were unchangeable, but modern geologic science has shown that the face of nature is ever

changing, that rocks are constantly being formed, metamorphosed and disintegrated; that the earth has undergone radical changes, and that the geography of the world in many particulars may be for one generation very different from that for the following one. Much information on the details of these changes is gained from a minute study of rocks and earth materials.

By the aid of the microscope one is able to study the fine points in the relation of different rock materials to one another, and by the aid of the camera exhibit the result to others. As an illustration of this fact Fig. 5 shows the position of a crystal of chloritoid in quartz, and Fig. 6, quartz, crossed by laminae of mica, taken with crossed Nicols to properly differentiate the materials. These photographs are some of a number made for the Geological Survey to be used in connection with reports. The U. S. Geol. Report for 1899 on the geology of Yellowstone Park shows many photomicrographs, admirably illustrating special geologic features.



FIG. 12. COTTON FIBER INJURED IN THE PROCESS OF GINNING.  $\times 40$  DIAMETERS.

Much valuable information is also gained in this way of the structure and properties of metals both in the ore and after smelting and refining. Fig. 7 illustrates the appearance of iron whose tensile strength has been exceeded, and it is easily possible to show also differences in composition or quality of iron or steel by microscopic methods.

The photography of microscopic sections of wood aid very materially in a detailed consideration of forestry. It shows the character of the small tubes or cells of which wood is made up, indicating the definite way in which the cells of the new wood formed each year at the inner surface of the cambium layer are arranged, depending upon the climate where the tree grows. It shows the characteristic differences in cellular structure of different woods, together with the lines separating the growth of successive seasons in the trunk and bark; the medullary rays, which make the silver grain in quartered oak; and a host of other inter-



FIG. 13. PLUMOSE QUINIDINE.  $\times 70$  DIAMETERS. POLARIZED LIGHT.

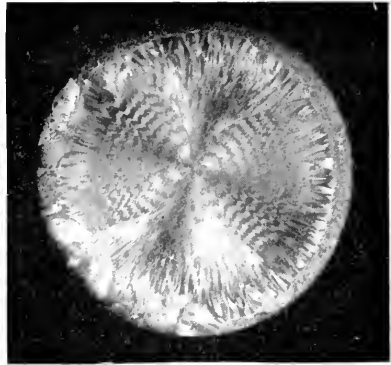


FIG. 16. CINCHONIDINE.  $\times 50$  DIAMETERS. POLARIZED LIGHT.

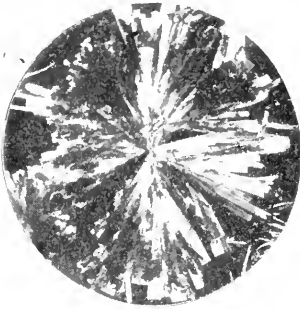


FIG. 14. PLATINO-CYANIDE OF MAGNESIA.  $\times 70$  DIAMETERS. POLARIZED LIGHT.

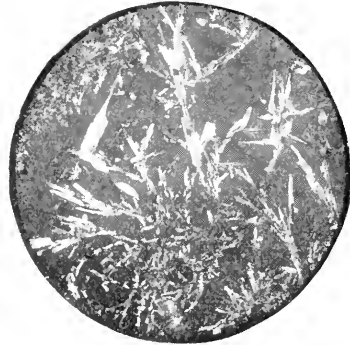


FIG. 17. BICHRAMATE OF POTASH CRYSTALS.  $\times 70$  DIAMETERS. POLARIZED LIGHT.

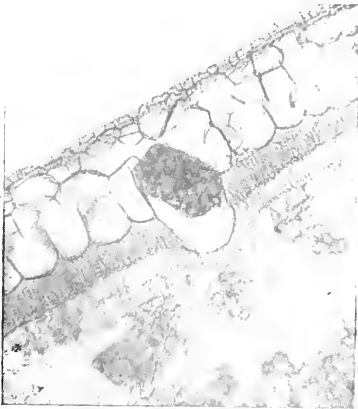


FIG. 15. CRYSTAL OF  $\text{CaCO}_3$  IN INDIA RUBBER PLANT.  $\times 120$  DIAMETERS.



FIG. 18. BRUCINE CRYSTAL.  $\times 70$  DIAMETERS. POLARIZED LIGHT.



esting details about seeds, leaf structure, etc. It is quite possible that the microscope may yet serve to answer the present disputed question as to how the water can rise into the tops of the great trees of California, some of which are over 300 feet from the ground. It may also be mentioned that photomicrographs are of much importance in studying insects and parasites that infest and destroy forest and fruit trees. In fact, the preservation or annihilation, as seems best to serve man's purpose, of certain organisms is determined very largely by the revelations of the microscope. When such a thing as the lack of assimilating power of a leaf due to insufficient amount of light may be shown by a photograph, the far-reaching value of this science can be understood.

Its intimate connection with botany and plant structure in general is in fact so well recognized as to need little comment here. Some work in connection with cotton fibers, however, is interesting as it shows how it is possible to detect injury to the fiber in the process of ginning; such photographs in connection with others of like character, render valuable information concerning textile materials (Fig. 12).

In crystallography the photomicrograph is useful. Figs. 13-18 illustrate the appearance in polarized light of a few crystals of both organic and inorganic substances. Perhaps one of the richest of all

substances in variety of form of crystals is snow. While the geometrical form is invariably hexagonal, it occurs in countless combinations and many of the crystals are very beautiful. For procuring pictures of snow crystals it seems necessary to use the apparatus in a temperature below the freezing point. The snow crystals are collected as they fall upon a surface too cold to tend to melt them, and if the work is done quickly,



FIG. 19. SNOW CRYSTALS.

excellent results are obtained. It is a singular fact that almost every snow crystal differs in some particular from all others collected. Mr. Bentley, of Nashville, Vermont, has doubtless given more attention to snow crystal photography than any one else, and the number of different forms which he has already obtained is remarkably large, and many of them are exquisite. Much has also been done on questions relative to the crystalline structure of various minerals by the aid of the microscope, as for example, 'Inclusions of Petroleum in Quartz' (*Jour. Am. Chem. Soc.*) 20: 795, and also concerning the 'Solution Vein Theory' for the origin of gold. In the same way it is possible that in the future a unanimity of opinion may be produced concerning the crystallization of iron, which is worthy of serious attention as the enormous amount of that metal used in construction increases year by year.



FIG. 20. COW HAIR.  $\times 2200$  DIAMETERS



FIG. 21. CROSS SECTION OF HORN OF AFRICAN RHINOCEROS.  $\times 60$  DIAMETERS. POLARIZED LIGHT.

The value of the part which the microscope plays in determining facts about the minute structure of the animal organisms can scarcely be overestimated. The bacteriological analysis of water in connection with zymotic diseases; the determination of disease germs in impure air; the examination of useful and injurious bacteria in food; all this and more must be credited to the microscope in the development of medical science and sanitation.

A detailed description of all the applications of photomicrography to nature study can not well be given here, and so a few of the important ones only have been briefly noticed. The chief value of it all seems to be the aid rendered in the dissemination of knowledge. To attempt to look beneath the superficial and discover the ulterior is a fundamental desire in the active, civilized mind. Since the beginning of the seventeenth century, when Galileo was imprisoned for stating his belief in the motion of the earth, we look with pride at the development of science

through the minds of such men as Newton, Kepler, Lyell, Huxley, Ohm, Faraday, Joule, Helmholtz, Le Conte, Darwin and scores of their contemporaries.

The beginning of the twentieth century finds the major part of the civilized world bound to recognize the power of scientific thought and investigation in its bearing upon the prosperity of nations, and the equality of man. More and more attention is wisely being given to methods of teaching in our primary and secondary schools as well as to college and university work. Such attention is even now beginning to manifest its results, as we note men having completed their university training for the Doctor's degree under twenty-five years of age. No doubt it may truly be said that such men are brilliant, or have

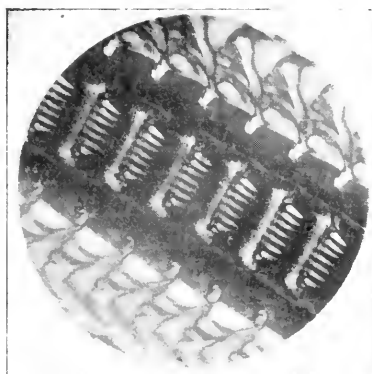


FIG. 22. PALATE OF A WHEEL.  $\times 90$  DIAMETERS. POLARIZED LIGHT.

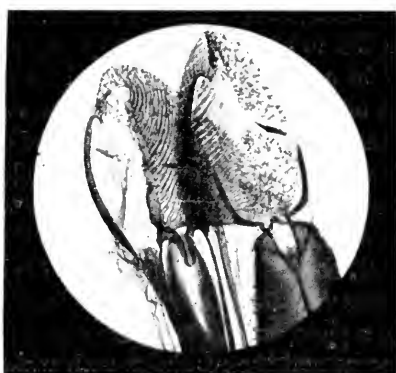


FIG. 23. PROBOSCIS OF FLY.  $\times 80$  DIAMETERS.

exceptional advantages or both combined for the result attained, yet the fact remains that elementary knowledge gained from secondary instruction molds to a great extent the future of the individual. This phase of study is all the more important since it is beyond the control of the pupil. Beyond his control, for though volumes may be written, and instructors may be at hand, the average student does not early in life appreciate the necessity or value of application to study.

*Interest in a subject is the prime factor in its mastery,* and the *method* of presenting the subject will tend either to stimulate or allay the interest of the pupil.

The time devoted to the study of a subject in the secondary school is frequently very limited, and the teacher may profitably consider the needs of the pupils and seek to originate such methods as will accomplish the most for the time allotted. One important saving of time in the classroom, both for elementary and advanced work along most scientific lines, is the use of pictures in making certain points clearly understood, and

it seems that either the stereopticon, or wall pictures large enough to be seen by the class as a whole, are most desirable. The instructor may thus explain to a class in a few minutes what would under other conditions require hours to make clear to them. This mode of procedure is as useful with pictures of the infinitesimal organisms and material in nature as with views of miles of landscape concerned with the geography of the globe.

Take for example the little daphnia, shown in Fig. 4, magnified 150 diameters. This when thrown from a slide on an eight-foot screen makes the original magnified to nearly six thousand diameters. A class of students may look first at a tiny speck in a glass of clear water, which is perhaps one third the size of a pin-head, apparently without definite form, and of no consequence, but which, when seen enlarged, is shown to possess all the organs of a living animal. And further to illustrate how very tiny a particle of matter may become and yet be a *mass* as distinguished from molecules and atoms, the student has only to note such an illustration; for he sees that this microscopic animal is a mass as truly as is the elephant. In the study of rocks, of plants, of animals, even in a most elementary way, some very instructive lessons concerning their minute structure and how it concerns their outward forms and functions may be learned by such pictures.

Of course, all schools are not so situated as to be able to use a lantern in this way, though many have felt the importance of its use and of making a place for it. With the cheap forms of apparatus on the market at present and the readiness with which electricity or acetylene gas is obtained for an illuminant, the lantern should find its proper place in the class-room. Various forms of apparatus are also accessible for the projection of the microscopic slides directly, but in general, they give more trouble in handling to the average person than they are worth. The lantern slide is infinitely more satisfactory for general illustrative teaching. Another and in some cases better method for illustrating a subject is by the use of large pictures which can be hung up before a class and readily explained. Where classes are not too large, a photograph 20" x 24" in size is large enough, and there is then no necessity for a darkened room as with the lantern, and the picture may be considered in just the proper place in the course of a talk on the subject. These pictures are simple enlargements on bromide or velox paper from the original microscopic negative and cost but little more than lantern slides.

Since the scientific knowledge structure is continually building upon the foundation of accepted results of earlier investigators, it may be said in conclusion that photomicrography serves a double purpose. First, it enables the scientific investigator to determine accurately a knowledge of the minute physical structure of matter, and secondly, it provides a means of placing such information before others in a comprehensive manner.

## SUGAR AND THE SUGAR BEET.

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THE total production of sugar in the world is between seven and eight million tons yearly; in 1898-99 it was 7,839,000 tons. Of this amount about three eighths is obtained from sugar cane and five eighths from beets.

The United States in 1898 consumed 2,047,444 tons of sugar, each ton being 2,240 pounds. This was an average of sixty-one pounds for every man, woman and child in the country. In 1897 the consumption was nearly sixty-four pounds per head, and this figure is approximately the average for the last ten years, the average for the preceding decade being ten or twelve pounds less.

The United States consumes much more sugar per head than is consumed in Europe. In 1895, when the consumption in the United States was 62.60 pounds per capita, the consumption in Europe was 25.64 pounds per capita. The consumption in nearly all the countries of Europe is very low, and the average would be very much lower if England were left out of account. In England it is far in advance even of that of the United States, being 86.09 pounds in 1894-95, when Denmark, which in Europe stands next to England, consumed 44.66 pounds, that is, only slightly more than half as much. The great consumption in England is largely due to the amount of jams and confectionery manufactured, much of which is exported. Germany exports large quantities of sugar to England and imports confectionery. This is due to the special bounty arrangements in Germany. The government does not bonus the production of sugar, but taxes it. It however gives a rebate on the sugar exported, in such a way as to constitute a bounty. An excise duty is placed upon beets used in the manufacture of sugar. On any sugar exported a drawback is allowed. The law passed in 1869 assumed that beets contain eight per cent. of sugar, so that the manufacturer would get as much drawback from the government if he exported eight tons of sugar as he had paid on one hundred tons of beets. But owing, on the one hand, to improved cultivation of the beet, and, on the other hand, to improved methods of extraction, instead of twelve and one half tons of beets being necessary for the production of one ton of sugar, less than eleven tons were required in 1877, and in 1898 only seven tons. Now, therefore, the German manu-

facturer obtains fourteen instead of eight tons of sugar from one hundred tons of beets, and if he exports the whole amount receives a drawback of fourteen dollars from the government for every eight dollars he has paid into the treasury; in other words, he has a bounty on six tons out of fourteen. This has so far encouraged the manufacture of sugar in Germany that it increased from 378,000 tons in 1878 to 1,755,000 in 1898, or over 400 per cent.

England exports so much of the sugar that is tabulated as consumed that it is probable that the average actually eaten by each person in the United States is greater than in any other country. Each person uses about \$2.50 worth of sugar each year, making for the whole country approximately two hundred million dollars' worth. About half this amount of money is now sent to foreign countries for the sugar we import; for while we refine most of our sugar ourselves, we manufacture only an eighth of it.

Of the sugar consumed in the United States, three quarters is provided by the sugar cane, the remainder being manufactured from beets. There is little likelihood of much growth in the manufacture of domestic cane sugar, though at present there is more cane sugar made than beet sugar. In 1899, 160,400 tons of cane sugar were manufactured, as opposed to 79,368 tons of beet sugar. But the cane sugar industry is of long standing, while in 1888 the quantity of beet sugar manufactured was only a thousand tons.

Germany not only was the pioneer in the manufacture of beet sugar, but she has easily held the first place, except for a few years in the early part of last century when France took the lead. In 1747 Margraf showed in a paper, read before the Berlin Academy of Sciences, that he had been able by means of alcohol to extract 4.5 per cent. of sugar from red beet and 6.2 per cent. from white beet. The manufacture was not, however, begun on a commercial scale. Extraction by alcohol was expensive, and comparatively cheap sugar came in from the British colonies. It was not until 1799 that the first beet sugar factory was established by Achard, director of the Royal Prussian Academy of Sciences, and the beet sugar industry is therefore little more than a century old. Even by Achard's process, the cost of making beet sugar was greater than its value in the market; but in 1811 Napoleon blockaded the European ports and prevented the entrance of colonial sugar. This enormously raised the price of cane sugar, which cost in 1811 between one and two dollars a pound, though in 1805 five or six pounds could be bought for the same money. After Napoleon's downfall, the former state of affairs returned, but, in the meantime, the beet sugar industry had been stimulated and methods had been improved. In France political enmity towards England prevented the inroad of colonial sugar to the same extent as in the rest of Europe, and up till

1836, or thereabouts, France was the leading producer of beet sugar. Though Margraf had been able on a small scale by using alcohol to obtain from four to six per cent. of sugar, at first only two or three per cent. was extracted by the factory processes, but owing to improvements introduced in its manufacture as well as to the cultivation of beets with greater sugar content, five or six per cent. of sugar was obtained in the early thirties.

Schatten's invention of a saccharometer for estimating the amount of sugar in beets, and of several very important processes, revived the industry in Germany and placed that country in the van, which position it has held ever since. The growth of late years is shown by the fact that whereas in 1877-78 4,090,968 tons of beets passed through the factories, in 1898-99 the amount was 12,144,291 tons or 2.97 times as much. The amount of raw sugar produced in the same time increased from 378,009 tons to 1,710,000 tons or 4.52 times as much. It will be noticed that the increase in sugar produced is much more than the increase in beets treated. This is because of the greater amount of sugar extracted. Whereas in 1877, one ton of sugar required 10.82 tons of beets, in 1899 one ton of sugar required only 7.01 tons of beets. In other words, in 1899 three tons of sugar were made from the same weight of beets as in 1877 yielded but two tons.

Hardly had France and Germany succeeded in establishing the beet sugar industry before the United States made some experiments in the same direction. In 1840 a factory was located in Connecticut. It did not prove successful. Later other efforts were made, but with no better success. Among the causes of failure were careless methods of beet culture and very inadequate methods in the factory. It was even thought by many that simple apparatus, like that used in making maple sugar, was sufficient; moreover, the early factories were located in places that were not suitable. The first factory that had any appreciable success was at Alvarado in California. It was built in 1870; the company failed in 1876, but was reorganized in 1879, and the factory has been in operation ever since.

The Department of Agriculture under the federal government for a number of years carried on investigations and published reports and reviews, but its work was suspended in 1893. In 1897, however, it was resumed with renewed and increased vigor, and since then the government has taken great interest in the matter. It has distributed seed in a large number if not all the states and has sent out instructions to farmers who accepted seed for experiment. The Department of Chemistry has made analyses of thousands of samples of beets, and investigations have been made upon the influences of soil, temperature, rainfall and other conditions upon the growth of the beet, its sugar content and the purity of the sugar. In 1898 over twenty thousand

pounds of seed were sent out to experiment stations for distribution. The value of the government's work is shown by the rapid strides with which the industry has advanced. In 1897 there were nine factories in operation in the United States, of which four were in California. In 1900 there were thirty-six, ten of them being in Michigan, which three years earlier had none. Germany has four hundred factories and turns out an average of between four thousand and four thousand five hundred tons of sugar for each factory. The average increase per annum in the consumption of sugar in the United States between 1881 and 1899 was over sixty thousand tons. In order to meet this increase alone, fifteen factories would need to be added each year. It is thus evident that though the industry has grown so markedly, the *increase* in consumption is not provided for. Nearly five hundred factories would be required for our present needs, and, after those were provided, ten or fifteen should be added each year to provide for growth, if the increase in consumption keeps up at the rate of the last twenty years.

As has been stated, one of the causes of the early failure of the beet sugar industry in this country was the location of factories in unsuitable places, and one of the most important features of the government's work of late years has been the investigation of the places where beets can be grown profitably. Beets should have a sugar content of at least 12 per cent. and perhaps even 13 per cent. or 14 per cent., otherwise it will not probably pay to erect a factory. This is not because at present prices a factory using beets of 12 per cent. sugar could not pay, but because in many parts of the country a considerably higher percentage is obtainable, and, in view of competition, the most favorable locations should be chosen. In the examination made by the Department of Agriculture of beets sent in during the year 1897, '98 and '99 from thirty-nine states and territories, it appeared that Arkansas was least suited for beet culture, giving an average of a little over seven per cent. of sugar. On the other hand, Nevada showed an average of eighteen per cent. of sugar in the samples examined.

A matter which is almost, if not quite, as important as the percentage of sugar is its purity and in this respect Nevada was almost at the top of the list, the 'coefficient of purity' being 83.8. The coefficient of purity means the percentage of sugar in the total solids dissolved in the juice. For example, if one hundred pounds of beets yield a juice containing fifteen pounds of solid matter dissolved in it, twelve pounds of which is sugar and the remaining three something else, the sugar content is said to be 12 per cent. with a coefficient of purity 80. Impurity keeps part of the sugar from crystallizing and so prevents its recovery in the factory and hence a high coefficient of purity is exceedingly important.

A very important factor in the cultivation of beets is the tempera-



ture. A large part of the United States has too high a temperature. Where the temperature is high beets grow luxuriantly, but they contain a small percentage of sugar. On the other hand, where frosts come early in the autumn, the beets can not arrive at maturity. Other things being equal, the farther north the beets can grow to maturity the greater will be the sugar content. In 1897 the Department of Agriculture gave as a provisional area a zone having a mean temperature between 69° F. and 71° F. for the months of June, July and August. This forms a strip across the country sometimes very narrow, sometimes quite wide—in New Mexico and California running south of the thirty-third parallel of latitude, in Dakota north of the forty-sixth, forming on the map a serpentine band which, owing to its many folds and twistings, has a length considerably greater than double the width of the continent. In addition to this belt there are a few outlying areas as for instance a portion of Washington. The belt begins on the east in the neighborhood of New York City, and on the Pacific it forms a long strip stretching between four and five hundred miles, almost due north and south, and extending to the Mexican boundary. Later investigation has widened this area a little, chiefly on the north, but has not very materially affected it. It must not be supposed that all parts of the belt are equally favorable. For instance, though North Dakota and southern California have the same average temperature in June, July and August, in the former place frosts come very early and the winters are severe, while in the latter there is little frost at any season.

The rainfall is a matter of importance. Warm rains in the early part of the season and dry weather during the period of maturing are best. In arid districts, irrigation may be resorted to, and has the great advantage that the supply of moisture can be regulated. Irrigation works are usually expensive and do not ordinarily pay in the raising of cereals, but the sugar beet is a valuable crop and experiments already made point to the probability that Colorado, Utah, New Mexico and other similar states will become extensive producers of sugar beets. Ten million acres of arid land could be irrigated comparatively easily and that would more than supply the world with sugar.

The growth of the sugar industry in Michigan is very interesting. In northern Michigan lumbering has been carried on very extensively for a number of years. The result is that the timber areas have been rapidly denuded. The question as to the use to be made of the land from which timber was removed became pressing. The soil was considered too sandy for ordinary agricultural purposes but it turns out to be very suitable for beet culture and sawmills are being replaced by sugar factories.

The sugar is not the only valuable part of the beet. When the juice

is extracted there is a pulpy residue from which the liquid is pressed out. This pulp is very valuable as food for stock. Some factories have dairies in connection with them. The experiments already made have been very satisfactory. The pulp is probably the cheapest food that can be used considering the amount of nutrition. The leaves are also valuable as food, but probably still more valuable as a fertilizer. Sugar takes nothing from the ground. It is made from the water vapor and carbon dioxide of the air. But the tissue of the beet contains considerable potash, magnesia, phosphoric acid and nitrogen, and all these are removed to a greater extent by the leaves than by the roots. If then the leaves are left on the ground or are plowed under, the soil is much less exhausted than if they are taken away. For beet-raising the cultivation of the soil must be very carefully attended to. This cultivation has a very beneficial effect on other crops grown in rotation with the beet, hence the advantages of beet-growing are indirect as well as direct.

The cost of raising beets is considerable, but, on the other hand, the returns are large, and the profits may be estimated as on the average twenty dollars an acre.

## PETER GUTHRIE TAIT.

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NEXT to Lord Kelvin, perhaps the most notable figure among the physicists of Great Britain during the past forty years has been Peter Guthrie Tait, professor of natural philosophy in the University of Edinburgh since 1860. One of the first to establish laboratory instruction in Great Britain, and beginning his career at a time when the now prevalent ideas of energy were yet unborn, he has had much to do with the shaping of scientific thought and education during the latter half of the nineteenth century.

He was born at Dalkeith (a town of several thousand inhabitants, about six miles southeast of Edinburgh) in 1831. His early education was obtained at the Dalkeith Grammar School and at the Circus Place School in Edinburgh. Tait was a distinguished pupil, and those of his schoolfellows who are still alive speak of him with so much love and respect that he must have been a leader among them. Clerk Maxwell was his most intimate school and college friend, and the friendship thus begun continued till Maxwell's death, undisturbed by the fact that they were rivals for the Edinburgh chair in 1860. 'Both were men of playful disposition and of absolute frankness and sincerity.'

Tait studied at Edinburgh University for one session under Kelland and Forbes, and the promise he then gave was amply fulfilled at St. Peter's College, Cambridge, where he became senior wrangler and first Smith's Prizeman in 1852, being just twenty-one years of age. His private tutor was William Hopkins, to whose tuition Tait attributed much of his mathematical skill. Tait seems to have joined heartily in all phases of undergraduate life at Peterhouse. He was a keen golfer, and for forty years he spent an annual holiday on the links at St. Andrew's. It is said that his son's progress to the championship in golf was dearer to him than his own scientific fame. And some declare that the untimely death of his son, an officer in the Black Watch in the South African War, hastened his father's last illness, to which he succumbed on July 4, 1901, at seventy years of age.

In 1854 Tait was appointed professor of mathematics in Queen's College, Belfast, and became acquainted with Andrews, the chemist, and Rowan Hamilton, the mathematician. Andrews stimulated his love for physical research and helped him to gain the power of apprehending the facts and of plainly formulating the theories of natural philos-

ophy. Through the works and the personal influence of Hamilton he was led to the study of quaternions, to which he gave much attention.

In 1860 he was elected to the chair of natural philosophy in Edinburgh, resigning it in February, 1901, on account of a lingering illness, which resulted in his death four months later. It is estimated that about ten thousand students passed through his class-room during those forty years, and few could do so without carrying away some impress from this notable teacher. Among the first of his 'researchers' were a remarkable trio—Robert Louis Stevenson, Wm. Robertson Smith, the distinguished Scottish Biblical scholar and orientalist, and Sir John Murray, the well-known publisher. Great must have been the attraction of Tait's personality to bring together three men so highly distinguished, yet so utterly different.

About the time of his appointment to the Edinburgh chair, Tait became acquainted personally with Lord Kelvin, who, though also a Peterhouse man, had left Cambridge before Tait came up, "and was already independently and in conjunction with Joule, and concurrently with Rankine and Clausius, writing his classical memoirs on the theory of energy. The first edition of Tait and Steele's 'Dynamics of a Particle,' published in 1856, does not contain either of the words *work* or *energy*. In its original form it was founded on Pratt's 'Mechanical Philosophy,' and written on the old-fashioned Cambridge lines, which knew not of Lagrange and Hamilton. Six years later it is on record that in his introductory lecture Tait handled the notions of the *energetic* school with freedom and laid down the foundations of a thoroughly modern course in physics. Probably, therefore, he had come under the influence of Joule and Kelvin before he met the latter personally." The conjunction with Kelvin produced the famous treatise on 'Natural Philosophy' by Thomson and Tait in 1867, which began a new era in mathematical physics. Dozens of men nourished by the strong meat of its pages have written treatises in continuation of the lines there laid down.

Tait's contributions to text-book literature include, besides the two works just mentioned, 'Elements of Quaternions,' 1867; 'Introduction to Quaternions' by Kelland and Tait, 1868; 'Recent Advances in Physical Science,' 1876; 'Thermodynamics,' 1868; 'Light,' 'Heat,' 1884; 'Properties of Matter,' 1885 (revised to 1899), and 'Dynamics,' 1895.

Although Tait rarely spoke on religious topics, and in general avoided theological controversy, his friends were aware that he held decided views on such matters. He was the joint author with Balfour Stewart of the 'Unseen Universe' (first printed privately in 1875), a book showing, to use Tait's own words, how baseless is the common belief that science is incompatible with religion. "It calls attention

to the simple fact, ignored by too many professed instructors of the public, that human science has its limits, and that there are realities with which it is altogether incompetent to deal."

Tait's collected scientific memoirs have been published by the Pitt Press, and embrace between one hundred and two hundred papers relating to a great variety of subjects. It would be out of place in this paper to attempt any detailed examination of these articles. A rapid sketch of the contents of the two volumes already published will however be given.

A large proportion of each volume is given up to quaternion investigations, a subject and method in which Tait remains almost the sole authority. Lord Kelvin has given the following reminiscence of the collaboration in 'Natural Philosophy': "We had a thirty-eight years' war over quaternions. He (Tait) had been captivated by the originality and extraordinary beauty of Hamilton's genius in this respect, and had accepted, I believe, definitely from Hamilton to take charge of quaternions after his death, which he has most loyally executed. Times without number I offered to let quaternions into Thomson and Tait, if he could only show that in any case our work would be helped by their use. You will see that from beginning to end they were never introduced." In a note in his second volume Tait states that Klein's account of quaternions rests on a misapprehension; and remembering that, though 'the grandest characteristic of quaternions is their transparent intelligibility,' men like Cayley and Klein have gone astray, we may be excused from any attempted discussion of them here. Other abstruse papers are those on 'Amphichieral Knots,' and 'Knottedness.' Many addresses and notes of a less technical nature serve, as Lord Rayleigh has remarked concerning his own, 'to relieve the general severity.' Here and there a biographical notice as of Listing, Kirchhoff, Sir Wm. R. Hamilton and Rankine, or the reprint of an encyclopedian article, as on 'Mirage,' 'Force,' etc., gives interest to the miscellany. Tait was a party—and an active party—to many polemical discussions, but very properly all traces of these keen controversies are omitted in his collected papers.

We have yet to notice the best of his researches. The most noteworthy theoretical discussions are those on the kinetic theory of gases (five papers, *Trans. Edin. Roy. Soc.*, 1886-92), on impact (three papers, 1888-92), and on the path of a rotating spherical projectile. These latter were due to his interest in golf, and on this subject he wrote a series of popular articles, which it is said were widely read and appreciated.

His most important theoretical paper is the review of the kinetic theory of gases, in which he analyzed into their logically simplest elements, the first principles of a difficult subject. He gave several new

view-points from which to examine the foundations of the theory. There are three advances in the details of the theory with which his name is generally mentioned, as follows: (1) He showed that the analogy between the coefficient of diffusion for gases and the conductivity for the propagation of heat can not be pushed to the conclusion that since the conductivity is a constant magnitude, the coefficient of diffusion is a constant also, for experiments with the same pair of gases. Tait showed that this expectation is not justified by the formula in terms of which the coefficient is deduced, showing in fact that it depends at any instant not only on the temperature and on the pressure of the mixture, but also on the ratio in which the two gases have mixed with each other by that time. (2) He showed that in applying Maxwell's law of the distribution of velocities (a law deduced for a gas without total progressive or rotational motion) to the case of a gas the body of which is in rotation, the interval of time within which the mechanical theorems (deduced for the static conditions) remain valid with sufficient exactness for a single layer (the whole body of gas being considered as divided into layers between which the interchange of energy is slow) may be long enough to allow the very rapidly resulting arrangement in the distribution of velocities according to Maxwell's law to occur. In each of these layers, then, Maxwell's law holds good for the distribution of velocities on the condition that the velocity in which a particle shares by the flow or rotation of its layer is to be subtracted from the value which it would have in the state of rest and equilibrium of the gas as a whole. (3) The calculation of the coefficient of viscosity on the assumption of Maxwell's law of distribution of velocities.

In reading Tait's papers on the kinetic theory of gases it is interesting to note the author's frank confession: "I have abstained from reading the details of any investigation (be its author who he may) which seemed to me to be unnecessarily complex. Such a course has, inevitably, certain disadvantages, but its manifest advantages far outweigh them!"

Tait's chief experimental research was that on the compressibility of water, undertaken in connection with an investigation of the errors of the deep-sea thermometers used on the famous voyage of the *Challenger*. It is an interesting record of a laborious investigation undertaken to decide a very important practical question.

Several earlier investigators had studied the compressibility of liquids, always chiefly of water. Only the chief among them need be mentioned here. Canton, a hundred and twenty-six years before, had not only exhibited the compressibility of water, but had shown that it decreases as the temperature is raised; and Perkins in 1826 showed very clearly that in water at 10°C. the compressibility diminishes as the pressure increases, quickly at first, afterwards more and more slowly;

but Perkins' estimates of pressure are inaccurate, and no numerical data of any value can be obtained from his results. Regnault in 1847 attempted to take into account the compressibility of the piezometer by applying pressure alternately to the outside and the inside of the piezometer, and then simultaneously to both. But this method gives the elastic constants of the piezometer only when dealing with an absolutely incompressible liquid. Amaury and Deschamps measured the change in external volume of the piezometer, but Tait points out that unless the bulbs are truly spherical or cylindrical, of uniform thickness and homogeneous material, errors due to application of pressure on the outside or inside alone may be introduced of the same order as the quantity to be measured. A very complete series of measurements had been made for water from 0°—100°C. by the two Italian experimenters, Pagialini and Vincentini, but only for low pressures. Moreover, though they made careful determinations of the change in the glass due to changes of temperature, they failed to eliminate the effect of pressure on the piezometers, applying pressure to the inside only, and so their results are some forty per cent. too great. Lastly, Amagat made very extensive experiments up to 3,000 atmospheres, but he considered the compressibility of the glass to be of small effect and consequently left it out of account, and the first really satisfactory work on this important subject was that accomplished by Tait and his assistants, the full report of which appears in the 'Challenger Reports.\*'

The great merit of Tait's work was the careful determination of the pressures used, and the preliminary researches on the compressibility of mercury and of glass, so as to apply the proper corrections to his thermometers and piezometers, together with the fact that his investigations extended to sea-water and to solutions of salt of various strengths. A brief summary of his most important results follows:

As an approximation for the compressibility of fresh water through the whole range of the experiments (pressure from 150 to 450 atmospheres and temperatures from 0° to 15°C.), he secured the formula:

$$\frac{0.00186}{36 + p} \left( 1 - \frac{3t}{400} + \frac{t^2}{10,000} \right)$$

where  $t$  is the temperature of the water in degrees centigrade and  $p$  is the pressure in tons per square inch.

The point of minimum compressibility of fresh water is about 60°C. at atmospheric pressure, but is lowered by increase of pressure.

The average compressibility of sea-water is about .92 of that of fresh water, with a minimum compressibility at about 56°C., lowered by increase of pressure.

The average compressibility of salt solutions for the first  $p$  tons of additional pressure beyond atmospheric pressure is, at 0°C.—

$$\frac{0.00186}{36 + p + s}$$

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\* Vol. II., 'Physics and Chemistry,' London, 1889.

where  $s$  parts of salt are dissolved in 100 of water,  $s$  varying in Tait's experiments from 0 to 21.4.

Six miles of sea water, at  $10^{\circ}\text{C}$ . throughout, are reduced in depth 620 feet by compression. Hence the pressure at a depth of six miles is nearly 1,000 atmospheres.

The maximum density-point of water is lowered about  $3^{\circ}\text{C}$ . by 150 atmospheres of additional pressure.

The maximum density-point coincides with the freezing-point at  $-2^{\circ}.4\text{ C}$ ., under a pressure of 2.14 tons.

As to the proper correction to apply to the *Challenger* thermometers, Tait showed that that previously given by Davis, viz.:  $.5^{\circ}\text{F}$ . per ton per square inch, was greatly too large, and that of five sources of error which entered into the test experiments, only one held for the circumstances under which the *Challenger* thermometers were actually used, that the other four were proper for the experiments in the laboratory, but not for sea-soundings. The only cause of error active in the case of sea-soundings was the direct effect of pressure on the glass and mercury of the thermometer, and the correction due to this was but  $0^{\circ}.14\text{ C}$ . for every mile of depth.

Next to his work on the compressibility of water and the allied investigations, come Tait's experiments in thermo-electricity. He made two contributions in this field.

1. Having supposed that the Thomson effect (the absorption or liberation of heat-energy in a conductor whose temperature varies from point to point when traversed by a current of electricity, the effect being reversible, in any given conductor, with the direction of the current) might, like thermal and electrical resistance, be directly proportional to the absolute temperature, he verified his assumption by experiment, finding that the curves for the e. m. f. in terms of absolute temperature for junctions of any two of iron, cadmium, zinc, copper, silver, gold, lead and some others are parabolas with their axes vertical, if the e. m. f. be taken as ordinates, the apex corresponding to the neutral point, or point of reversal. This amounts to showing that the curve representing the thermo-electric power\* of any couple in terms of the mean temperature of its junctions is a straight line. We need only draw the diagrams of the thermo-electric powers of all the metals taken separately with one of their number in order to learn the values of the thermo-electric powers of all the metals taken in pairs in any combination. Lead was adopted as the metal of comparison, because as Le Roux had shown, its specific heat of electricity is zero.

By the 'specific-heat of electricity' is meant the amount of heat-energy developed in the given conductor, according to the Thomson

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\* The 'thermo-electric power' of a couple for a given temperature is the e. m. f. between its junctions when they are kept respectively  $\frac{1}{2}^{\circ}$  above and  $\frac{1}{2}^{\circ}$  below that temperature.



effect, between two points whose difference in temperature is  $1^{\circ}\text{C}$ ., when a unit quantity of electricity passes between them. And Tait's work amounted to showing experimentally that the 'specific heat of electricity,' as defined by Kelvin, was for any given substance directly proportional to the absolute temperature. This is sometimes spoken of as Tait's Law.

From these experimental results Tait suggested the well-known form of the thermo-electric diagrams, the rough preliminary suggestions for which Lord Kelvin had already given. Under Tait's development the diagrams exhibit not merely the relative thermo-electric positions of the metals at various temperatures, with their neutral points, but also the specific heat of electricity in each metal in terms of temperature, the amount of the Peltier effect, and the e. m. f. (and its direction) for a circuit of any two metals with given temperatures of the junctions.\*

2. Tait also discovered a multiplicity of neutral points for thermo-electric couples of certain substances, such as circuits of iron coupled with various alloys of platinum with iridium, nickel and copper. In each of these cases there are at least two neutral points below the temperature of white heat, and others at still higher temperatures.

Professor Chrystal gives† the following vivid picture of Tait:

Ready to take a blow, he did not always spare his strength in giving one, and his opponents did not always relish his rough play. It may be doubted whether many of them carried for long any resulting bitterness; but undoubtedly some of them were led, temporarily at least, greatly to mistake his character. Personal contact with him at once dissipated any such misconception. To feel the magic of his personality to the full it was necessary to visit him in the little room at the back of his house, the Spartan simplicity of whose plain deal furniture and book-shelves, unpainted, unvarnished, ink-spotted, littered with books and pamphlets and with piles of manuscript bristling with quaternion symbols, was finely in tune with the tall, rugged figure, the loud, hearty greeting and the radiant, welcoming smile of the kindly host. Ten minutes in that sanctum would have made a friend of the bitterest foe. Thither at various times came Joule, Andrews, Kelvin, Stokes, Helmholtz, Rankine, Clerk Maxwell, Balfour Stewart, Rowland, the Wiedemanns (father and son), Adams, Newcomb, Huggins, Newton, Lockyer, Hamilton (at least in spirit), Cayley, Sylvester, Hermite, Cremona, Clifford, Klein, Bierens de Haan and many more, the majority, alas, now departed like their common friend."

\* For a discussion of these diagrams see J. J. Thomson's *Elec. and Mag.*, pp. 499-505.

† *Nature*, July 25, 1901.

## CONCERNING THE AMERICAN UNIVERSITY.\*

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POLITICAL, social and educational institutions rise and decline, as species and genera have come and gone in the history of organic life. Evolution has been on the whole progressive, leading to greater differentiation and more complex interdependence. But there have been strange creatures—suited perhaps to their environment, but monsters from our point of view—brutes encased in impenetrable armor and dragons undecided as to whether they should crawl or fly. Our universities have developed in the main by the crude and wasteful methods of natural selection; but a new factor in evolution has in these latter days become possible and perhaps even potent. The struggle for existence, prodigal of time and careless of the individual, resulted in the production of animals that could learn by experience, and finally in such as can consciously look before and after and plan for what is not. Hitherto human foresight and reason have had but little to do in the selection and direction of educational methods, but the time has come when we can at least form opinions and judgments. We realize that certain surviving dinosaurs should be exterminated, that certain fads spread like weeds, that the 'fittest' is not always the best. Our reason is as yet only a toy in the hands of a child, but as the child grows the toy may become an engine competent to direct our civilization. We have not at present a science of education or an art of education based on science, but we are beginning to have ideas. However vague and immature these may be, it is well that they begin to exist, for thanks to the contagion and possible immortality of ideas, natural selection can here work more rapidly than in the case of organisms. It may take a million years to mold a new whorl on a shell, whereas the entire system of higher education in America has developed since the Johns Hopkins University opened its doors twenty-five years ago.

The outline history of the American university is a familiar story. We had the English college, beginning with Harvard in 1636, for the training of the clergy and as a denominational school. With many

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\* An address read before the members of Phi Beta Kappa of the Johns Hopkins University on May 2, 1902.

sects colleges multiplied like churches in a village, supported, so far as they were supported, by religious zeal. Free education has been fostered by our states as never before, and where the field was clear, beginning with Michigan in 1837, state universities became the head of the public school system. Technological schools and departments—beginning with the Rensselaer Polytechnic Institute in 1824—were founded in answer to the needs of a country requiring material development. Independent or quasi-independent schools of divinity, medicine and law gave the inadequate preparation that the pressing demand for clergymen, physicians and lawyers allowed. University work did not exist, and our B.A.'s swarmed to Germany, where ideals of research and creative scholarship had arisen, which took kindly to transplantation and an unexhausted soil. Certain native agencies, the Smithsonian Institution, the scientific academies, the geological surveys and the like, modestly furthered research and contributed to the university ideal.

In a general way the old Cambridge college, adjusting itself to the practical needs of a democratic and industrial country, adding the German faculty of philosophy, and gathering in the professional schools, has given us our American university. These three elements, represented by the bachelor's degree, the doctorate of philosophy and the professional degrees, are variously combined and developed in our different institutions; and this certainly gives great flexibility and possibilities to university development. The foundation of new universities—Cornell, Johns Hopkins, Stanford and Chicago—and the enlargement of the resources of private and state institutions have greatly favored progress and differentiation. We have no one kind of university, but many types, each seeking to work out its own salvation. Here surely is ground for hoping that we shall soon set educational models.

But twenty-five years is a short period, and it would be no cause for surprise if it has given us more problems than solutions. The college, originally for secondary education, but with higher education attached, is in a state of unstable equilibrium. The distinction between courses for culture, courses for higher specialized liberal training and courses fitting for the professions appears to have a historical explanation rather than a logical justification. Every student during all his course of education—namely, from the time he is born to the time he dies—should do the three things that are artificially separated in our universities. He must learn to do his share of the useful routine work of the world, he should aim to improve the methods of doing this work and he should have some acquaintance with the work of others.

The prolongation of infancy marks off the higher animals from the lower, and men from all others. If the sensori-motor arcs are

closed at birth or soon thereafter, the creature can learn but little. So long as the brain is kept plastic, permitting the formation of new associations, there is room for intellectual progress. We have thus a psychological justification for the artificial extension of babyhood, but possibly the college senior at the age of twenty-three has been kept too long in this condition. Certain sensori-motor arcs should be early closed and certain associations definitely formed, or we shall never have the expert; but certain other paths must be kept open or the result will be a machine.

We begin as a matter of fact by teaching the child, supposing it to have escaped the snares of the kindergarten, certain strictly utilitarian studies—the three R's. Under a poorly paid and partially educated woman, we place a flock of children. They sit silent and cramped when movement is essential, not only for bodily health but also for the formation of ideas; they are crowded into an unhealthful room when all out-of-doors surrounds it; the individual child is as far as possible reduced to the average child; in six or eight hours a day for six or eight years the child laboriously acquires certain technical knowledge, the surviving part of which could probably be got in two hours a day during two years. Then in the high school, the youth perhaps takes up Latin, Greek, French and German, while decent English remains a foreign language; text-books in mathematics are arranged for the suppression of thought, and if science is taught it is made as remote as possible from human experience. At the age of eighteen or nineteen the boy has put on the quantity of cerebral fat which, when duly measured by the college entrance examination board for the Middle States and Maryland or some other automatic weighing machine, admits him to college. Here his physical and social environment is suddenly changed, but he finds himself pursuing the secondary studies of the preparatory school—more Latin, Greek, elementary mathematics and English composition—usually under immature tutors. Later in his course, he is allowed to elect miscellaneous, and his daily program may have some resemblance to that of a vaudeville performance. Then finally at the age of twenty-two or three those who stick to the educational system enter the professional schools and go to work in earnest, with no time for culture or research; while a few students prepare to be teachers and are encouraged to undertake independent investigation under the faculty of philosophy.

Mere criticism is nihilistic, and no sensible person would wish to alter suddenly an educational system that has slowly grown. The fact of its existence is evidence that it is the best we can do, but by no means proof that it is the best we shall do. I have no idea what a century will bring, but it is reasonable to assume that there are certain things that it will take. Ten years of age is early enough to begin

to read, write and calculate; primary education should be chiefly for the formation of motor habits; a child's head will not hold more miscellaneous facts than can be injected in a year or two; he can learn nearly as much of his present scholastic studies in two hours a day as in eight. If the required school attendance for each child were reduced to one half or one third, then without additional expense the fewer buildings and smaller equipment might be doubled or tripled in value, and the salaries of teachers might be doubled or tripled. The best trained teachers, more men than women, should be in charge of the younger children. If society must develop a class similar to the neuter insects, it should not have charge of the education of children. The boy should stay in the high school until he is eighteen and then go to the university, or he should enter the college at sixteen and pass forward to the university in two years. The man should begin to take part in the real work of the world at twenty-one, but he should never regard his education as complete, and should for many years, if not always, continue to spend some time in work at the university.

I believe in the practice system from start to finish. Let the child learn the best that the home can teach, let the younger child learn from the older, let the novice learn by helping the master. Each child should have as wide interests and as generous sympathies as may be; he should learn to do some useful work; he should strive to become an originator and a leader. Never in our educational system should these three chief ends of education be separated, least of all in the university.

The word 'culture' has for me acquired an objectionable connotation—it calls up a picture of manure applied to turnips or of microbes growing fat by feeding on gelatine. Boys of twenty-one, chiefly interested in quasi-professional athletic competitions and social organizations, incidentally nibbling at the academic flowers and fruits from which the fences have been removed, supported by their parents at the cost of \$1,000 a head, are a variety of prize animal that can not become universal. The elective system, in so far as it means that a Procrustean course of study shall not be imposed mechanically on all students, but that his work shall be selected by the boy with the advice of judicious councilors, is one of our great educational advances. But the boy should have some definite aim from the outset; he should usually prepare himself to follow the trade or profession of his father, always aiming to reach a higher plane, while at the same time he and his teachers should always be on the watch for any special aptitude or sign of genius. The boy's studies should be related to his life's work, and the relation should be evident to him. Then apart from his main interest, he should have one or two recreations or avocations, as a sport or game, some branch of science or one of the fine arts. Here too he should be an expert, only an amateur in so far as he is led by

love. The group system of the Johns Hopkins University seems to be the best plan hitherto devised for securing the advantages and avoiding the dangers of the elective system.

Even an indiscriminating use of the elective system appears to me better than the obsolescent required course in Latin, Greek and elementary mathematics. Latin was once as much of a professional study as electrical engineering is to-day. By a natural evolution it became part of the insignia of a leisured aristocracy, educated with priests and by them. The use of quotations in which the quantities were given in accord with the peculiar accent of the English universities was a mark of birth and breeding, as are to-day the scars on the face of a German student. Literature and art based themselves on the classical tradition; the intrinsic beauty of the Greek civilization and the part played by Rome in history added to its strength. Even the most iconoclastic must regret the bankruptcy of classical culture, but at the same time the most conservative must acknowledge that the idol is broken. We certainly still feel entitled to sneer at the millionaire who orders a painting of Jupiter and Io and complains that only one of the ten is supplied, and she without her clothes; whereas it is not regarded as a lack of culture when an eminent historian regards the Fissure of Rolando as a chasm in the Pyrenees. But Latin versification is becoming as obsolete and as little used to mark the fine gentleman as the carrying of a rapier. A classical education is essential for certain lines of research, and will always attract its full share of the keenest intellects; but it is no longer wise or possible for a boy to devote eight years of his life to the dead languages in order that he may be admitted to an artificial aristocracy. Latin will survive for a long time in the secondary school on the ground that its illogical constructions supply an intellectual gymnastic, or because its roots are useful in learning French, understanding law terms and naming new species; but its part in education is no longer leading or dignified. In the twilight of the classical tradition it is the once radiant elder sister that I regret:

Müszig kehrten zu dem Dichterlande  
Heim die Götter, unnütz einer Welt,  
Die, entwachsen ihrem Gängelbande  
Sich durch eignes Schweben hält.

There should surely be in our system liberal education, as well as opportunity to learn a trade. I can not, however, believe that superficial knowledge of many subjects is culture, while a thorough knowledge of a few is not; that studies are liberal in direct proportion to their uselessness; or that certain studies are humanistic and others inhuman. Greek literature may be a 'Brodstudien' and dentistry may be followed as a liberal art. That education is liberal which enlarges the sym-

pathies and emphasizes our common interests, not that which forms an exclusive clique. On the whole the sciences in their application to human life seem more likely to form an adequate basis for a common culture than the dead languages. But intellectual training demands specialization, whereas the emotions are more nearly shared in equal measure by all. Civic life or art, if we but had a native art, seems to be a better basis for common culture than any special sort of knowledge.

In my opinion the university is or should be a group of professional schools, giving the best available preparation for each trade and profession. It is more feasible to give such training than to teach culture or research. These, like the building of character, are not the result of any particular kind of curriculum. Culture comes from daily and immediate association with the best that the world has; and this should be found at the university. The leader is born a leader; what the university can do is to give him an opportunity. The kind of research that may be taught to the second-rate man is not the highest ideal of the university. The presumption is that the new facts recorded by the student are unimportant; just because they are new and discovered by the student. But if by research we mean the discovery of new truth and the creation of new lines of activity, then research is indeed the highest function of the university. When we find the man who can advance knowledge and the applications of knowledge to human welfare, be he student or professor, him we should all serve and reverence. But we do a grievous wrong if we assume that this man is found, and should be found, only in the faculty of philosophy. I am glad that our great leader, President Eliot, in his address at the inauguration of President Remsen, emphasized particularly the forward movement made by the establishment of the Johns Hopkins Medical School. Not because it requires for entrance the equivalent of the bachelor's degree, but because we have there the best specialized training, united with the highest culture and the freest research, it will become and has become the model for our medical schools, and for our schools of law, theology and technology. So long as we must have degrees, let the A.B., the A.M., the M.D. or other professional degrees, and the Ph.D., each mean, according to its measure, culture, expert training and independent research.

The general public doubtless regards the university as simply a place for the teaching of students, and there may be some justification for this opinion in the actual state of affairs. But over the doorway of the building in which is my laboratory of psychology we have inscribed the words 'For the advancement of natural science.' Historically the university has been far more than a school for boys. In

medieval Italy, France and Germany, men of maturity, usually attracted by a great personality, came together for mutual stimulus. The colleges of Oxford and Cambridge were monasteries for learned men before they became boarding schools. It may be our part here in America to develop the true university: A place where each would gladly learn and gladly teach; open summer and winter, night and day; a center in each community for the conservation of the best traditions and for the origination of the newest ideas; closely in touch with every forward movement of civic and national life; a home from which will go out, and to which will return, our leaders in every department of human activity. Twenty-five years ago perhaps only an Eliot or a Gilman could have realized the future of the American University, but to-day even the man in the street must have some vague notion of its possibilities. Our college presidents and professors are called upon for the most important and difficult public functions. When New York City needs its leading citizen it finds him in the presidential chair of Columbia University. When Mr. Cleveland retires from public life, he allies himself with a university. There is no other office so fit for a past president of the United States as the presidency of a university.

The university is those who teach and those who learn and the work they do. The progress of the university depends on bringing to it the best men and leading them to do the best work. Our president, Mr. Remsen, in his admirable inaugural address, told us that the chief function of the university president is to find the right man, and his chief difficulty the lack of enough such men to go round. He considered the question of how far an increased salary would add to the supply of good men. I quite agree with Mr. Remsen that a professor will do about the same kind of work whether his salary is \$4,000 or \$10,000. If anywhere, in the university it should be to each according to his needs, from each according to his ability. The professor who must live in a city or who has children to educate should be given the necessary income. He should have an adequate pension in old age or in case of disablement; the university should insure his life in a sufficient sum to provide an income for his wife and minor children. The professorial chair can be made attractive by freedom, responsibility and dignity, rather than by a large salary. Still it must be remembered that we live in a commercial age, and men are esteemed in accordance with their incomes. While it may not, or at all events should not, matter greatly to the professor, it may be well for the community that those who do the most for it should be paid on the same scale as those of equal ability in other professions. It may not be necessary to double the salaries of all university men, but it would probably be desirable to have certain prizes that would represent to the



crude imagination of the public the dignity of the office and would perhaps attract young men of ability. The average salaries of teachers are about the same as in the other professions, but there are no prizes corresponding to those in the other professions. A clergyman may become a bishop, a lawyer may become a judge, a physician may acquire a consulting practise; and they may earn incomes of from \$10,000 to \$100,000. A professor can only earn a larger salary and an apparent promotion by becoming president of his university; and this I regard as unfortunate. As Mr. Remsen told us that the professor would be pleased but not particularly improved by an increase in salary, I may perhaps be permitted to suggest that a president might be pained, but would not be seriously injured by a reduction of his salary to that of the professor. My preference in this matter would be for the professor to have a fixed salary—perhaps \$3,000 to \$6,000, according to the expense of living in the neighborhood, with \$300 to \$600 subsidy for each of his children between the ages of 10 and 21. Advances in salary dependent on the favor of the authorities appear to be undesirable. If salaries must vary from \$3,000 to \$5,000, a man should be appointed at such salary as may be necessary, but should thereafter receive automatic increases, say of \$500 after each five years of service. Then there should be a few research chairs in each university, promotion to which would be a mark of distinction, and occupancy of which would dispense from all routine work and carry a salary equal to that of the presidency.

The man of parts is born, but he must be found and given an opportunity. Lincoln, Grant and Lee stand forth in history, owing to the events of history, and if they had not been born others would have been found. The chief difficulty in securing the right men for university chairs is the small field from which they must be drawn. When we have a hundred thousand men of university training teaching in the schools, there will be those deserving promotion. When we have more students doing research work at the universities, there will be more men of genius for the higher offices. The Rockefeller Institute for Medical Research, and especially the Carnegie Institution, by encouraging men to carry on research at the universities, will perform in more ways than one a service of immense value. We should without delay introduce the *Privatdocent* system of Germany. We should not exclude a man from the university because there is no vacant position, but should welcome to affiliation every one who will add to its strength.

Our universities have suffered from in and in breeding and the promotion of men by a kind of civil service routine. The president should maintain a detective office for the discovery of exceptional men. It is more important to find a good man than to fill a vacant position.

The German plan of calling the best man without regard to whether he will accept or decline is better than our secret process. The English plan of having an expert board of electors for each chair possesses certain advantages. Migration of instructors as well as of students is desirable. Much would be gained if instructors in different universities would exchange places for a year, and especially if men from the small colleges were called to spend a year as lecturers at the great universities. When a national university is established at Washington, it would be well for its faculty to consist in part of men from other institutions who should spend one year in five or seven at the central university.

It is difficult to find the right man; and it is particularly unfortunate when the wrong man has been selected. Academic rights and academic freedom are troublesome problems. It seems that an opportunistic policy must be followed rather than definite rules. A university can not be conducted as a factory; and even a factory does not entirely ignore the human element. It is better that an occasional man should be retained who is not quite up to the standard, rather than that all professors should feel that their chairs are insecure, subject to the automatic law of supply and demand, or to the possible caprice of an individual. Assistants and instructors should be appointed for limited terms of years, and better men should replace them if better men can be found. They should never be promoted simply because they are the men on the ground. A professor's appointment should be for life, unless he violates the conditions implied in the contract. In making such an appointment, the university should accept the responsibility, fully realizing that a man, however carefully observed, is subject to a large probable error. Even on the commercial side it pays to take the risks, for with permanent tenure, men will accept smaller salaries; but the chief gain is the moral advantage of securing the complete loyalty of the professor and setting him free to do his work. Less competent men should not, of course, be permitted to teach required courses, and the departments to which they belong should be strengthened. Permanent tenure of office carries with it as a corollary a pension system. Some men are old at sixty and others are young at seventy, but as it is difficult and rather invidious for any authority to decide to which class a man belongs, it is perhaps desirable to pension all professors at a fixed age, permitting them thereafter to offer elective courses or not as they prefer.

Academic freedom is a subject that has not lacked discussion during the past year. So long as universities are dependent for support on gifts from rich men or on appropriations made by a legislature, there is real danger that the teaching of economics, sociology and some departments of history and philosophy may suffer improper limitations.

But so far as I am aware this is a danger rather than a fact. It should also be remembered that the university professor has responsibilities as well as rights. He should realize that views radically opposed to the sentiment of the community are not proper subjects for undergraduate teaching or for exploitation in the newspapers. On the other hand, there should be of course no inquisition in regard to a professor's private beliefs; there should be as little interference as possible with his graduate teaching and none with the presentation of his work or theories to experts in his own field.

The university is its men and their work. But certain externals are necessary or at least usual—buildings and equipment, a president and trustees. One of the notable services of the Johns Hopkins was to show that a great university can be lodged in humble quarters. I almost regret the erection of more expensive buildings and the present removal and rebuilding of the university. Yet it is certainly for the interests of the community as a whole that the exterior presence of the university should represent its dignity and influence. As the loving devotion and art of the community were once lavished on its cathedral, so they should now go toward making the university stately and beautiful. The university, with its affiliated libraries, museums, hospitals, art galleries, theaters and parks, should be the chief pride of the community; and the money that is needed should come freely. We do not, however, want imitation parthenons and pantheons; architects should be found who can plan the buildings that are best adapted to their uses.

The best scientific work has usually been done with modest equipment and inexpensive apparatus—it depends chiefly on the man. But as science becomes more exact and complex, there is undoubtedly increasing need of large expenditures. A million dollars or ten million dollars should not be grudged, if this sum is needed for an astronomical observatory or for an experimental farm. The investment is sure on the average, and likely in each individual instance to pay large interest to the public by actual decrease in the cost of production or distribution. But in any case the community can afford to contribute for ideal ends an amount that is insignificant when compared with its total expenditures. Books required by the worker should always be at hand, but it does not seem necessary for each university to maintain a museum of a million volumes. We should have two or three such collections in the country, but it is more economical to move books or even men, than to store and care for books that are used but once in a century. Museums and art galleries can also be limited in size without serious loss. Each should maintain certain typical exhibits and have in addition some well developed special departments. In general it

would be in the interest of economy and efficiency if there were more division of labor and cooperation among our universities than has hitherto obtained. It is not necessary for every university to have a complete equipment in every department.

The main ends of the university are the same in all lands, but our American presidents and boards of trustees are indigenous products which can scarcely be regarded as essential. They are the natural outcome of the denominational college, and have developed in line with methods of business organization that have proved themselves highly efficient. Given a small and compact group of men who represent a certain policy, but whose chief duty it is to elect an absolute dictator, who in turn appoints minor dictators, and the result is an economical and powerful machine. In politics, in business and in education, this form of despotism has prevailed, and has on the whole justified itself by the results. But it appears to be only a passing phase in educational development.

The college president has enjoyed a rapid evolution in the course of a single generation. Thirty or forty years ago he was a clergyman, as a matter of course; later he was likely to be selected for business qualifications; now he is a member of the faculty who unites executive ability with high scholarship. We seem to have made a further advance at Columbia by the election of a president who is at the outset an educational expert. He alone does not begin as an amateur and can devote himself to his work while cultivating his scholarship. But the demands now made on the university president are so diverse and exorbitant that even when he gives up both teaching and research they can scarcely be met. He can not be *in loco parentis* for 5,000 students; select and control 400 officers; coordinate the conflicting demands of incommensurable schools and departments; arrange diverse curricula in accordance with changing needs; superintend buildings and grounds; manage an estate of \$10,000,000 and secure the additional funds always needed; be a public orator and monthly contributor to magazines; attend bicentennials, sesquicentennials and semi-sesquicentennials; occupy positions of honor and trust whenever called upon by the community or nation, and all the rest. It has become necessary to delegate part of these duties to deans and other officers, and it seems probable that the office of president should be divided and filled by two men of different type: one an educational expert, in charge of the internal administration; the other a man of prominence and weight in the community, in charge of external affairs.

The president and trustees as they now exist have their chief justification in financial conditions. We know that the lack of money is the root of all evil. Our private educational corporations, dependent on the generosity of millionaires, are in a remarkable and almost

anomalous position. Yet it is evident that this unique phase of development has not only kept the university in advance of popular appreciation, but has also tended to maintain the stability of society. At a time when large fortunes and monopolistic corporations are needed for the material development of the country, the generous gifts of a few men of great wealth have done much to allay popular clamor. It seems likely, however, that in the end the people will control monopolies and the universities supported by the profits of monopolies. There is no more reason for depending on the generosity or caprice of millionaires for our universities than for our ships of war. It has always seemed to me a curious perversion that elementary education, chiefly useful to the individual, should be free and supported by the state, whereas higher education, chiefly for the benefit of the state, should be a charge to the student and depend on private charity. I believe that the state universities are more nearly in the line of evolution than the private corporations, but there is every reason to hope that the latter will remain sufficiently plastic to adapt themselves to conditions that are likely to prevail. Even at present I think it would be desirable for our boards of trustees to be gradually increased in size, until they become large corporations, consisting of those who are most actively interested in the work of the university.

However it may be to-day, it does not seem likely that the money question will be the most troublesome one of the future. The people of this country spend \$200,000,000 annually for sugar. The same quantity of sugar a hundred years ago would have cost five times as much, \$1,000,000,000; the reduction in cost has been due to the applications of science in chemistry, agriculture and transportation. The saving on the cost of sugar for a single country in a year or two would pay for all the higher education and scientific investigation from the establishment of the University of Salerno to the present day. This is a statement easily understood by every voter and legislator; when it is once grasped the question for our universities will not be how to get money, but how to spend it judiciously. I also believe that the people of this country are not only good business men, but are idealists beyond others, and that patriotism and civic pride will lead them to increase the wealth of their universities as rapidly as it can be wisely used.

With the passing of the money question, I look forward to the passing of the president and the board of trustees. Democracy, as I understand it, does not mean that we shall not have leaders, but that we shall follow leaders because we recognize them as such. Our absentee and quasi-hereditary boards of trustees, and our presidents, ranging from King Log to King Stork, have on the whole administered their trusts in accordance with common sense and the opinion of the well-informed.

In so far as they have done so, their dictatorial power has been both harmless and useless. The professor is, as a rule, a free man, even though he may be looked upon as a fetus shut up in an incubator. The type of professor, who is exclusively concerned with settling 'the doctrine of the enclitic *De,*' or with distinguishing one beetle from another, survives on the stage and in novels, rather than at the university. In the scientific departments, at least, executive ability of a high order is needed for the conduct of a laboratory or the prosecution of research; and the demand is fully met. The university could not continually supply presidents and administrators of all kinds were there not a large supply of material. It has been said that university faculties are poor legislative bodies; if true, this would not be surprising, so long as their deliberations are confined to discussing questions such as whether they shall wear gowns at commencement, the decision being with the trustees. I believe that the university community is competent to direct the policy and administration of the university and will soon do so.

In these remarks I have used the freedom of speech that a teacher may claim; but it has certainly not been my intention to run amuck through our educational system. The man of science is by profession an optimist. None can write the equation giving the world's trajectory, but I believe that we are moving along an ascending curve. Never before has the average intelligence been so high, never before has a civilization been so securely established. Nor, I trust, are great men lacking. They say that we are failing in art and in literature; but those who are at the foot of a rainbow can see only the fog. In science and in other great departments of human activity progress is at a geometrical ratio. I also believe in the present and in the future of this democracy. Not only is the average well-being of the individual higher than elsewhere or hitherto, but we are contributing and shall increasingly contribute to political, business and educational organization; we are contributing and shall increasingly contribute to science, to scholarship and to art. The knowledge and the culture of the world have been freely given to us; it is our part to return them with usury. While in the energy of our pride we lord it over land and sea, we shall discover the truth, the beauty and the righteousness that lie hidden everywhere:

In this broad earth of ours,  
Amid the measureless grossness and the slag,  
Enclosed and safe within its central heart,  
Nestles the seed perfection.

## SCIENTIFIC LITERATURE.

## BOTANY.

A NOTABLE book on modern botany has been prepared by Professor Campbell under the title of 'A University Text-book of Botany' (Macmillan) which fairly outlines the essentials of the science as understood to-day. Unlike many text-books it is a well-balanced presentation of the whole subject, and not a setting forth of some transient fad which the author may have taken up recently. Professor Campbell has succeeded in giving in the compass of a book of moderate size a good view of modern botany. His is not a radical view, but rather a conservative one, and his book indicates a distinct tendency away from the extreme position assumed by some American botanists in recent years. Instead of page after page of fine 'half tone' pictures of landscapes showing plants under all kinds of conditions, we have here a solid treatise in which the various parts of the subject are taken up in the order which has commended itself to the author as a teacher of many years' experience. After an introductory chapter, the author follows the usual sequence, viz., general morphology, cytology and histology, and then the special morphology, cytology and histology of the principal groups of plants, beginning with the lowest and passing

from these by successive steps to the highest. This is the principal part of the book, occupying as it does fully four fifths of the pages. After this come several chapters on physiology, relation to environment, and geological and geographical distribution. Modern botany, as interpreted by Professor Campbell, is largely and quite emphatically structural. Physiology and ecology are distinctly subordinated to structure, as indeed they must be in any scheme of scientific instruction. Here as in mechanics, it is essential that the mechanism be clearly understood before the working of the machine can be critically studied. It will not do to study mechanism alone; there must be a study of the activities as well. We must see the machine in operation, but merely to 'see the wheels go round' gives little accurate knowledge, however diverting it may be to the participants in the entertainment. Modern botany is not a diversion; it is a science, and must be seriously studied. It requires hard work, and it is not wise to attempt to eliminate the serious parts, leaving only the easy and entertaining portions. The training in botany is and always should be as severe as that required of students doing work in other sciences.

## THE PROGRESS OF SCIENCE.

## LORD KELVIN IN AMERICA.

THE ways of a democracy must appear past finding out to those who observe us from a distance. When Prince Henry visited the United States the newspapers devoted half their space to the event; yet it might be supposed that Emperor William, the energetic, would come to America, if he wished to extend to us the social etiquette of foreign nations, and that we should regard with slight interest a lesser royal guest. When the greatest living Anglo-Saxon man of science visits us, the event passes unnoticed by the general public; yet Lord Kelvin's contributions to the applications of electricity, and especially his connection with the trans-Atlantic cable, might be expected to attract general attention.

Lord Kelvin has, of course, been cordially welcomed by his scientific colleagues. He accepted an invitation extended by wireless telegraphy to attend the installation of President Butler at Columbia University, and on April 21 he was entertained at the University by the national societies concerned with the physical sciences. Professor F. B. Crocker presided, and addresses of welcome were made by President Butler; by Professor Elihu Thomson, representing the American Institution of Electrical Engineers; by Professor A. G. Webster, representing the American Physical Society, and by Professor R. S. Woodward, representing the American Association for the Advancement of Science and other scientific societies. Lord Kelvin in his reply referred to his previous visits to America. He first landed on this continent in 1866 in Newfoundland when the work of Mr. Field in connection with

the trans-Atlantic cable was of special importance; ten years later he came to the Centennial Exposition, where he saw the telephone invented by Mr. Bell; in 1884 he found the electric light of Mr. Edison; in 1897 he saw the electrical industries of Niagara Falls. Lord and Lady Kelvin were very cordially greeted and applauded by the 2,500 people present. In addition to the reception at Columbia University, Lord Kelvin was entertained at Cornell University, at the University of Rochester—the main object of his visit was to attend a meeting of the Kodak Company at Rochester—and at Yale University, where the degree of Doctor of Laws was conferred on him. In conferring this degree, President Hadley said: "You have joined the different regions of the earth by your investigations of the submarine telegraph; you have joined the different realms of human thought by your contributions to physical theory."\*

## THE NATIONAL ACADEMY OF SCIENCES.

THE spring meeting of the National Academy of Sciences did not differ in any unusual respect from other annual stated meetings. The Academy has three main objects—it is the official adviser of the government in scientific matters; it holds scientific sessions for the presentation of papers, and it has certain functions in recognizing scientific eminence and in bringing scientific men together. The first of these objects has become relatively unimpor-

\* The portrait of Lord Kelvin given as a frontispiece is from an etching made for *Minerva* by Professor Hubert Herkomer.



tant since the government employs scientific experts in all departments, and is likely to apply to them rather than to the Academy for advice. The second function has also become less essential than formerly, owing to the development of special societies for each of the sciences. The third object has consequently become perhaps the most important. The annual elections are a recognition of scientific merit, and it is well that our leading scientific men should have the opportunity of meeting together to become acquainted with each other and with the work being carried on in different sciences and in different parts of the country. The program at Washington was of considerable interest. Mr. Alexander Agassiz, who was last year elected president of the Academy, reported on his recent expedition to the coral reefs of the Maldive Islands, and the evidence presented, in addition to that which he had already collected, seems definitely to negative Darwin's theory of the origin of coral reefs. This theory, it will be remembered, explains the atolls as due to the gradual subsidence of the floor of the ocean, the insects building the reefs as the floor sank. Mr. Agassiz has discovered a great number of facts which seem to be entirely incompatible with this theory. As is usual at the meetings of the Academy, astronomy was well represented. Dr. Seth C. Chandler offered a paper on the constant of aberration, which, however, was only read by title. Professor E. C. Pickering presented facts regarding the relations of the planet Eros to the solar parallax and its variations in brightness. Professor Asaph Hall described the disintegration of comets. Papers on chemistry and physics were presented by Professor Theodore W. Richards dealing with the atomic weight of cesium and the significance of changing atomic volume; by Professor James M. Crafts on catalysis; by Professor E. W. Morley on the

weight of the vapor of mercury, and by Professor E. L. Nichols on the optical properties of asphalt. Paleontological papers were presented by Professor H. F. Osborn and Professor A. S. Packard; psychological papers by Mr. C. S. Peirce and Professor J. McKeen Cattell, and an illustrated account of the physiological station on Monte Rosa by Professor H. P. Bowditch was given by Professor C. S. Minot. Mr. William Sellers read a paper adverse to the compulsory introduction of the metric system. Biographical memoirs of William A. Rogers, J. G. Barnard, Francis A. Walker and J. S. Newberry were presented, respectively, by Professor E. W. Morley, General Henry L. Abbot, Dr. John S. Billings and Dr. C. A. White. The new members elected were: William W. Campbell, director of Lick Observatory, Mount Hamilton, California; George E. Hale, director of Yerkes Observatory, Williams Bay, Wisconsin; C. Hart Merriam, chief of the Division of Biological Survey, U. S. Department of Agriculture, Washington, D. C.; William Trelease, director of the Missouri Botanical Garden, St. Louis; Charles R. Van Hise, professor of geology, University of Wisconsin, Madison.

#### THE METRIC SYSTEM IN THE UNITED STATES.

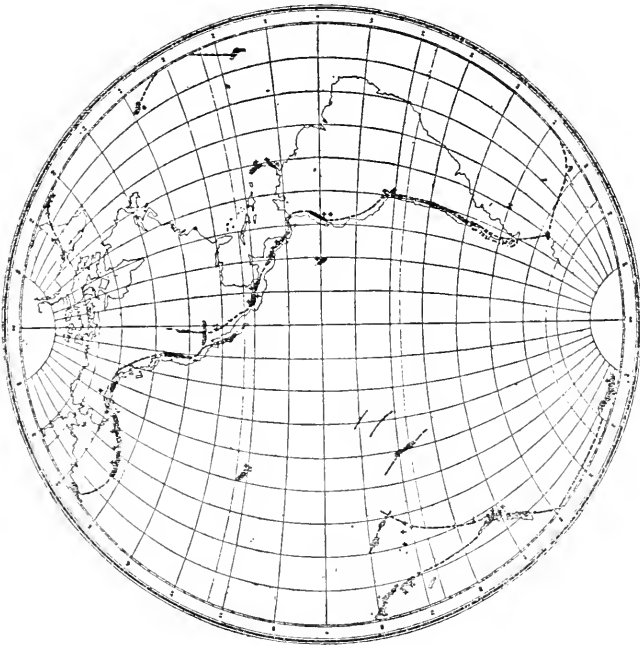
A BILL is now before Congress adopting the metric system of weights and measures as the standard in the United States. Though it does not seem likely that the bill will be passed during the present session it has been recommended by the committee on coinage, weights and measures, and the chances of its adoption seem more favorable than ever before. The bill requires the departments of the government to use the metric system after the beginning of the year 1904 and makes it the legal standard in the United States after January 1, 1907. The house committee has given a num-

ber of hearings on the subject, published in a pamphlet of 240 pages, and has drawn up a careful report. This report covers familiar ground, but in an unusually clear and straightforward manner. The attitude of Washington, Jefferson and Adams is referred to, and the history of the metric system of weights and measures is briefly reviewed. It is pointed out that the adoption of a decimal system of coinage in the United States was one of the strongest influences leading to the adoption of the metric system by France, and that Great Britain and the United States are practically the only non-metric countries. The weights and measures of Great Britain and the United States are not identical as is generally supposed, and there is no chance whatever that either system will become a universal system. The metric system has become necessary for scientific work; it would decrease the cost and labor of education; it would give unity to our manufactures, and is almost necessary for the extension of our commerce. The admitted expense and trouble involved in the adoption of the system are less, as has been shown in other countries, than is feared, and in any case the longer the adoption is delayed the greater will be the difficulty. The scientific, manufacturing and commercial interests of the country are under great obligations to Mr. John F. Shafroth, who, as chairman of the house committee on coinage, weights and measures, has devoted much careful attention to the subject.

#### *THE CAUSES OF VOLCANIC ERUPTIONS.*

THE recent volcanic outbreaks in the Lesser Antilles have naturally aroused much popular and scientific interest in these geological phenomena and have made a brief statement of current and accepted explanations of them a matter of interest. All these manifestations of heat are derived from the great stores which exist in the interior of the earth. The consideration of them and

of the known increase of temperature with depth led earlier geologists to believe that the earth possessed a heated molten core and a cold and relatively thin exterior shell. But as further investigation developed correct conceptions of the rigidity of the globe in resisting strains produced by its rotation and the attraction of other heavenly bodies for its mass; and as the elevating effect upon the fusing points of rocks of an increase of pressure was realized, it was seen that the earth is practically solid clear through and that local reservoirs of molten rock beneath volcanic districts are alone admissible. That local reservoirs exist seems quite well established, and that the rock is sufficiently fluid to enable complex parent magmas to break up into various differential products is the latest result of the investigation of eruptive areas. Volcanoes are moreover arranged along great lines of geological disturbance and fracture as shown in the accompanying illustration. The fractures are naturally the conduits through which the great tension of the internal molten masses is eased by eruptions. The immediate propulsive force which drives the lava to the surface is the next topic of importance which challenges attention. Some geologists believe that the contraction of the globe and the sinking of one side of the great fractures above referred to force out the lava as juice might be squeezed through a rent in an orange. Others, however, attribute the propulsion to the vapors which are held dissolved or occluded in the lava and which are so much in evidence at times of eruption. The frightful explosions and the vast exhibitions of power which they present give much force to this conception. Imagine then a rising tide of lava. As it forces its way through the conduit it spreads earthquake shocks abroad. Reaching the surface its dissolved vapors explode with greater and greater violence and scatter tuffs and breccias over the neighboring country. They may rend



MAP OF VOLCANIC DISTURBANCES. (From Bonney's 'Volcanoes,' Putnam's Science Series.)

□ Signifies Extinct Volcanoes.

+ Signifies Active Volcanoes, but is not intended to indicate either the number or the exact position.

- - - Signifies the probable direction of lines of weakness in the earth's crust.

the crater and set loose floods of lava. As the energy expends itself, the violence declines and disappears. The volcano then yields only hot springs and gaseous emissions called fumaroles, until it is stone-cold.

#### SOME FACTS AND FIGURES CONCERNING THE EARTH.

THE earth is easily the most interesting and the best known to us of the bodies of the universe which have been subjected to scientific investigation. Not only do we know more of the earth than of any other member of the solar system, but we know more of the earth than of any of the smaller bodies which have been studied minutely in laboratories. It is true, of course, that a few bodies, like standards of length and mass, have been determined with great precision with respect to one or two of their properties; but our knowledge of the earth includes many of its properties, and some of them are known with a precision only surpassed by that of the standards referred to.

The surface of the earth is closely that of an oblate spheroid whose axes are known within about the hundred thousandth part, a precision near the limit possible in laboratory measurements of such bodies as inch ball-bearing spheres now made with wonderful exactness for commercial purposes. The surface and volume of this spheroid are found to be in round numbers two hundred million square miles and two hundred and sixty thousand million cubic miles respectively; and these numbers are known with an accuracy far surpassing that of the measured areas, for example, of the most valuable city properties, which are relieved of the necessity for precise measurement by the legal phrase, 'be the contents of the same more or less.' The magnitude of the work which has led to these results may be appreciated to some extent if one considers seriously how one would

measure an area of two hundred million square miles with an error not greater, say than one fifty-thousandth part.

Less definite but of a higher order of magnitude are the figures expressing the quantity of mass of the earth, or what is sometimes designated by the scientifically meaningless phrase 'the weight of the earth.' We all have a tolerably clear idea of the mass in a ton of coal, but few of us are fitted to realize the nearly equally definite quantity of the earth's mass, which is in round numbers six thousand six hundred million million million tons. Of this total mass, the atmosphere, whose lenticular-shaped envelope includes a volume about one hundred and fifty times that of the solid part of the earth, contributes somewhat more than one millionth part, a small fraction of the whole, but yet millions of millions of tons in amount.

The regularity of rotation of the earth, or its constancy as a time-keeper, is no less surprising when expressed in numbers. The variation from day to day in the time of rotation is probably less than the hundredth of a second, or no greater, say, than the ten-millionth part of a day. Our best clocks and chronometers, and they are marvels of mechanical perfection, fall far short of this degree of constancy. Equally remarkable for stately regularity are the precession and nutation of the earth, by reason of which its axis of rotation describes a slightly fluted cone in the heavens, making one complete revolution in the leisurely interval of about twenty-six thousand years and thus rendering it essential for us to change pole stars from time to time. And still more noteworthy are the lately discovered minute wabblings of the earth with respect to its axis of rotation, whereby the latitude of a place varies from month to month, running through a lesser cycle in about fourteen months and through a greater cycle in some-

thing like seven years. That these recondite phenomena have been disentangled and reduced to precise numerical statement is at once conclusive evidence of method in the madness of terrestrial motions and of exquisite refinement in astronomical science.

The much discussed question of the age of the earth may now be said to have risen from the level of figures of speech to the higher plane of numerical expression. We are not able, and we may never be able, to assign the age of the earth in years, or in thousands of years as our most respected teachers have done in the recent past; but we may say without fear of anything worse than literary contradiction that the age of the earth must be reckoned in millions of years. Probably some hundreds of millions of years have elapsed since the earth became habitable to organic forms. Nature has plenty of time for her operations; and old as the earth must be in comparison with the centuries of human affairs, it is still active with the energy manifested in the earliest geological times. The processes of erosion and sedimentation, and that of secular contraction from loss of internal heat, are still asserting themselves occasionally (frequently, if a million years be used as the time unit) by such appalling outbursts as that which has just overwhelmed St. Pierre. And these processes, though fraught with calamities here and there to our race, must go on for millions of years yet to come.

#### BIOGRAPHIES OF EMINENT CHEMISTS.

WITHIN the last few years several particularly attractive biographies of distinguished chemists have been issued as volumes of the 'Century Science Series,' edited by Sir Henry E. Roscoe; they differ from other works in the same line in that they portray the men and their careers more graphically and concisely, and embody at the same time the results of the latest researches.

One of these, written by Roscoe himself, bears the title 'John Dalton and the rise of Modern Chemistry' (New York, 1895).

Half a dozen memoirs of the Founder of the Atomic Theory had previously appeared, the most noteworthy being those by W. C. Henry (1854), by R. Angus Smith (1856), and by H. Lonsdale (1874). The first named forms one of the volumes printed for the Cavendish Society, the second includes a History of the Atomic Theory from the days of the Greeks to the time of Dalton, and is embellished with the most satisfactory of the printed portraits.

Roscoe's charming work is enlivened with facsimiles, extracts from letters, papers and books by Dalton, reminiscences by contemporaries, appreciations by later chemists and amusing anecdotes, the whole so simply and yet so vigorously written as to make a delightful narrative. There has always been much speculation as to the mental processes which led Dalton to conceive of the great theory indissolubly connected with his name, and this problem has only been quite recently solved by the discovery in the rooms of the Literary and Philosophical Society of Manchester (where the whole of the experimental work was carried on by Dalton) of his laboratory and lecture notebooks, in a number of volumes. It has been supposed that it was the experimental discovery of the law of combination in multiple proportions that led Dalton to the idea that chemical combination consists in the approximation of atoms of definite and characteristic weight, the atomic theory being thus adopted to explain the facts ascertained by chemical analysis. But an examination of these newly discovered manuscript notes shows that he arrived at these ideas from purely physical considerations along the line of the Newtonian doctrine of the atomic constitution of matter; he conceived of chemical combination as taking place

between varying numbers of atoms of definite weight, and then succeeded in confirming this view by the results of analyses made both by other chemists and by himself. This is precisely the inverse of the commonly accepted supposition.

This view of the genesis of Dalton's Atomic Theory has been published in a small volume with the title: 'A New View of the Dalton's Atomic Theory,' edited by Sir Henry E. Roscoe and Arthur Harden (London, 1896). The work contains also documents and letters by Dalton not previously published. No student of Dalton or of the atomic theory can afford to ignore this important contribution to history of chemistry.

Another volume in the Century Science Series deals with Sir Humphry Davy, poet and philosopher, and is by T. E. Thorpe (London, 1896). In preparing this Dr. Thorpe made use of the memoir on Davy by Dr. Paris (London, 1831), and that by Sir Humphry's brother, John Davy (London, 1858), as well as of contemporary periodicals, letters, and diaries of his friends and brother scientists. The first named of the earlier biographies has been found inaccurate as to matters of fact and extravagant in laudation; the second is written with candor and greater simplicity, and on the whole is more reliable. Dr. Thorpe's portrayal of the brilliant chemist is more correct and satisfactory; Davy's versatility is well brought out, his poetical writings, his philosophic studies, and his scientific labors, as well as his character as a man. Davy's discovery of the physiological effects of breathing 'laughing gas,' as it was called, made him conspicuous in the world of science when he was twenty-one years of age, and this prominence he maintained by his genius throughout life; at the age of thirty he isolated the metals of the alkalis, at the age of thirty-eight he invented the safety-lamp, at the early age of fifty-one he died.

One of Sir Humphry's most notable

discoveries, certainly that which proved of the greatest benefit to mankind and to the progress of civilization (not excepting the safety-lamp), was Michael Faraday. The biography of this simple-minded and remarkable scientist, by Silvanus P. Thompson, forms another volume of the Century Science Series; two others deal with Justus von Liebig (by W. A. Shenstone) and with Pasteur (by Professor and Mrs. Percy Frankland), but the limited space at our command forbids further details.

Less brilliant, but no less patient an investigator was the Scotch chemist, Thomas Graham, whose career was very nearly conterminous with that of Liebig, and differed but little from that of Faraday. The Life and Works of Thomas Graham was prepared by Dr. Angus Smith, but owing to his feeble health (which terminated in death) the volume was edited by J. J. Coleman (Glasgow, 1884). Graham's life is rather inadequately depicted, but the book is enriched by more than sixty of his letters interspersed by brief notes of his contributions to science as well as by abstracts of all his published papers; among the latter may be mentioned those on the diffusion of gases and of liquids (1838-1863) and on the occlusion of hydrogen by metals (1863). In spite of his confining duties as Master of the Royal Mint, Graham found time for many other important investigations and for preparing a text-book which afterwards in connection with Friedrich Julius Otto became the celebrated and voluminous German 'Lehrbuch der Chemie' that passed through several editions.

The discovery of argon, and of other constituents of the atmosphere by Lord Rayleigh and William Ramsay in 1895 aroused renewed interest in the eccentric philosopher Cavendish, who narrowly escaped anticipating the recent discovery. The life of the Honorable Henry Cavendish, 'le plus riche de tous les savants et probablement aussi le plus savant de tous les riches,' was published by the Cavendish Society in

1851, being edited by Dr. George Wilson; Cavendish's electrical researches were edited by J. Clerk Maxwell from original manuscripts in the possession of the Duke of Devonshire, and published in 1879; since then there has been no important monograph concerning him.

#### THE ORIGIN OF THE HUMAN SPECIES.

THE discovery by Dubois of the much discussed remains of *Pithecanthropus erectus* in a situation which seems to indicate for them a late Pliocene horizon, has reawakened interest in the phylogeny and antiquity of man, and has led to a reexamination of some of the more interesting prehistoric remains. The Neanderthal skeleton has recently been carefully studied by Schwalbe and Klaatsch and minute comparisons have been made with recent races on the one hand, with the Spy remains and *Pithecanthropus* on the other and also with the recent anthropoids.

The results of these studies have demonstrated a great similarity between the Neanderthal and Spy skeletons and the possession by these of so many peculiarities which lie beyond the limits of variation in recent human races, that it has been thought necessary to recognize them as representatives of a distinct species of *Homo*, the *H. Neanderthaliensis*. Of this species we know at least three individuals and possibly more, and it seems certain that it is quite distinct from the *Pithecanthropus*, the skull characters of this Javanese form placing it on a much lower level than the Neanderthal-Spy skulls, and showing a more pronounced approach toward generalized anthropoid condition than is to be seen in the European skulls. There is, however, an enormous gap between even *Pithecanthropus* and the recent anthropoids, and, indeed, it seems certain that the latter cannot be regarded as coming into the direct line of human descent,

but both these and existing human races must trace back to a common ancestor, whose characteristics are perhaps indicated in the cranial peculiarities of young anthropoids.

If this be the case it would seem that the origin of the human race must be referred back to a period antedating considerably the horizons to which *H. Neanderthaliensis* and *Pithecanthropus* belong. The former is assigned by Klaatsch to the first interglacial period, at the close of the Chelléan era, while the latter seems to pertain to the late Pliocene, and the divergence of form which led to the genus *Homo* would accordingly seem to be referable to the early Pliocene or possibly even to the Miocene period.

#### SCIENTIFIC ITEMS.

WE regret to record the death of Henry Morton, the eminent engineer, president of Stevens Institute of Technology since its foundation in 1870.—J. Sterling Morton, ex-Secretary of Agriculture, died on April 27.—The death is announced of Mr. Patrick T. Manson, son of Dr. Patrick Manson, on Christmas Island, whither he had gone to investigate the cause and treatment of beriberi, on behalf of the London School of Tropical Medicine.—M. Alfred Cornu, the eminent physicist, since 1867 professor at the Ecole polytechnique, Paris, has died at the age of sixty-one years.—M. Emile Renou, founder and director of the Meteorological Observatory at St. Mauri, died in Paris on April 7, aged eighty-seven.—M. Henri Filhol, professor of paleontology at the Jardin des Plantes, Paris, and the author of numerous important contributions to this science, has died at the age of sixty years.—Immanuel Lazarus Fuchs, since 1884 professor of mathematics in the University of Berlin, died on April 26 at the age of sixty-eight years.—Dr. E. von Pfeleiderer, professor of philosophy at Tübingen, has died at the age of sixty years.

DR. ALEXANDER AGASSIZ has been appointed director of the Museum of Comparative Zoology, and Dr. A. E. Kennelly, of Philadelphia, has been appointed professor of electrical engineering at Harvard University.—The Hon. Carroll D. Wright, commissioner of labor, has been appointed president of the collegiate department of Clark University. It is understood that Mr. Wright will not, for the present at least, resign his position under the government or his work at Columbian or Catholic University.—The Secretary of War has sent to the House a recommendation that Surgeon-General Sternberg be granted the rank of major-general before his retirement on reaching the age limit June next.—The University of Edinburgh has conferred its LL.D. on Professor William James, the eminent psychologist of Harvard University, and on Dr. J. G. Schurman, president and formerly professor of philosophy at Cornell University.

DR. DANIEL COIT GYMAN, president of the Carnegie Institution, sailed for Europe on April 17, with a view to studying foreign scientific institutions.—Professor Solon I. Bailey, of the Harvard Astronomical Observatory, is about to leave for the observatory's branch at Arequipa, Peru, where he will especially study the planet Eros. Dr. W. H. R. Rivers, of Cambridge University, will shortly start on an expedition for the psychological study of the Todas of southern India on the lines of his work in Torres Straits.—Professors Victor C. Vaughan and Frederick G. Novy of the medical department of the University of Michigan will leave for Asia about the middle of June to investigate tropical dysentery.—Dr. J. L.

Wortman, of the Peabody Museum of Yale University, will be in the West until September, exploring the fields in Dakota, Wyoming and the Bad Lands, where the late Professor Marsh made his important paleontological discoveries.—Ernst A. Bessey, in charge of the Section of Seed and Plant Introduction in the United States Department of Agriculture, has been detailed to proceed to Russia, the Caucasus, and Turkestan for the purpose of securing certain seeds of forage and cereal plants. He is to sail on July 2.—An expedition to northern Brazil will be sent out by the Austrian Government in the autumn under the direction of Dr. M. Steindachner, curator in the Vienna Museum of Natural History.

IN accordance with our plan of reprinting in each number of THE POPULAR SCIENCE MONTHLY an article which appears to be of special interest and which is inaccessible to most of our readers, we published last month part of a paper on the physiological effect of electrically charged molecules by Professor Jacques Loeb, of the University of Chicago, originally contributed to *The American Journal of Physiology*. The consent of the editor of the journal and of Professor Loeb was asked, but Professor Loeb wrote that he would prefer not to have the article republished, as owing to the misrepresentation that his work had suffered in the daily papers and in the magazines, he preferred to have his researches published only in technical journals. Unfortunately Professor Loeb's letter was not received until after the form had been printed, and we can only express our regret that the extracts were reprinted without his approval.







*A. Hall*

# THE POPULAR SCIENCE MONTHLY.

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JULY, 1902.

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## STUDIES IN THE NATURAL HISTORY OF THE SACRAMENTO SALMON.

BY CLOUDSLEY RUTTER,  
ASSISTANT, U. S. FISH COMMISSION.

THE following notes are derived mainly from a series of investigations carried on under the direction of the U. S. Commissioner of Fish and Fisheries, by whose permission they are here used.

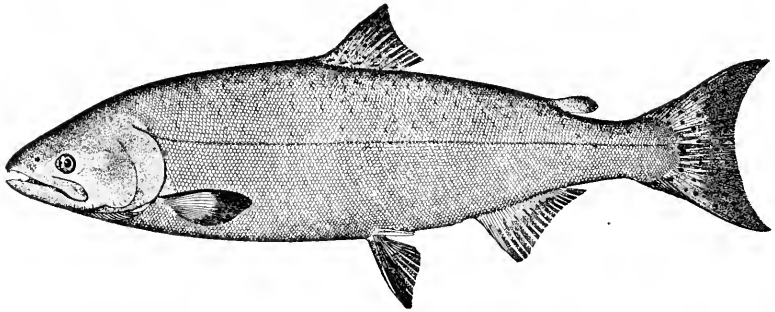
The Pacific salmons, the genus *Oncorhynchus*, of which there are five species, are very distinct from the Atlantic salmon of the genus *Salmo*. In fact, they have no more right to the name salmon than wolves have to the name fox. Anatomically the two genera do not differ greatly—*Oncorhynchus* having 14 or more rays in the anal fin, and *Salmo* 10 to 12—but physiologically and in life-history they differ in a marked degree.

The most important difference lies in the fact that the Pacific salmon, of whatever species, dies immediately after spawning once. This is true of both males and females, and is a very remarkable characteristic. It is often denied upon a *a priori* reasoning, the common argument being that, if they all died on the spawning beds the rivers would be full of dead salmon floating down stream. But the common idea that dead fishes float is erroneous. Those that die a natural death do not float, and the salmon is not an exception.

### *Natural Propagation.*

Under natural conditions, the female salmon extrudes the ova, a few at a time, in a swift current near the bottom of the stream. Many are carried several feet, or even yards, down stream by the current, and are nearly always devoured by other fishes, such as the trout, sculpin,

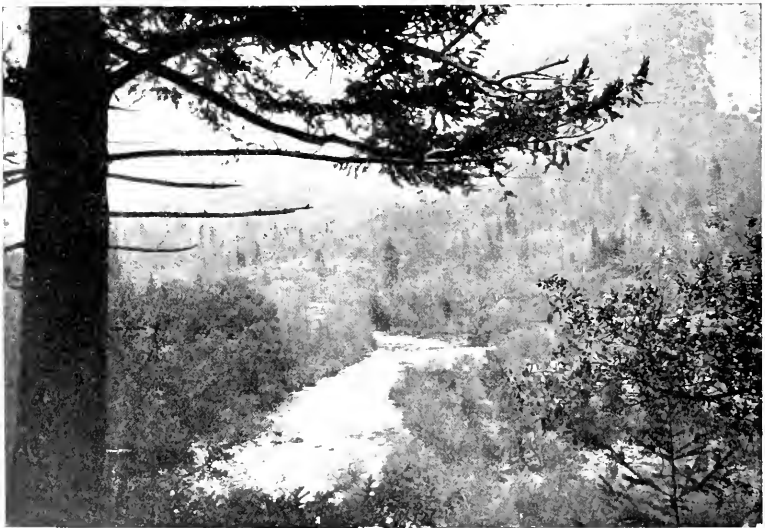
Sacramento pike and split-tail. Some of them, at least, are caught in the eddies formed among the cobble stones, and are held near the 'nest,' or hillock of gravel thrown up by the spawning fishes. These



SACRAMENTO SALMON.

are covered by the sand and protected, though many are covered too deeply and are killed.

Salmon ova are about .25 inch in diameter. The 'shell' is membranous and finely porous, with a minute aperture, somewhat larger than the pores, known as the micropyle. When first extruded the ova



MCCLOUD RIVER, NEAR BAIRD, A TYPICAL SPAWNING STREAM.

are soft and compressible, and it is while in this condition that they must be fertilized. Within two or three minutes after being deposited in the water they become turgid, and are then incapable of fertilization.

Immediately after the extrusion of a few ova, the female moves away from the 'nest,' and the male takes her exact position, or sometimes a little down stream from it, and extrudes a small quantity of milt. The milt is a milky white fluid as full of spermatozoa as blood is of corpuscles. It rapidly disseminates through the water, and is carried away by the current just as the ova were. Doubtless many hundred spermatozoa come in contact with each ovum, though probably only one finds its way through the micropyle, which causes fertilization. The salmon egg is too large to permit a microscopic examination of the process of fertilization, though without doubt it is the same as in other fishes.

#### *Artificial Propagation.*

Fertilization is secured at fish culture stations by expressing the ova and milt simultaneously into a pan and thoroughly mixing them by stirring with a feather or the fingers. Two methods of procedure are in vogue among salmon culturists. The one, known as the 'dry' method, consists in expressing the ova and milt into a pan that has been merely rinsed with water; in the other, known locally as the 'wet' method, about a pint of water is placed in the pan before the spawning. A careful comparison of the results has failed to show any difference. The 'wet' method requires a less quantity of milt, which is sometimes a desideratum.

Numerous experiments were performed testing the vitality of ova and milt under various conditions, of which I note the following:

A quantity of the ordinary creek water, such as was used in artificial propagation, was spermatized, and a portion of it used for fertilizing ova at various periods after the spermatization, in order to test the vitality of spermatozoa in water. The following results were obtained from one experiment, which may be considered typical:



Time milt had been in water. Minutes.	Percentage of fertilization.	Time milt had been in water. Minutes.	Percentage of fertilization.
$\frac{1}{4}$	98	4	0
$\frac{1}{2}$	88	5	0
1	38	6	0
$1\frac{1}{2}$	4	7	2
2	8	8	0
3	8		

Similar experiments were performed with the ova, to determine their susceptibility to fertilization after being immersed in water for various periods. The following results were obtained from one series, which are typical of the others:

Time ova had been in water. Minutes.	Percentage of fertilization.	Time ova had been in water. Minutes.	Percentage of fertilization.
$\frac{1}{4}$	98	4	4
$\frac{1}{2}$	96	5	4
1	95	6	0
$1\frac{1}{2}$	68	7	1
2	57	More than 7	0
3	17		

The average salmon produces about 6,000 ova. In artificial propagation from 5 to 20 per cent. cannot be spawned. These can be removed only by slitting the fish open, in which case a considerable quantity of blood is mixed with them. If the blood is not washed off, the fertilization cannot be made complete, as many of the ova become surrounded with clotted blood. But, if the blood is washed off with water, the ova immediately become turgid and not susceptible of fertilization. The difficulty was overcome as follows:

Among the many experiments testing the vitality of the ova and their susceptibility to fertilization under various conditions, one determined their reaction to normal salt solution. By normal salt solution, is meant water of the same degree of saltiness as the body fluids, which in the case of the salmon we assumed to be .75 of 1 per cent., no chemical determinations having been made. Ova were spawned into a pan containing normal salt solution, and after various periods of time a few were removed and spermatized in the ordinary manner, with the following results:

Time ova had been in salt solution. Minutes.	Percentage of fertilization.	Time ova had been in salt solution. Minutes.	Percentage of fertilization.
2	99	8	99
4	100	15	97
6	100	25	86

Compare this table with the one showing the effect of pure water on the ova. Acting upon the information gained in this experiment, we removed the unspawned ova from the fishes, washed off the blood with normal salt solution, and fertilized them just as we did other ova, thus saving a large percentage that had previously been lost.

### *Habits of the Young.*

Before this series of investigations was begun, fish culturists were able to hatch artificially from 80 to 90 per cent. of the eggs taken, and it did not seem that much improvement in that line was probable. But there was considerable question as to the best methods of planting the young. We were entirely ignorant concerning the life of the young in the streams, knew nothing of their food, nor of their enemies, and knew only in a general way that they migrate to salt water. Our most important study, therefore, was that of the natural history of the young, and later of the adult also. The following are some of the results of our investigations:



AN ALEVIN.



A FRY, AT THE BEGINNING OF THE MIGRATION.

The time required for salmon eggs to hatch is about 50 days, though it varies from one to six months, according to the temperature of the water. When the young first leaves the shell, it is attached to a large mass of yolk, and is known as an *alevin*. It is a very helpless creature, cannot swim and fortunately does not need to eat, the yolk supplying the needs of growth.

For three or four weeks the alevin lies quietly at the bottom of the stream in the crevices of the stones. By that time the quantity of the yolk becomes so small that there is a desire for more food, and the alevin occasionally leaves the bottom to snap at some floating particle. It is at this time, while the movements are slow on account of the unabsorbed yolk, that the young under natural conditions are in the greatest danger from other fishes. In artificial propagation they are protected during this period, and it is only after the complete absorption of the yolk that they are liberated in the streams. At this age they are known as *fry*.

The fry are practically without enemies. The stomachs of more than a thousand trout taken in streams inhabited by young salmon have been examined, but in no instance has a fry salmon been found, though alevins were common enough. Many Sacramento pike and striped bass have also been examined with a like result. There can be

little doubt that the salmon fry in fresh water is able to take care of itself.

Our most extended observations were made on the migratory habits of the fry, and I give a somewhat detailed account of them. In May and June, 1898, we visited all parts of the Sacramento River, from its source to Suisun and San Pablo bays, and even traveled 250 miles down the river in a rowboat. We were equipped with fine-meshed seines which we used wherever it seemed practicable or desirable to gain information concerning the young salmon. We found them abundant everywhere above the middle portion of the river, and in a decreasing number all the way down to the mouth, and along the shores of the bays. We considered them abundant when we caught anywhere from 25 to 400 at a single haul of a 50-foot seine. They were about two inches long wherever taken. The same observations were made again in July. In the headwaters, at the Sims, the fry were as abundant as at the previous examination. There were fewer at Redding, very few at the mouth of Battle Creek, and none at all below the latter point. All that we had found on the previous examination had gone down stream and had passed into salt water. As we afterward learned, the salmon fry observed during this first examination were merely the last of the season's migration, and not all of it, as we first supposed.

While at Battle Creek Hatchery during October and November, 1898, we continued the observations by setting a trap in Battle Creek, and so arranging it that it caught only such fishes as were going down stream. By this means we soon learned that the fry begin their migration much earlier and younger than our previous summer's work had led us to suppose. The following is a record of the daily catch of the trap:

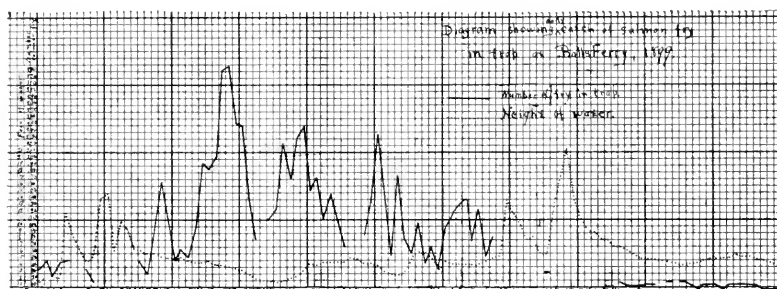
Date.	Time.	No.	Date.	Time.	No.
Oct. 7	Day	0	Nov. 12	Night	6
" 8	Night	5	" 13	Day	0
" 9	Night	1	" "	Night	26
" 11	Night	3	" 14	Night	27
" 12	Night	17	" 17	8-9 P. M.	17
" 13	Day	0	" 21	3-4 A. M.	83
" "	Night	7	" 22	4-5 A. M.	6
" 14	Day	0	" 24	12-1 A. M.	1
" "	Night	10	" 25	1-2 A. M.	5
" 16	Day	0	" 26	1-2 A. M.	15
" "	Night	8	" 27	2-3 A. M.	0
" 17	Day	0	" 28	2-3 P. M.	0
" "	Night	6	" 30	1-2 A. M.	49
" 21	Night	11	" "	8-9 A. M.	24
" 24	Day	0			
" "	Night	2			
" 25	5-9 P. M.	4			
" "	Night	6			



Of the 339 young salmon taken in the trap, 322 were under 2 inches long, and 17 over 4 inches. 178 of the smaller specimens were measured accurately with the following results:

Size, inches,	1.4	1.5	1.6	1.7	1.8
Number,	23	100	53	1	1

The smallest had just absorbed the yolk-sac, and in many there was yet a small quantity of yolk remaining. Those 1.6 inches long had not been feeding over three weeks, as other observations show that they grow at the rate of .3 inch a month. That we found young salmon that had barely absorbed the yolk-sac indicates that they begin their migration as soon as they are able to swim. That they remained of the same size from October 8 to November 30 indicates that practically all start down stream at the same age. If any of the same age as those taken October 8 had been taken during the last days of observation, the fact would have been indicated by their increased size. In 53 days they would have grown over half an inch, and would have been at least two inches long. There were no intermediate sizes

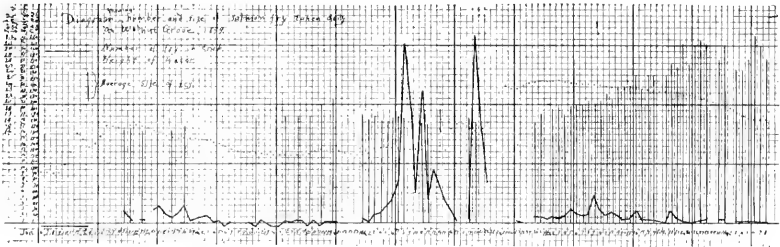


between 1.8 inches and 4.0 inches. The larger individuals had remained over from the previous year. The trap was so set that they could not have avoided it during the day. The fact that none was taken during the day indicates that they travel more or altogether at night. The last record shows that 24 were taken from 8 to 9 A.M., which is the only day record. This is accounted for by high and muddy water, caused by a heavy rain during the previous night. This and other observations indicate that high and muddy water, especially the latter, is an incentive to day travel.

The two months' observations with the trap at Battle Creek were deemed of such importance that two observation stations were established on the river the first of January, 1899, and equipped with similar traps. The upper station was established at Balls Ferry, some three miles above the mouth of Battle Creek; the other at Walnut Grove on the lower river. The diagrams indicate the number of salmon fry taken in the traps at the two stations:

The diagrams indicate the passage of the fry from the fall run of adults; those from the summer run passed the upper station earlier, some of them being noted at Battle Creek during October and November. Observations in 1900 show that they may begin migrating in September.

The work at Balls Ferry indicates that the greater part of the young salmon passed that portion of the river between the middle of January and the middle of March. Practically all had passed by March 20. Numerous measurements made at frequent intervals show that the daily average size varied but one tenth of an inch during the three and a half months. The average of all measurements is 1.53 inches. This confirms the inference from the Battle Creek work that practically all the fry begin their migration as soon as they are able to swim, otherwise the later ones would have been larger.



Both diagrams show that a big run of fry is not necessarily coincident with a rise in the river. From the Walnut Grove diagrams we note. From the middle of January to the middle of May there were salmon fry in various numbers passing Walnut Grove. The height of the migration was from March 4 to about the 24th, lasting about 20 days. Practically all had passed by April 22. The size of those taken during January was 1.6 inches, during February 1.8 inches, during March 1.7 inches. From March 30 to May 7 they increased from 1.7 inches to 3.0 inches. The field notes show that as many fry were taken during the day as at night. The water of this portion of the river is muddy.

Comparing the two diagrams we note that a large run of fry passed Balls Ferry February 2, and that 34 days later, March 8, there was a large run of fry passing Walnut Grove. Again, a large run passed Balls Ferry February 14, and 34 days later, March 20, there was a large run passing Walnut Grove. The later Balls Ferry runs were caught by the high water the last of March, and their passage was not noticed at Walnut Grove. The high water probably carried them down faster, and they may have passed while the trap was out of the water, March 23 to 26.

The average size of the fry passing Balls Ferry January 30 was 1.51 inches, and of those passing Walnut Grove 34 days later 1.79 inches, an increase of .28 of an inch. Those passing Balls Ferry February 18 were 1.48 inches long, and 34 days later at Walnut Grove 1.77 inches, an increase of .29 inch. We have learned from other sources that the fry increase in length about .30 inch a month, and .28 and .29 inch in 34 days is not far from that rate.

It seems, therefore, both from the size and number taken at the two stations, that fry are about 34 days in passing from the upper to the lower station. The distance between the two stations is about 350 miles, as the river winds, and their average daily progress is therefore about 10 miles a day.

An object floating with the current would make the distance between the stations in less than 10 days, and if fry traveled only at night and merely kept with the current, they would be only 18 or 20 days on the way. It is probable that fry in migrating drift down stream tail first, keeping the head up stream for ease in breathing, as well as for con-



WALNUT GROVE TRAP.

venience in catching food. In this way they would drift more slowly than the current. I have seen fry at Battle Creek fishery traveling with the current, and always with the head up stream, unless frightened. The later and larger specimens found at Walnut Grove had simply been longer on the road. The larger they became the more slowly they drifted. Without doubt there are a few passing down the river all summer, though we have been unable to find any after June.

Much seining was done along the shores of Suisun, San Pablo and San Francisco bays, and in Tomales Bay, to determine something of the fry in brackish and salt water. Very few specimens were taken, probably not over 50. The smallest specimens taken in San Pablo Bay were 2.4 inches long, which indicates an age of about  $4\frac{1}{2}$  months, and a period of three months for the migration.

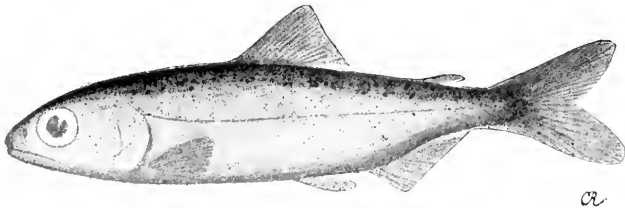
A net stretched across the mouth of Olema Creek, emptying into

Tomales Bay, caught salmon fry coming back into the stream at flood tide. This indicates that they regularly travel back and forth with the tides. We should expect this, as it is hardly probable that they know any directions, except with or against the current.

Many experiments were performed at the Hopkins Seaside Laboratory for the purpose of determining the effect of sea-water upon young salmon of various ages. 25,000 salmon were hatched in the laboratory, and at various ages a few were placed in separate tanks and subjected to various mixtures of fresh sea-water. Without going into details of the experiments, the following are the results obtained:

The young of any age can bear with impunity a density of 25 per cent. sea-water; that is, 1 part sea-water to 3 parts fresh water. Not until forty days old, at the time of the complete absorption of the yolk-sac, could they withstand a density of 50 per cent. sea-water. At the age of 50 days 75 per cent. sea-water could be endured. Pure sea-water could be endured at the age of 60 days, though there was a slight loss. It is doubtful whether they can enter salt water with complete impunity until 3 or 4 months old. The loss was much less when the density alternated from low to high and back again, simulating the change of density in the estuaries with the change of tides. In all cases the young salmon died when changed directly from fresh to salt water, or when the density was rapidly increased until that of sea-water was reached.

To summarize the notes on migration: The fry begin their down stream migration as soon as they are able to swim. In clear water they travel more at night; in muddy water, as much or more during the day. Much of the time they float down stream tail first. In the larger streams they travel more or less in schools. Their regular migration is not dependent upon the height of the water, but upon age. Their rate of progress is about 10 miles a day, and they are about six weeks in reaching brackish water. They are probably four or five months old when they reach the ocean.



A PARR, SIZE UPON ENTERING THE OCEAN.

#### *Summer Residents.*

In the upper portion of Sacramento River and its tributaries there remains after the winter and spring migration a large number of young

salmon. In the vicinity of Sims in 1898 we found 700 to 1,000 in the various pools. They were common in McCloud River in September, and in Fall River in August.

These summer residents, as they may be called, are confined to the headwaters, the clear streams with rocky bottoms. They do not stay much of the time in the swift current or riffles, but remain in the more quiet pools, where they feed on insects and take the angler's fly the same as trout. Considerable effort was made to learn as much as possible concerning them, and Sacramento River near Sims and its tributary, Hazel Creek, were visited each month from May to December with that end in view.

During July and August, all specimens taken were marked by cutting off the adipose fin, by which means we were able to make estimates of the number in the pools, their rate of migration, and their rate of growth. The number estimates were made thus: After having marked a few and released them in the pool, the following proportion was formed with the data from each seine-haul: the number of marked fry taken is to the number of marked fry in the pool, as the total number taken is to *the total number in the pool*. In August, when we could distinguish those just marked from those marked in July, we were able to make estimates of the number of July-marked fry in a pool and, knowing the number released there in July, to compute the rate of migration for the month.

The following table gives the result of the work in one pool, and illustrates the data used in making the number estimates:

Date.	No. caught.	No. previously marked.	No. marked fry caught.	Estimated No. in pool.
Aug. 16 P. M.	66	1	1	
"	148	66	13	751
"	146	197	30	992
Aug. 17 A. M.	83	312	38	682
"	47	357	19	883
"	19	385	4	1804
"	64	400	25	1024
"	149	439	62	1055
"	71	525	40	932
"	35	556	15	1297
Aug. 17 P. M.	19	576	9	1216
"	3	586	3	586
Total different individuals, 24 hrs.,	586		Average of estimates,	1022

The average estimates for two other smaller pools are 685 and 861. From these estimates it seems probable that there were about 10,000 young salmon to the mile in the upper Sacramento during the summer of 1898, or less than a million in all the headwaters, which is a very

small percentage of the year's product for the river. At Battle Creek Hatchery alone that year, 1897-8, there were nearly 50,000,000 eggs taken. There is little migration of the young salmon during the summer months. In August we could account for 94 per cent. of the fry we had marked in one of the pools in July; 76 per cent. in the pool in which they were released, and 18 per cent. in the pool below.

The growth of the larger fry in fresh water is slow. The average size of the marked fishes in August was 3.91 inches, in September 3.86 inches, in October 4.20 inches, in November 4.20 inches, being a total gain of but .29 inch in three months. The earlier rate was .3 inch per month. Another effect of this summer residence in fresh water is the maturing of the male genital organs. A large proportion of the males that remain in fresh water until they reach a length of four inches becomes sexually mature. Its significance is not understood, and its effect upon the future growth of the fish is not known. The number of parasites found in the stomachs of young salmon living in fresh water increases with their size and with the time of year, there being more in the fall than earlier. Their food in fresh water at all ages, seasons, and places is insects, about two thirds being aquatic larvæ, and the other third adult insects.

#### *The Adult.*

As stated above, young salmon reach the ocean when four or five months old. Concerning their habits from that time until they return to fresh water at maturity, we know very little. They are occasionally taken in the ocean near San Francisco, but so rarely as to indicate very little concerning their habits. They are abundant in Monterey Bay during the spring and early summer, but their appearance there is only the first step in their migration up the rivers to spawn.

The length of their stay in the ocean has been determined with considerable certainty by a series of observations carried on recently with the Columbia River salmon, which is the same species as the Sacramento salmon. In May, 1896, 5,000 young salmon 2.5 inches long were marked by cutting off the adipose fin, and were released in the Clackamas River, a tributary of the Columbia. The eggs from which they were hatched were spawned in September, 1895. During the summer of 1898, a little over two years after the marking, and a little less than three years after the spawning of the eggs, 375 of the marked salmon were taken in the Columbia, and five were taken in the Sacramento River in California. A few more were taken both in the Columbia and in the Sacramento in 1899, and again in 1900. The size of those taken in 1898 varied from 10 pounds to 57 pounds.

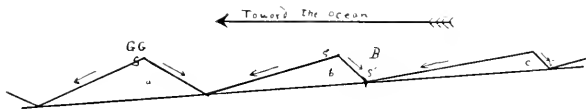
Besides indicating the age of the spawning salmon, this experiment shows that most salmon return to the river through which they reached the ocean. They do not do this because it is the stream in which

the parent fishes spawned—the 5,000 mentioned in the experiment were from eggs taken in California—but because their ocean feeding grounds are not far off-shore, and in their two years' residence in the ocean they have not wandered far from the point at which they entered it. When it comes time to return to fresh water, their native stream is the first to attract attention.

Adult salmon may be found in the Sacramento River at any time of year. There are, however, two distinct runs, the earlier of which passes up the river during April, May and June, and the later during August and September. The former is known as the spring run and the latter as the fall run. The salmon of the spring run ascend the river to the headwaters, such as the upper Sacramento, McCloud River and Hat Creek, and some of the earlier ones even pass Pit River Falls and enter Fall River. The salmon of this run spawn mainly in August. The fall salmon do not ascend the river so far as those of the spring run, but turn aside into the lower tributaries, or spawn in the main river. They reach their spawning grounds during the latter half of October, November, and the first half of December. The main river is very low at this time of year and only a small portion enter the tributaries.

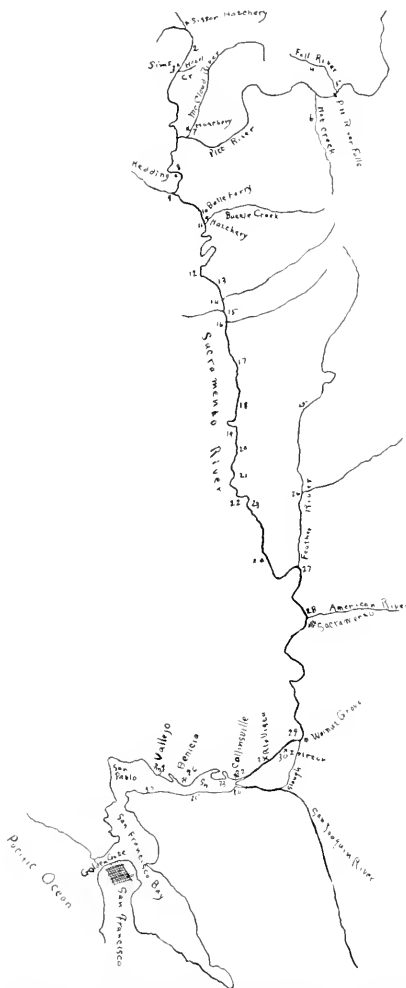
#### *Details of Migration.*

When the salmon enter the bay from the ocean, they come in against the ebb-tide. They stem the current till the tide changes, and then run out against the flood-tide, losing much of the distance gained during the ebb. That they do not lose altogether as much as they gain may be understood from the following explanation:



The tide runs up the bay and river as a broad low wave, on the upper side of which is flood-tide, and on the lower side ebb-tide. This wave is about three hours going from San Francisco to Benicia; it reaches Collinsville in about four hours, and Rio Vista in four and a half hours. When the crest of a wave is at Isleton, its trough is about at the Golden Gate. The farther the tide extends up stream, the smaller the wave, the shorter the flood, and (as the flood and ebb must together equal twelve hours) the longer the ebb. The following diagram will illustrate the movements of a salmon in passing through the bays: *a b* and *c* represent the tide-wave at successive points as it passes up the bay.  $\leftarrow$  indicates ebb-tide, and  $\rightarrow$  flood-tide. Suppose that a salmon enters the Golden Gate, *G G*, at the beginning of ebb-tide,

which would be the most favorable time. His position on the wave will be at *S*. If he is able to travel up the bay as fast as the wave he will keep his position near the crest, that is at *S*. But he can hardly



MAP OF SACRAMENTO RIVER AND OUTLET, SHOWING STATIONS, BY NAMES OR NUMBERS, WHERE SALMON INQUIRIES HAVE BEEN MADE.

determine the length of time required to reach Vallejo after leaving the ocean.

The spring run passes up the river quite rapidly, reaching their spawning grounds in the McCloud River in about six weeks after entering the river at Collinsville. The fall run moves more slowly. The flood and ebb tides are more nearly equal, owing to the small amount of water coming from the rivers, which makes a longer passage through

do that, especially as the current would be very slight, and in the broad bay hardly strong enough for his guidance. Let us suppose that by the time he reaches Benicia, *B*, he has fallen behind the wave until he has the position at *S'*. It is then slack low water, and he can make no headway. Soon the next wave reaches him and he is in flood-tide. He will therefore swim back against the current. As the wave is going up the bay and he is going down, he soon gets past the crest and finds himself in the ebb-tide at *S''*. He then turns and stems the ebb-tide, and as the wave is going in the same direction he is, he goes much beyond Benicia, *B*, before he again falls back to slack low water at *S'''*, and gets into the flood of the next tide-wave.

By taking the statistics of the daily catch of salmon at various points, we have been able to trace the progress of a school up stream, and find that it requires four days to pass from Vallejo to Sacramento.

We have been unable to determine



the bay. After reaching the shoals in the middle portion of the river they move slowly, having already found pretty good spawning grounds. They are about two months reaching their spawning grounds (between stations 17 and 8 of the accompanying map), which are but little more than half as far up stream as those of the spring run.

In September, 1901, over a hundred salmon were weighed and branded with serial numbers and released in the river at Rio Vista. Three of these were taken later upon their arrival at the spawning grounds. The following is a tabular statement of the data concerning them, the loss in weight being due to migration alone. No. 34 was 8 days in spawning, extruded all but 20 ova, and lost thereby 21 per cent. more of the Rio Vista weight.

No.	Sex.	Distance traveled, miles.	Time, days.	Loss in weight, percentage.
8	female	300	65	28
34	female	300	61	20
43	male	350	65	26

The salmon of the spring run reach their spawning grounds from two to six weeks, or even longer, before spawning, which time they spend lying quietly in the pools. The fall salmon are more nearly ripe when they arrive at the spawning grounds, many of them ceasing to ascend only when ready to spawn.

#### *Spawning and Death.*

Salmon are in fairly good condition when they begin spawning, notwithstanding the fact that they have been without food for several weeks or even months, and have traveled several hundred miles in the meantime. The male has changed his appearance. His snout has grown longer and much hooked: large, conical, hooked teeth have appeared in his jaws: his body has grown thinner and apparently deeper, though the latter point has not been determined yet by measurements: his skin has thickened and embedded the scales. The larger males become somewhat reddish in color as spawning time approaches. The female has changed less. The abdomen is somewhat distended from the ripening ova, the skin thickened as in the male, and the color has become more or less of a dull olive.



HEAD OF A SALMON WITH THE OPERCLE CUT AWAY, SHOWING THE GILLS ATTACKED BY FUNGUS AND PARASITIC COPEPODS. YET ALIVE WHEN TAKEN.

As spawning progresses, both sexes rapidly become emaciated. Their fins become frayed and worn, especially the caudal fin of the female, which is frequently entirely worn off. Fungus attacks the skin in various places, especially the top of the head and the fins, and it frequently destroys one or both eyes. The gills are nearly always

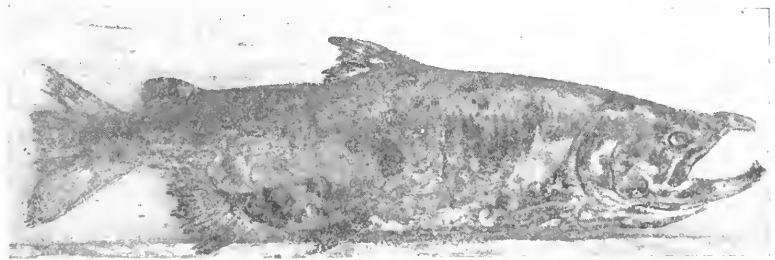


ALIMENTARY CANAL OF A SALMON TAKEN  
IN MONTEREY BAY.



ALIMENTARY CANAL OF A SALMON AFTER  
SPAWNING, TAKEN AT BATTLE CREEK  
FISHERY

attacked by fungus and parasitic Copepods, and half or even three fourths of the gill filaments are sometimes thus destroyed. The skin is worn off in many places, such as the side of the tail, the projecting edges of the jaws and fins, and the snout of the male. They have eaten nothing since leaving the ocean, and the alimentary canal has

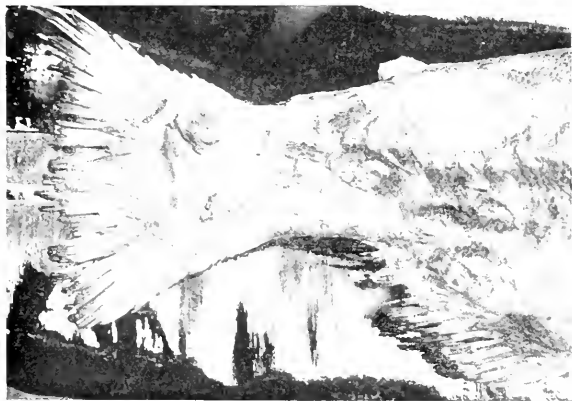


MALE AND FEMALE AFTER SPAWNING.

long since shriveled up until the stomach is scarcely one tenth its normal size; a catarrhal desquamation takes place all along the digestive tract, but especially posterior to the stomach, which portion is frequently filled with tapeworms. At least two other kinds of

parasitic worms are frequently found in the abdominal cavity. Both sexes lose from 30 to 40 per cent. of their weight.\*

Such is the condition of the salmon at the time of death. It is not the spawning itself that produces this effect, but the continuation of the spawning efforts after all ova have been extruded and fertilized. Usually there is considerable vitality in both sexes at the time of the complete extrusion and fertilization of the ova, and they have enough energy left, in many cases, to carry them back to the ocean. But they exhibit no inclination to go. Instead, they continue on the spawning beds, persevering in their efforts to spawn and fertilize more eggs. When one fish of a pair dies, the other seeks or is sought by a new mate. Probably the female never notices the death of the male, as there are nearly always several males fighting around each 'nest.' If there happens to be no salmon in the vicinity when one of a pair dies, the



THE TAIL OF A SPAWNED-OUT FEMALE.

survivor continues his or her efforts alone, futile though they are.

This extreme devotion to a purpose is almost without parallel. There is no instinct whatever to return to salt water. It is even doubtful whether they would revive if taken back. The dog salmon and hump-back salmon spawn in small streams that empty directly into the ocean, and they are found dying and dead in brackish water. The fact that all salmon, of the genus *Oncorhynchus*, die immediately after spawning once cannot be questioned.

\* The description here given of the spawning salmon should not prejudice any one against the fish as found in the markets, either fresh or canned. Such are taken either in salt water or within a few days after leaving it, and are in prime condition. Indeed, they must necessarily be, in order to make the long journey up the river and live several months without food. Chemical analyses have shown that the Sacramento salmon is the most nutritious of fishes.

## A MODERN STREET.

BY DR. S. F. PECKHAM.

NEW YORK CITY.

A MODERN street is laid on a concrete foundation, the surface of which may consist of brick, asphalt block or sheet asphalt.

It is of the greatest importance that the foundation should be properly constructed. It is true that in cities where a large area of Belgian block pavement has been already laid, sheet asphalt is often laid upon these blocks; but while streets can be made in this way, they are, when so constructed, more or less liable to criticism in several respects; but chiefly from the fact that the Belgian block, as compared with concrete, is an unstable foundation, liable to yield under unusual or excessive strain and always sure to carry the surface with it. While this cause of the criticism is usually absent, especially upon residence streets, there have been conspicuous examples of its presence in almost every large city, where the custom of laying asphalt surfaces on Belgian block prevails. We therefore consider the normal modern street as laid on a concrete foundation.

The French engineers determined the elements of this problem, nearly half a century ago, by very costly experiments for which the city of Paris was mainly responsible. As all the roadways of France are more or less completely under governmental supervision, the results of these experiments have been described in several masterly memoirs by some very able French engineers, in the *Annales des Ponts et Chaussées*, which is the official organ of the French governmental supervision of bridges and roads. Space forbids mention here of more than a summary of these results. It was found that of all the materials that were available, only a concrete made of Portland cement of good quality mixed with clean sharp sand and broken stones was always to be depended upon. If a concrete foundation could always be laid on well drained earth properly rolled or rammed, that was never invaded by frost and never disturbed by openings for all the multitudinous purposes that disturb modern streets, concrete that will not stand such rigid tests might be used instead of that made of Portland cement. But, streets laid under such conditions and subjected to such use are an exception, indeed they are rare, and for that reason should not be made the rule. The French engineers determined that under *any* circumstances, nine inches of concrete would hold *any* traffic; that six inches

would hold up all ordinary traffic and that four inches would hold in many special cases. They adopted a thickness of six inches of Portland cement concrete as a general rule, and that rule has been followed in England and the United States with very general satisfaction.

It is imperatively necessary that this foundation should present to the material laid upon it an absolutely unyielding surface, for the reason that the bricks or blocks being jointed and the thin sheet of asphalt, while continuous, possessing very little strength in itself, either of them is bound to follow a yielding foundation with disastrous results. As before stated, an unyielding foundation is therefore, within reasonable limits, an absolute necessity; for, while the average street in our northern cities is liable to the vicissitudes of frosts, and still more liable to the vicissitudes of frequent openings, the evil effects of these vicissitudes can be for the most part avoided by constructing a concrete foundation sufficiently strong to form a bridge over any such weak spots of limited extent, and thus hold up the surface. This very obvious requirement will never be found in a concrete that is neither thick enough nor strong enough.

The action of the Commissioners of Accounts of the City of New York in insisting that only Portland cement of good quality should be used in the street foundations of Greater New York only confirmed and was confirmed by the conclusions reached by the French engineers more than a generation ago. Why such a question should have been raised at this time by engineers presumably familiar with the literature of their profession is not apparent.

In constructing this foundation the contractor is required to proceed as follows:

The concrete shall be composed of one part cement, three parts of sand and six parts of broken stone. . . . Unless machinery be used, concrete shall be mixed in batches, one barrel of cement with the requisite proportion of other material, on suitable tight platforms, not less than twelve feet by twelve feet in size. The cement and sand shall be thoroughly mixed dry and then made into a mortar with as little water as possible, after which the broken stone, having first been watered, shall be added. The whole mass shall then be turned and worked until a moist resultant is obtained, with the stone uniformly distributed.

It is very necessary that the concrete should be thoroughly set and dried out before the surface should be placed upon it. It is therefore advisable that a modern street should be constructed during dry and warm weather.

If the surface is to be of brick, a brick made especially for the purpose is used that is uniformly burned until vitrified. The size should be as uniform as possible, they should be hard enough to resist abrasion and of a texture that renders them impervious to water. When they

are laid the dry surface of concrete is swept clean and strewn with dry, clean sand, upon which the bricks are laid and pounded to the proper contour. The joints are filled either with sand or bituminous grout. In the latter case the pavement is impervious to water and the surface makes a very clean and excellent street.



WOODWORTH AVENUE, DETROIT, MICH. LAYING CONCRETE FOUNDATION.

The asphalt blocks are made of asphaltic cement and pulverized rock in the form of large bricks. The materials are thoroughly incorporated together and pressed out while hot in a sort of brick-machine

of great power, which renders the resulting block as solid as the materials can be made. The blocks are required by the specifications to be 4 x 5 x 12 inches and to vary not more than one quarter of an inch in dimensions. They are laid on their edges on a cushion of two inches of sand, so that the surface presented to wear shall be 4 x 12 inches, either in parallel rows or in a diagonal across the street. The surface, after the wear of a summer, during the heat of which it softens slightly, becomes nearly coherent and as continuous as sheet asphalt. On grades, the slight irregularities due to jointing offer a better foothold to the hoofs of horses than sheet asphalt and in this respect the asphalt blocks are the best. It is found in practice that on streets subjected to very heavy traffic, asphalt blocks are more easily broken than a good quality of sheet asphalt, but for streets that are subjected only to light traffic, asphalt block pavements are durable, clean and slightly, and cost little or nothing for repairs over long periods of time.

The larger number of so-called asphalt streets are laid with sheet asphalt, in imitation of the surface first laid about fifty years ago in France from the natural bituminous rock occurring at Pymont and Seyssel, near the border of France and Switzerland and near the headwaters of the river Rhone. This material consists of chalk saturated with bitumen, which, when extracted, is found to be very permanent in the air, impervious to water and very tenacious. When the bituminous rock is heated to a moderate temperature it falls into powder that can be screened to remove the flints that are in the chalk. It is then spread, while hot, with rakes, and rolled into a sheet that lasts until it wears out. This bituminous rock was called 'asphalt' by M. Léon Malo, the distinguished French engineer, through whose efforts and inventive skill the laying of these streets became an established industry in France.

M. Malo did not identify 'asphalte' as thus named by him, with asphaltum, which is the solid variety of bitumen, and had been known for an immemorial period before any one thought of using bituminous limestone in the construction of streets.

M. Malo says in his paper, published in 1861:

The first point is to establish the value of the definitions and of the words.

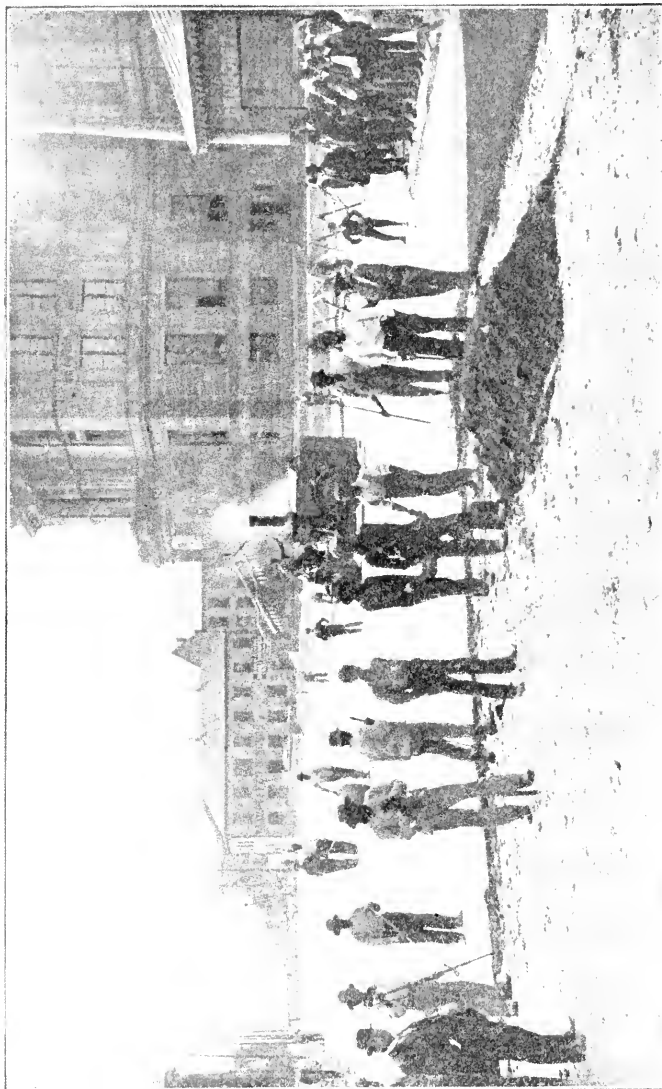
To this end he proposes a nomenclature of which he gives the following summary:

First, bitumen or pitch, the materials which impregnate asphalte.

Second, asphalt, the calcareous rock, impregnated naturally by bitumen or pitch.

This definition gave this peculiar bituminous mineral a name that passed to the streets made from it, and these streets became known in England and the United States as 'asphalt streets.'

The great popularity of these streets in Europe led to attempts to construct similar streets in the United States. This was at first a difficult problem as at that time no bituminous limestone was known in America, and those who attempted to introduce an imitation of an



LAYING ASPHALT SURFACE, OHIO STREET, TERRE HAUTE, IND. PAVEMENT LAID 1867.

asphalt-surfaced street were forced to use such materials as were available. A number of streets were laid in Washington, D. C., of a sort of bituminous concrete, made of coal tar pitch and broken stone that was laid very thick. Some of these streets are now in existence, more



than 20 years old, and in fairly good condition. A better imitation, or what was supposed to be a better one, was made of pitch from the celebrated pitch lake of Trinidad and the liquid residuum of the petroleum stills, which was then a drug on the market. This mixture was tempered with sufficient sand to make about 90 per cent. of the mineral matter and laid, spread and rolled like the European asphalt. The experiment proving a success, the name 'asphalt street' was applied to these artificial imitations of asphalt. No harm came from this wrong application of M. Malo's word for many years, as the use of it was confined to street surfaces of which natural bitumen was the principal constituent.

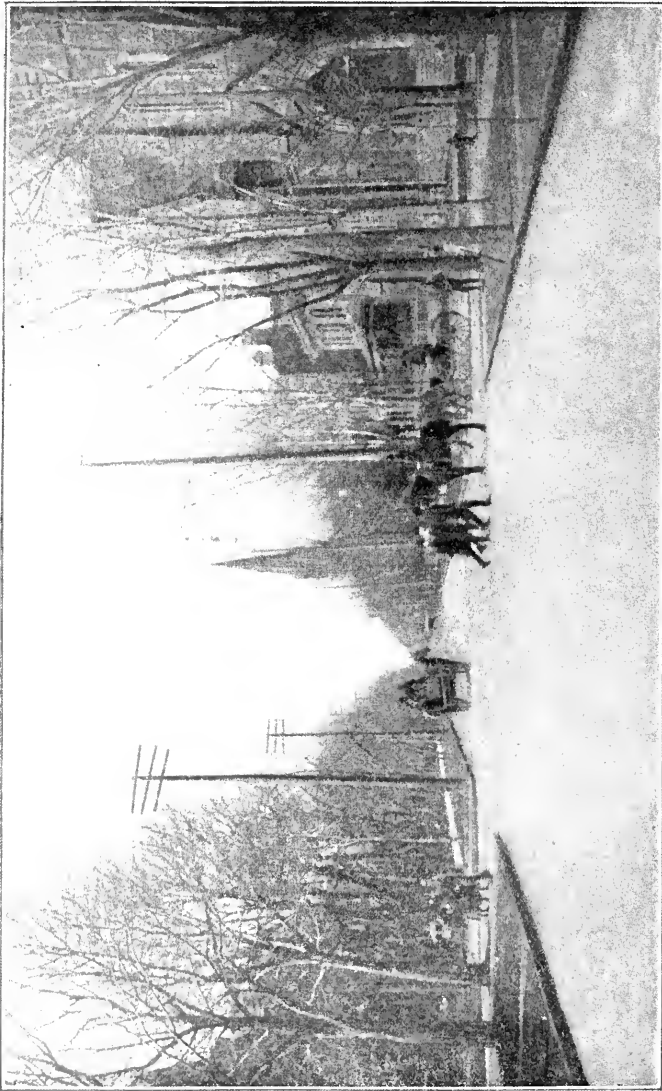
About 1890, the late Joseph D. Weeks, of Pittsburg, visited the Pacific Coast and found that the petroleum refiners of California were making a solid residuum from the distillation of petroleum and calling it 'asphalt.' Mr. Weeks immediately conceived the idea that California petroleum contained 'an asphaltic base,' or in other words, it might be considered to be asphaltum dissolved in petroleum from which it could be separated by distilling off the petroleum. This very erroneous conclusion led to a second one, viz., that the residuum of the distillation of California petroleum is practically the same thing as natural asphaltum. On the contrary, these residuums of petroleum, no matter in what manner they may be made, are the product of destructive distillation and should be made the subject of prolonged and careful experiment before they are used in any considerable quantity as an equivalent for natural asphaltum.

The difficulty which M. Malo feared would follow the careless use of terms to designate the different forms of bitumen has overtaken us, inasmuch as the word 'asphalt' is now applied to a large number of the most heterogeneous substances, quite unlike in many respects, but having other properties, denominated bituminous, in common.

An enumeration of these materials will illustrate my meaning. The natural solid bitumens are M. Malo's asphalts, called in the United States rock asphalt, and including bituminous sandstones, as well as limestones, of which there are large deposits in California, the Indian Territory and Kentucky; Trinidad pitch; Bermudez, Cuban, California, Mexican and other asphaltums; Gilsonite, the bituminous coquina or shell limestone of Uvalde County, Texas, with the extracted bitumens of California and the Indian Territory. All these materials have been used successfully in making asphalt surfaced streets.

The so-called artificial asphalts, called asphalts by local application of the word, are the solid residuums of the so-called asphaltic petroleum, found in California and Texas; Pittsburg Flux, which is the residuum made by burning out the hydrogen from petroleum with sulphur; residuums made by several other patented methods and sold under various

trade names, with the solid residuums from the ordinary distillation of petroleum, all of which are very unlike natural asphalts or any imitation of them in which natural bitumen is used and among which there is great diversity of properties and qualities.



JARVIS STREET, TORONTO, CANADA. PAVEMENT LAID 1889.

To construct a street of any of these natural or artificial materials, all passing under the name of 'asphalt,' the same general method of procedure should be followed.

If the crude asphalt is to be refined, it is put into an enormous ket-

tle, or still, where it is slowly melted in order to drive off the water and light oils. Such oils make the work on the street dangerous from liability of fire. The refined pitch or asphaltum, from which an excess of mineral matter has settled or any sticks or other organic matter has been skimmed off, is drawn into barrels.

A fluid residuum of heavy petroleum or mineral tar, which has also been deprived of water and light oils, is mixed with the asphalt in the proportion of 20 parts by weight of oil to 100 parts of asphalt. It is of the highest importance that this mixture should be very complete. If the blending is imperfectly done, the oil will wash out from the asphalt after the street is laid and the surface will dry out, crack and disintegrate. This asphaltic cement should be plastic and very tenacious and should preserve these properties through a wide range of temperature. If it becomes brittle at zero or nearly fluid at or about 100° Fahr., it will not answer, as it will be brittle and break up in winter and will soften and flow in summer.

To prepare the surface mixture, an asphaltic cement possessing the proper qualities is mixed with sand and pulverized rock in such proportions that when finished it will contain about eleven per cent. of bitumen. The proportions depend upon the kind and quality of the crude bitumen, the locality in which the street is to be laid and the traffic to which it will be subjected. The sand should be clean and sharp and should consist of both fine and coarse particles in such proportions that the fine particles will fill the voids between the coarse particles, leaving the bitumen to hold all of the particles together.

Every element in the construction of an asphalt-surfaced street is important if the result is to be in every respect a durable and satisfactory street. No part can be slighted or neglected in either materials or workmanship. If the street is to be first class each and all of these must be first class of its kind.

The material and drainage of the sub-soil is of the highest consequence. Water is a great enemy to asphalt streets, particularly to those constructed of Trinidad pitch. It is therefore of the greatest importance that the subsoil on which the concrete foundation is laid should be as solid and dry as possible. All excavations made in the subsoil should be puddled and rammed, in order that the rolling may result in a perfectly uniform and unyielding surface.

Of equal importance is a proper concrete foundation. It should not only be sufficiently strong, but it should be as impervious to water as possible. Soft, spongy foundations of natural cement or Portland cement of inferior quality are not only an inadequate support for the yielding surface, but they are easily penetrated by water from below and act as conveyors of water, while a sound and firm foundation of the best Portland cement concrete not only presents an unyielding support

to the surface, but also, when properly set and dried before the surface is laid, keeps the surface as free as is possible under the circumstances from ground water, and thus contributes to the longevity of the surface.



CASS AVENUE, DETROIT, MICH. PAVEMENT LAID 1880, SHOWING STREET-CLEANING UNDER THE 'ORDERLY SYSTEM.'

The concrete surface, having been laid as nearly as possible of the proper contour, and having been thoroughly set, dried out and swept clean, is covered with a binder course to fill the inequalities of the concrete and form a bond between the concrete and surface that will

not only attach the surface to the concrete, but will hold the surface in place and keep it from sliding from the center towards the gutters. The binder consists of small broken stone, which should be sound and clean. Each piece should be completely covered with a soft asphaltic cement containing more residuum oil than the surface mixture. The stone and cement should be thoroughly mixed by machinery at a temperature that will render the bitumen perfectly fluid, but not sufficiently high to burn or otherwise injure it. It is then dumped into carts and carried to the streets, where it is spread with hot rakes, and rolled to the proper contour.

The binder is an important part of an asphalt street surface, and should be carefully compounded and laid. If it is deficient in bitumen, it will absorb bitumen from the surface, causing the surface to crack and disintegrate. If it is well supplied with bitumen that is not too soft, the surface is preserved from becoming too dry by absorbing bitumen from the binder, or, in the technical phrase of the art, 'is nourished from the binder.'

The binder being laid and rolled presents a surface that should be exactly parallel to the surface of the finished street. Upon this surface the surface mixture of asphaltic cement and sand is brought in carts, while still hot, and is spread also with hot rakes and rolled, first with hand rollers and finally with heavy steam rollers, until cold. The rollers are prevented from sticking by strewing the surface with hydraulic cement or fine sand. The rolling is an important element of a good asphalt-surfaced street, as upon that depends the complete solidity of the surface mixture.

As both good and bad streets have been made of about every variety of natural bitumen in the form of asphalt or asphaltum that can be had, the quality of a street appears to depend quite as much upon the technical skill of those who lay the street as upon the kind of material of which it is constructed. Of the various substitutes now being offered for natural bitumens too little has been demonstrated by use to warrant any conclusions concerning them.\*

\* I wish herewith to express my obligations to the Warren-Scharf Asphalt Paving Company for the illustrations accompanying this article.

VIEWS OF DR. RIZAL, THE FILIPINO SCHOLAR, UPON  
RACE DIFFERENCES.\*

PROFESSOR BLUMENTRITT, the German ethnologist, was a friend of Dr. Rizal, the famous and lamented Filipino scholar and ethnologist, and after his death published an account of his life and studies in the *Internationales Archiv für Ethnographie* (Bd. X., Heft II.), together with his views upon the comparative intellectual endowments of the white and colored (Filipino) races. A translation of portions of that paper is presented here. It is a curious and pathetic spectacle which is presented in the sketch—that of a cultivated Filipino making comparative studies of himself and the domineering whites in order to discover the cause of their assumption of superiority, yet conscious all the while of the hopelessness of protesting against fate.

Incidentally the study is instructive as illustrating the natural bent of Filipinos for higher studies, a feature of their character which is ignored by the American newspaper writers, who have in mind, apparently, when speaking of education in the Philippines, only the elementary studies taught in the public schools of the United States.

The anniversary of the execution of Dr. Rizal is observed in the Philippines, both by the native public and in the schools, where the day is known as Rizal day. It is a singular fact, and perhaps one significant of some trait in the character of the race, that the national hero of the Tagals was neither a military man nor a politician, but a man of intellectual gifts, and a student, who devoted his talents to his country and became a martyr to its cause. [Tr.]

Professor Blumentritt writes as follows:

On December 30, 1896, the Spanish authorities in Manila shot to death the greatest son of the Philippines, Dr. José Rizal, ostensibly because he had been an instigator of the insurrection then in full blast in the archipelago. Dr. Rizal was a Tagal, born in Calamba, a small city in the province La Laguna de Bay in Luzon. He was originally intended for the priesthood, but his own tastes inclined him to medicine and he accordingly studied that science in Manila and Madrid, at which latter university he took the degree of doctor of medicine and philosophy. He continued his medical studies in Paris, Heidelberg, Leipzig and Berlin, and also devoted himself to linguistic and ethnographical investigations, being made in consequence a member of the

\* Translated by R. L. Packard, Washington, D. C.

Anthropological Society of Berlin. Upon returning to his native land he was soon compelled to emigrate because his novel 'Noli me Tangere'\* had drawn upon him the unextinguishable hatred of the Old Spanish party. After a short sojourn in Japan and North America, he established himself in London where, under the guidance of Dr. Rost, he broadened his acquaintance with languages, and meanwhile edited the second edition of the well-known work of DeMorga upon the Philippines which was published in Paris.† In Biarritz, Paris, Ghent and Brussels he wrote his second political novel 'El Filibusterismo.' He then returned to the East and practised medicine for some time in Hong Kong, from which city he removed to British Borneo with a view to establishing a Filipino farming colony there. He meanwhile obtained permission to visit his home again, but was arrested upon his arrival upon the charge that anti-Spanish writings had been found in his trunks at the Custom House. He was thereupon banished to Dapitan in the island of Mindanao, whence he could easily have made his escape, but in the full consciousness of innocence he did not hesitate to remain there in exile. When the insurrection of 1896 broke out he was immediately charged with instigating it, was brought to trial on this charge three times in five months, was acquitted twice, but the third time his unchristian enemies succeeded in their purpose of convicting him and he was condemned to death.

Rizal devoted himself particularly to the analysis of the sentiments with which whites and the colored races mutually regard each other. No one was so well qualified as he to study this question which is of such importance for folk-psychology, for he was himself of a colored race, had lived among his fellow countrymen at his own home, as well as among the whites, mixed bloods and other classes at Manila, and had besides come to know Hong Kong, Japan, Europe and the United States, and that in a thorough way and not as a mere tourist. His extensive acquaintance with languages opened for him the ethnological writings of all civilized nations, and his own penetrating intellect prevented him from remaining content with the surface of things. It should be said, however, that Rizal concerned himself wholly with the relations between the whites and the colored people of the Philippines because, as he explained, he knew nothing of the psychology of other colored races.

He said that when a boy he was deeply sensible that the Spaniards treated him with contemptuous disregard for the sole reason that he was a Filipino. From the moment when he discovered this attitude

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\* Published in an English translation in the United States under the title 'An Eagle Flight.'

† De Morga was viceroy in Manila in 1598 and wrote a most valuable work upon the Philippines which was published in Mexico in 1609.

of theirs he endeavored to find out what moral right the Spaniards, and the whites generally, had to look down upon people who think as they do, study the same things they study, and have the same mental capacities they possess, simply because these people have a brown skin and stiff straight hair.

Europeans regard themselves as the sovereign masters of the earth, the only supporters of progress and culture and the sole legitimate species of the genus *Homo sapiens*, while they proclaim that all other races are inferior, by refusing to acknowledge their capability of acquiring European culture, so that, according to the European view, the colored races are varieties of the genus *Homo brutus*. Rizal then asked himself, Are these views just? He began asking this question when he was a school boy and at the same time began to answer it by observing his white fellow students closely while he studied his own mental processes and emotions in order to make comparisons. He soon remarked that, in school at least, no difference could be detected between the intellectual level of the whites and Filipinos. There were lazy and industrious, moral and immoral, dull and intelligent boys among the whites as well as among the Filipino scholars. Soon this study of race spurred him to exert himself to the utmost in his school studies and a kind of race rivalry took possession of him. He was overjoyed whenever he succeeded in solving a difficult problem which baffled his white companions. But he did not regard these events as personal successes so much as triumphs of his own collective people. Thus it was in school that he first became convinced that whites go through the same intellectual operations as Filipinos and—*ceteris paribus*—progress in the same way and to the same extent. From this observation he came to the conclusion that both whites and Filipinos have the same natural intellectual endowment.

In consequence of this conclusion there manifested itself in Rizal, as he himself avowed, a sort of national self-exaltation. He began to believe that the Tagals must stand higher intellectually than the Spaniards (the only whites he had known up to that time), and he used to like to tell how he came to this fallacious conclusion. In the first place, he said, in his school the whites received instruction in their own language while the Filipinos had to worry with a strange idiom in order to receive instruction which was given in it alone. The Filipinos therefore must be better endowed intellectually than the Spaniards, he inferred, since they not only kept up with the latter in their studies but even surpassed them, although handicapped by a different language. Still another observation caused him to disbelieve in the superiority of the European intelligence. He noticed that the Spaniards believed that the Filipinos looked up to them as beings of a superior nature and made of a finer clay than themselves. But Rizal knew very well that



the respectfulness which the Filipinos manifested towards the Spaniards did not proceed from self-depreciation, but was simply dictated by fear and self-interest. By fear, because they saw in the Spaniard their lord and master who oppressed them arbitrarily even if with good intentions; by self-interest, because they had observed that his pride of race lays the European open to flattery and that they could get large concessions from him by a little subserviency. The Filipinos do not, therefore, have any real respect for the European, but cringe and bow to him from interested motives alone. Behind his back they laugh at him, ridicule his presumption and regard themselves as in reality the shrewder of the two races. Because the Spaniards never divined the real sentiments of the Filipinos towards themselves, young Rizal felt justified in regarding them as inferior in intelligence to his own countrymen. But in later years he found it necessary to change this false impression of his youth, especially as he had found by his own personal experience how easy it is to draw mistaken conclusions about people of a different race from one's own. "Whenever," he used to say, "I came upon condemnation of my people by Europeans, either in conversation or in books, I recalled those foolish ideas of my youth, my indignation cooled, and I could smile and quote the French proverb '*tout comprendre c'est tout pardonner.*'"

Dr. Rizal's sojourn in Spain opened to him a new world. His intellectual horizon began to widen with his new experiences. New ideas thronged in upon him. He came from a land which was the very home of bigotry, where the Spanish friar, the Spanish official and the Spanish soldier governed with absolute sway. But in Madrid he found the exact opposite of this repression. Free thinkers and atheists spoke freely, in disparaging terms, of religion and the church; the authority of the government he found to be at a minimum, while he not only saw liberals contending with the clerical party but he beheld with astonishment republicans and Carlists openly promoting the development of their political ideas.

Still greater was the influence upon him of his residence in France, Germany and England. In those countries he enlarged his scientific information, or it would be better, perhaps, to say that there the spirit of modern philology was revealed to him, and there he learned the meaning of the word ethnology.

The personal influence of the late Dr. Rost, of London, was most marked in the philological training of Dr. Rizal. His teachings and the study of the works of W. v. Humboldt, Jacquet and Professor H. Kern opened a new world for the Filipino scholar. He formed a plan to write a work upon the Tagalog verb, which he afterwards modified and, while in exile in Dapitan in Mindanao, he began to write a Tagalog grammar

in English and at the same time prepared an essay upon the allied elements in the Tagalog and Visayan languages. The former work he intended to dedicate to Professor Kern in the name of the Malay race, the latter he wished to inscribe to the memory of Dr. Rost. It was not granted to him to complete the manuscript of either, for he was interrupted in the midst of his work to be dragged about from tribunal to tribunal until his final sentence and death by public execution.

Fortunately his work upon the transcription of Tagalog remains to us, a translation having appeared in the *Bijdragen* of the Indian Institute. Unfortunately this work only increased the hatred of his political opponents, for the Spaniards were bitterly opposed to any independent work on the part of the Filipinos, being convinced that everything of the kind was merely a cloak for separatist views, and whoever was suspected of separatism in the Philippines was certain of meeting an unhappy fate.

Rizal, brought up among Spaniards, was no better instructed than they themselves in modern ethnology and, indeed, it was through Professor Blumentritt's instrumentality that his attention was first directed to the defects in his education in that direction, whereupon he began with ardor to enlarge his knowledge in comparative ethnology. The works upon general ethnography by Perschel, F. Müller, Waitz, Gerland and Ratzel, the ethnographical parallels of Andrée, Wilkin's works, the culture-historical publications of Lippert and Hellwald became at once the subject of his industrious and thorough study, a study, furthermore, which not only enlarged his knowledge but afforded him the consolation of the assurance that his people are not an anthropoid race as the Spaniards asserted, for he found that the faults and virtues of the Tagals are entirely human, and, moreover, he became convinced that the virtues and vices of any people are not mere peculiarities of race but are inherited qualities, qualities which become affected by climate and history.

At the same time he continued what he called his 'course in practical ethnology,' that is to say, he studied the life of the French and German peasantry because he thought that a peasantry preserves national and race peculiarities longer than the other classes of a people, and also because he believed that he ought to compare only the peasantry of Europe with his own countrymen because the latter are nearly all peasants. With this object in view he withdrew for weeks and months to some quiet village where he observed closely the daily life of the country people.

He summed up the results of his scientific and 'practical' studies in the following propositions:

1. The races of mankind differ in outward appearance and in the structure of the skeleton but not in their psychical qualities. The same

passions and pains affect the white, yellow, brown and black races; the same motives influence their action, only the form in which the emotions are expressed and the way the actions are directed are different. Neither is this particular form of conduct and expression constant with any race or people, but varies under the influence of the most diverse factors.

2. Races exist only for the anthropologists. For a student of the customs of a people there are only social strata, and it is the task of the ethnologist to separate and identify these strata. And just as we mark out the lines of stratification in the mountain ranges of a geological sketch so ought we to mark out the social strata of the human race. And just as there are mountains whose summits do not reach to the highest strata of the geological system, so there are many people who do not reach the highest social strata, while the lowest strata are common to all of them. Even in the old established civilization of France and Germany a great proportion of the population forms a class which is upon the same intellectual level with the majority of the Tagals, and is to be distinguished from them only by the color of the skin, clothing and language. But while mountains do not grow higher peoples do gradually grow up into the higher strata of civilization and this growth does not depend upon the intellectual capacity alone of a given people, but is also due, to some extent, to good fortune, and to other factors, some of which can be explained and others not.

3. Since not only the statesmen who conduct colonial affairs but scientific men as well maintain that there are races of limited intelligence who could never attain the height of European culture, the real explanation must be as follows: The higher intelligence may be compared to wealth—there are rich and poor peoples just as there are rich and poor individuals. The rich man who believes that he was born rich deceives himself. He came into the world as poor and naked as his slave, but he inherits the wealth which his parents earned. In the same way intelligence is inherited. Races which formerly found themselves compelled, by certain special conditions, to exercise their mental powers to an unusual extent, have naturally developed their intelligence to a higher degree than others, and they have bequeathed this intelligence to their descendants who, in turn, have increased it by further use. Europeans are rich in intelligence but the present inhabitants of Europe could not affirm, without presumption, that their ancestors were just as rich in intelligence at the start as they themselves are now. The Europeans have required centuries of strife and effort, of fortunate conjunctions, of the necessary liberty, of advantageous laws, and of individual leading minds, to enable them to bequeath their intellectual wealth to their present representatives. The

people who are so intelligent to-day have become so through a long process of transmission and struggle. History shows that the Romans thought no better of the Germans than the Spaniards do of the Tagals, and when Tacitus praises the Germans he does so in the same spirit of philosophical idealizing which we see in the followers of Rousseau who thought that their political ideal was realized in Tahiti.

4. The condemnatory criticism of the Filipino by Spaniards is easy to explain but appears not to be justified. Rizal demonstrates this in the following way: Weaklings do not emigrate to foreign lands but only men of energy who leave home already prejudiced against the colored races and reach their destination with the conviction, which is usually sanctioned by law, that they are called to rule the latter. If we remember, what few white men know, that the Filipinos fear the brutality of the whites, it is easy to explain why they make such a poor showing in works written by the latter while they themselves can not reply in print. If we consider, further, that the Filipinos with whom the whites have dealings belong, for the most part, to the lower strata of society, the opinions of them given by the whites have about the same value as that of an educated Tagal would have who should travel in Europe and judge all Germans and French by the dairy maids, porters, waiters and cabdrivers he might meet.

5. The misfortune of the Filipinos is in the color of their skin and in that alone. In Europe there are a great many persons who have risen from the lowest dregs of the populace to the highest offices and honors. Such people may be divided into two classes, those who accommodate themselves to their new position without pretensions, and whose origin is consequently not reckoned to them as a disgrace, but on the contrary they are respected as self-made men; and the conventional parvenus who are ridiculed and detested universally.

A Filipino would find himself ordinarily in the second of these two classes, no matter how noble his character or how perfect a gentleman he might be in his manners and conduct, because his origin is indelibly stamped upon his countenance, visible to all, a mark which always carries with it painful humiliations for the unfortunate native, since it forever exposes him to the prejudices of the whites. Everything he does is minutely criticised, a trifling error in etiquette which would be overlooked in a shoemaker's son who had acquired the title of baron, and which might easily happen to a pure-blooded descendant of the Montmorencys, in his case excites amusement, and you hear the remark 'What else can you expect? he is only a native.' But even if he does not infringe any of the rules of etiquette, and is besides an able lawyer or a skillful physician, his accomplishments are not taken as matters of course but he is regarded with a kind of good-natured surprise, a feeling much like the astonishment with which one regards

a well-trained dog in a circus, but never as a man of the same capabilities as a white man.

Another reason for the mean opinion in which the Filipinos have been held by the whites is found in the circumstance that in the tropics all the servants are colored. They have the defects of their social class and of servants everywhere. Now when a German housewife complains of her servants she does not extend their bad qualities to the whole German nation, but this is done unblushingly by Europeans who live in the tropics, and they never, apparently, feel any compunctions, but sleep the sleep of the just, undisturbed by conscience.

The merchants also have contributed to the unfavorable judgment of the Filipinos. Europeans come to the tropics in order to get rich as soon as possible, which can only be done by buying from the natives at astoundingly low rates. The latter, however, do not regard this proceeding as a really commercial one, but they believe that the whites are trying to cheat them, and they govern themselves accordingly by trying, on their side, to overreach the whites, while their dealings with one another are far more honorable. Consequently the Europeans call the natives liars and cheats while it never occurs to them that their own exploiting of the ignorance of the natives is a conscienceless proceeding, or rather they believe that, as whites, they are morally justified in dealing immorally with the natives, because the latter are colored.

Dr. Rizal finally came to think that he need no longer wonder at the prejudices of the whites against his people after he saw in Europe what unjustifiable prejudices European nations entertain against one another. He himself was always benevolent and moderate in his judgment of foreign peoples. His active and keen mind, his personal amiability, his politeness and manner as a man of the world, and his good and noble heart gained him friends everywhere, and therefore the tragic death of this intellectually distinguished and amiable man aroused general concern.

Rizal was an artist of delicate perceptions, a draughtsman and sculptor, as well as a scholar and ethnologist. Professor Blumentritt possesses three statues made by him of terra cotta, which might aptly serve as symbols of his life. One represents Prometheus bound; the second represents the victory of death over life, and this scene is imagined with peculiar originality; a skeleton in a monk's cowl bears in its arms the inanimate body of a young maiden. The third shows us a female form standing upon a death's head and holding a torch in her high uplifted hands. This is the triumph of knowledge, of the soul over death.

Rizal, concludes Professor Blumentritt, was undoubtedly the most distinguished man not only of his own people but of the Malay race in general. His memory will never die in his fatherland. He never was an enemy of Spain.

## GOLD MINING IN KLONDIKE.\*

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MY visit to Klondike took place at the end of August, 1901, at a very interesting time, and under most favorable conditions. The journey was made at the invitation of the Hon. Clifford Sifton, Canadian Minister of the Interior, and in company with Professor Coleman, of Toronto. Mr. Sifton provided us with a most efficient military escort in the person of Captain Strickland of the Northwest Mounted Police, who possesses an intimate knowledge of the far Northwestern Territory and its inhabitants. Consequently, we were able in a short visit to see a great deal and to become acquainted with the leading features of the mining industry.

The time was particularly interesting, because in 1901 the conditions of life were still to a large extent those of a young mining camp, but were undergoing rapid transformation into the social and political conditions of an organized and civilized community.

Access to Klondike is now practically confined to a single route available for the ordinary traveler. It is true that a considerable amount of merchandise is taken in by the sea and river route which consists of a voyage (from Seattle) of 2,700 miles by sea to St. Michaels at the mouth of the Yukon, followed by a voyage of 1,370 miles up that mighty river to Dawson City—a total of about 4,000 miles. But the ordinary passenger route is the following:—a sea voyage of 900 miles, up the quiet waters that lie between the islands and the mainland, from Vancouver to the little American port of Skagway; a journey of 112 miles across the coast range, by the newly constructed White Pass and Yukon railway, to the little town of White Horse on the Yukon; and a voyage of 450 miles down the Yukon from White Horse to Dawson City in a stern-wheel steamer—a journey of only 1,460 miles in all. By this route the sea voyage occupies from three to five days, the railway journey about twelve hours, and the river voyage from two to three days.

The railway climbs the icy precipices of the coast range, and crosses into Canadian territory at the summit of the famous White Pass which earned so unenviable a reputation as the scene of disasters and deaths during the great rush into the country in the winter of

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1897; and the traveler is brought down to the banks of the Yukon just low enough to escape the terrible White Horse Rapids, where also so many lives were lost in those early days. The voyage hence to Dawson is a quick one, with a stream whose average current is five miles an hour.

Dawson City, which in 1898 was only a collection of huts on a frozen mud swamp situated at the point where the Klondike River enters the Yukon, is now a town of about 10,000 inhabitants, consisting, it is true, of wooden buildings and chiefly of log cabins, but possessing hotels, clubs, theaters, saw-mills, large stores, electric light, telephones, power works and all the resources of modern civilization. New government buildings were rising at the time of my visit, and the town wore an aspect of considerable and prosperous activity.

It is interesting to watch the life of this remarkable city, situated 1,500 miles from Vancouver and close upon the Arctic circle: upon the plank sidewalks are slouch-hatted, long-booted miners who throng dance-halls and saloons and pay from pouches of gold-dust; busy merchants, traders and storekeepers of all nationalities; well-dressed ladies and children; military men, surveyors, engineers and lawyers; while in the dusty roadway are to be seen men riding long-tailed horses with Mexican saddles, driving pack-mules laden with boxes, or urging yelping teams of dogs with the cry 'mush, mush.'

Popular accounts of this country generally represent it in its winter dress of snow, and relate tales of the rigorous severities of the Arctic frost. At the time when I was there Dawson was enjoying the mild and equable climate which prevails in the summer months, when the temperature may even rise to 90° F.; no snow was visible save that which clothed the serrated peaks of the northern Rockies, and their majestic chain was only to be seen from the summit of Moosehide Mountain above Dawson, and at a distance of about 40 miles to the north. The inhabitants had begun to grow potatoes, cabbage, lettuce and other vegetables, and a considerable market garden was being laid out on the left bank of the Yukon. And yet there is one remarkable feature of the country which prevents the traveler from ever forgetting that he is close upon the Arctic circle; if a hole be dug only three feet deep at any spot in the boggy ground, it will be found permanently frozen at that shallow depth; even in Dawson itself the log cabins rest upon a foundation of ice which never thaws.

There is also a striking feature of life in Dawson which ever reminds the visitor that he is in a mining camp. He will have to pay 1s. or 2s. for a bootblack or a barber, 2s. for a glass of cow's milk, 6s. for three boiled eggs or a mutton chop, 30s. for a bottle of claret, perhaps £20 a day for the hire of a rig and team of horses. The rent of a log cabin is about £120, and a sense of economic insecurity is

inspired by the fact that the rent of a house is about half its value, and that 60 per cent. is an ordinary rate of interest for loans. Laborers' wages are £2 a day. Although almost anything required may be purchased in Dawson, all goods have been imported at great expense into a country which of itself has produced nothing but gold and wood. The freight rates on the White Pass route are about six cents a pound, and £23 a ton may be paid from Vancouver to Dawson.

The mining camp is situated to the southeast of Dawson at a distance of about thirteen miles. The productive area is about thirty miles square, and is bounded on the north by the Klondike River, on the west by the Yukon River, and on the south by the Indian River. The district is a gently undulating upland or plateau, attaining an average height of nearly 3,000 feet above the Yukon, and intersected by deep flat-bottomed valleys which radiate from its central and highest point, a rounded hill named the Dome. The valleys are separated by hog-backed ridges; the whole district is fairly thickly wooded with spruce and poplar except on the summits of the ridges; the bottoms of the valleys are occupied by flat marshy bogs, and the streams are rarely more than ten feet broad. The bog, which is from five to ten feet thick, is frozen at a short depth below the surface and keeps the underlying gravel, which may be from ten to thirty feet thick, permanently frozen right down to the bed-rock.

The principal streams are known as creeks; the short steep tributaries which flow into them as 'gulches'; and the streamlets which feed these as 'pups.' The most important creeks are from seven to ten miles in length, and are productive over perhaps half their course, so that there may be about fifty miles of richly productive gravel in the district. I was informed that one stretch of three and one half miles on El Dorado Creek produced no less than £6,000,000 of gold.

Recently constructed government roads lead from Dawson to the camp and connect the various creeks; they were being completed at the time of our visit, and were still very rough or almost impassable at some points among the creeks; numerous rudely built but fairly comfortable 'road-houses' afford lodging to the traveler. A small town of log cabins, known as Grand Forks, has sprung up at the junction of the two most famous creeks, Bonanza and El Dorado, and is inhabited by perhaps 1,200 miners and others. There is another small town named Cariboo on Dominion Creek.

The creeks no longer present the dreary appearance of bog and forest, which made them look so unpromising to the early prospectors; the hillsides have been largely stripped of their timber, and the valley bottoms are in many parts the scene of active mining operations and rendered unsightly by machinery; the mining is also carried on upon the hillsides at a height of 300 or 400 feet, where



numerous adits penetrate the white gravel, and are marked by long heaps of tailings which descend from them towards the creek.

What little is known of the geology of the Klondike district can be stated in a few words. The auriferous area is occupied by Palæozoic schists, which may be roughly distinguished as grey or green chlorite-schist and mica-schist, and a light colored or white sericite-schist. These are bounded on the north—upon the right bank of the Klondike River—by a mass of diabase and serpentine, which constitutes the Moosehide Mountain; and on the south—on the left bank of the Indian River—by a series of quartzitic slates, schists and crystalline limestones.

The auriferous creeks are entirely situated in the micaceous schists, which constitute the bed-rock everywhere. Mr. McConnel, the government geologist, regards these schists as having originated from quartz-porphry and other eruptive rocks, but they have been much crushed and altered and entirely recrystallized from their original condition. They are intersected by numerous bands and bosses of more recent eruptive rocks—quartz-porphry, rhyolite, augite-andesite, diorite, basalt, etc.—and also by numerous quartz veins. In the northern and northwestern portions of the area occupied by these Klondike schists, are both broad and narrow bands of a black graphitic schist, which can sometimes be traced across the valleys.

The veins and stringers of quartz which are so frequent throughout the district have for the most part a very barren appearance, but they are sometimes mineralized to a small extent and contain a little iron pyrites, argentiferous galena, and—very rarely—gold.

Up to the present, however, the gold has been exclusively won from the gravels in the valleys, and not from the quartz veins.

The gravels are mainly of two sorts:—(1) those which constitute the floors of the present valleys and have been laid down by the present streams; (2) those which cover terraces upon the sides of the valleys and represent old valley gravels which have been cut through by the present streams.

The gold mining was at first carried on entirely in the lower gravels, and it was in them that the precious metal was first discovered. These are sandy gravels consisting of pebbles of quartz and schist—in fact, they are made up of the same materials as the bed-rock, and contain nothing that might not have been derived from the breaking up of the rocks of the district. There is no reason to believe that they were derived from any other source, and some of the pebbles are so lightly rounded that they have clearly not traveled far. Among the minerals which I have seen from these gravels are hæmatite, rutile, pyrites, graphite, cyanite, garnet, cassiterite, epidote and tourmaline; also barytes and mispickel.

The gold is very unevenly distributed in the gravel. The richest patches of pay-gravel seem to occur about half way down the valley. In the wider portions of the valleys the pay-streak may be sometimes on one side and sometimes on the other, following no doubt the former course of the stream.

The valley gravel is generally from ten to thirty feet thick, and is overlaid by from five to fifteen feet of frozen bog, locally known as 'muck.'

The hillside gravel is a very remarkable deposit; it consists almost entirely of boulders and pebbles of quartz and of sericite-schist, and, when it is exposed to view, presents the appearance of a uniform white ledge running horizontally along the hillside at a height of about 700 feet above the level of the Klondike River. It sometimes attains a depth of 120 feet, and may be as much as half a mile wide. The pebbles are to a large extent subangular and less worn than those of the valley gravels.

The early miners of course confined their attention to the valleys, and the discovery of these rich deposits upon the hillsides excited great surprise; they now rival the valley gravel in importance. The deposit is locally known as 'white-wash' or the 'White Channel.'

The origin of the White Channel is shrouded in mystery; it was at first supposed to be a glacial deposit; but there are no striations or other signs of glacial action, and it is now the opinion of the local geologists that it was laid down by the sudden inrush of tumultuous streams acting over a small area. The materials have clearly not been transported far, and the gold is even more nuggety and less worn than that of the valleys.

One is naturally led to inquire whether all the gold of the lower gravels was not brought down by streams cutting through the White Channel which occupied the bed of the valleys when they were broad and shallow, so that the White Channel may be the real source of the gold. This view is supported by the fact just mentioned that the gold of the valleys is more worn than that of the hillside, also by the fact that the valleys are richer in their central portions, which must have been covered by the White Channel, than in the upper parts which are above the level of that deposit.

Still there is no reason to doubt that the White Channel itself is of local origin: its materials are those of the district, and have not traveled far. (There are a few gravels in this area which consist of pebbles foreign to the district, and they are not auriferous.) The White Channel itself follows the present valley courses. On the whole therefore although the origin of this peculiar deposit is obscure, there can be no doubt, in my opinion, that the conclusion forced upon us by a glance at the map is correct, and that the gold has been derived from

the limited area intersected by the auriferous creeks which radiate from the Dome.

Some of the gold adheres to quartz, which exactly resembles that of the veins in the adjoining schists; and it is fairly certain that the metal came from quartz veins in the Klondike schists.

On the other hand it is certainly most remarkable that so little auriferous quartz has been found; at the time of my visit hundreds of quartz claims had been staked, but very few had been shown to contain any gold whatever; neither do the quartz boulders of the White Channel appear to be auriferous, or even mineralized. And yet it can hardly be doubted that where the valley gravels are rich in gold above their intersection with the White Channel the metal must have been derived from quartz veins in the schists.

In one instance I found direct evidence bearing on this question. In Victoria Gulch, a streamlet which descends into El Dorado Creek on its left bank high up the valley, have been found small flat crystals of gold of peculiar shape known as 'spinel twins.' In visiting a quartz vein at the head of Victoria Gulch (near the summit of the divide between El Dorado and Bonanza creeks), which had been lately opened and found to contain visible gold, I noticed precisely similar crystals. Here, at any rate, there can be little doubt that the gold in the creek has been derived from quartz veins in the schist.

No crushing has yet been carried on in Klondike; the gold has been entirely won by washing the gravels.

The chief difficulties of Klondike mining are due to the permanently frozen ground, which has led to certain peculiarities in the methods adopted. Every yard of gravel which is sluiced must first be thawed, either by artificial means or by exposing it to the rays of the summer sun after stripping off the overlying muck; for it is impossible to work the frozen ground with pick or spade, or even with dynamite.

Until recently shafts were sunk or tunnels were driven by laboriously thawing the ground with hot stones or wood fires; and I saw both methods in operation during my visit. The latter process—fire-setting, as it is called—is, in fact, quite frequent. A layer of dry wood is piled up against the face of the gravel, blanketed behind by a layer of green wood, ignited, and allowed to burn itself out; twelve hours of burning would thaw out little more than one foot in depth; and the process is then repeated.

Upon the larger properties this method has been entirely replaced by 'steam-thawing.' In this four- to six-foot lengths of iron piping, tipped with steel nozzles, are inserted into the gravel, and steam is forced through them at a pressure of about 120 pounds. These pipes are known as 'points'; one point is inserted to about each square yard, and is driven in gradually by taps from a hammer; each point will thaw

from two to five cubic yards of gravel. As contrasted with fire-setting, the steam-thawing obviates the suffocating fumes of burning wood, or the danger of thawing the frozen roof in underground workings.

A recent innovation which I saw coming into operation was thawing with water by means of the pulsometer pump, which seems to be economical since the water can be used over and over again; this process seems likely to come into more general use.

The gravel is raised from the shaft in buckets by windlass or steam-hoists, and in winter is dumped on to heaps for summer work, or in summer may be emptied straight into the sluice-boxes.

Much ingenuity has been exercised in the construction of self-dumping hoists, in which, by a single rope, the bucket is raised from the bottom of the shaft, caught by a traveling clutch, carried along a horizontal rope to the dump-heap or the sluice-boxes, where it is automatically tilted. All this is done by an engine in charge of one man, and saves much labor.

As regards the washing of the gravel, the old-fashioned hand-rockers are still to be seen in operation upon many of the gulches, but have been for the most part replaced by sluice-boxes. These are long wooden troughs made in 12-foot lengths and about ten inches broad; the bottom is lined with wooden riffles, consisting generally of longitudinal bars (Pole riffles), but sometimes of transverse bars (Hungarian riffles), by which the gold and heavy minerals are caught. Sometimes Auger riffles—planks with circular holes—are employed; mercury is seldom used. A sluice-head of 75 miners' inches, *i. e.*, 112 cubic feet of water per minute, is usual, and a fall of about eight inches in the 12-foot box length.

Water, which is very scarce in the district, and must be used economically, is conducted to the sluice-boxes by long wooden flumes, which are themselves a serious expense on account of the cost of wood (about \$110 a thousand feet). Some of these flumes are half a mile in length; in a wide valley, where the pay-streak is on the opposite side from the stream, it is necessary to raise it by centrifugal pumps to a height of 30 or 40 feet, and to convey it across the valley by a long flume.

In the final 'wash-up,' by which the gold-dust is extracted from the sluice-boxes, the riffles are taken out, and a copious stream of water is sent down, which carries away the fine gravel and leaves the gold, and a heavy black sand which accompanies it. This black sand consists mainly of magnetic ore, and it is removed partly by a magnet and partly by shaking with the hand and blowing with the mouth in a small metal tray.

The mining operations on the creeks and upon the hillsides are somewhat different. On the creek a shaft is sunk down to bed-rock,

four lateral tunnels are driven from the shaft along the surface of the bed-rock, and opened out in a fan-like manner to the limits of the claim. The outermost portions are worked out first, and as the excavation is carried back to the shaft, the roof and overlying muck are allowed to cave in and settle down on to the bed-rock. Timbering is thus entirely avoided. This absence of timbering in the Klondike shafts and tunnels is one of the most striking features in the mining; the frozen ground requires no support—it never thaws—and chambers as much as 100 feet square are covered by an icy roof which never breaks down.

The operations in the creeks are carried on upon a very considerable scale, and there is a large amount of machinery in the country; upon some groups of claims the work is not carried on by sinking and drifting, but is more of the nature of open quarrying. Night work is prosecuted by electric light or the acetylene lamp.

Formerly the raising of the gravel and its storage in dumps were mainly carried on in the winter, and the sluicing in the summer, and enormous winter dumps were accumulated for summer work. This last year the greater part of both has been carried on simultaneously during the summer, and it seems likely that the winter work will become less usual, and may even be abandoned altogether.

The mining upon the hillside claims bears no resemblance in appearance to ordinary placer mining. Horizontal tunnels are driven into the White Channel from the face of the hill, and shafts are sunk into it from the surface in a manner that more nearly resembles the working in ordinary metalliferous lodes. In one such mine which I visited, a horizontal tunnel 700 feet in length had been driven into the gravel, and at right angles to this, and at intervals of about 60 feet, lateral tunnels were being driven to a distance of 70 feet on either side; and there were 200 feet of pay gravel above the tunnel; the men were working with pick and shovel at the end of the long tunnels, and cars of rock were being wheeled along a tramway to the head of the long wooden shoot which carried the gravel down to the creek.

In these high-bench claims, as they are called, two great difficulties are encountered: (1) the difficulty of disposing of the tailings, which cannot be allowed to slide down upon the creek claims but must be artificially banked up; and (2) the difficulty of obtaining water at this height. Both have cooperated to prevent hydraulicking, which would otherwise be the obvious way of working gravels situated upon a steep hillside.

On Hunker Creek, however, Mr. Johanson, who owns both creek and hillside claims, has, with much enterprise and at very great expense, introduced hydraulicking upon a considerable scale. The

water was here derived from a reservoir in the creek, and was raised by a 140 horse-power engine to a height of 260 feet, the level of the hillside workings, and then to an additional height of 40 feet to an elevated tank, which gives a total fall of about 60 feet available for hydraulicking. The water was conducted through a 10-inch pipe and 6-inch hose terminating in a 2½-inch nozzle. About 1,200 Canadian gallons a minute could be delivered. This enabled one man to wash out no less than 8 cubic yards per hour, and the gravel was washed straight into the sluice-boxes without the necessity for intermediate labor.

If ever water becomes more abundant and accessible in the district, there can be no doubt that hydraulicking will be largely employed.

On Bonanza Creek I witnessed another novelty in the first operations of a new dredging plant which had just been introduced, having been formerly employed on an auriferous sand bar upon the Lewes River. It is very possible that dredging will prove to be an efficient and economical way of working over some of the old claims in the creeks which have only been treated by the cruder methods of the earlier miners.

There are other introductions which were new at the time of my visit; although no crushing of quartz had then been effected, a small Tremaine mill had just been erected on the banks of the Klondike in the immediate neighborhood of Dawson, and it is to be hoped that we shall soon hear of promising results among the quartz discoveries. An auriferous conglomerate found in considerable deposits on the Indian River was attracting much attention, chiefly on account of its superficial resemblance to the South African basket.

In default of resources other than gold, the prosperity of Klondike in the immediate future appears to me to depend mainly upon the extent to which in the creeks water can be more economically and bountifully supplied, labor and the necessaries of life more cheaply obtained, and communication be made more easy, so that it may be possible to work low-grade gravel at a profit. There is much auriferous material which it does not at present pay to touch. The Government is giving every encouragement, and in Mr. Ross the Territory has a strong governor; roads have been constructed; the royalty has been reduced to 5 per cent., and on all claims \$5,000 of gold are exempt. The necessary charges are only \$10 for a miner's license, \$15 for recording a claim, \$50 for surveying, \$15 for renewal, and an owner is only required to put \$500 worth of work on to his claim each year.

But the cost of water, wood, labor and materials is almost prohibitive; the standard of living is high, although there is, I think, a

constantly increasing number of steady and thrifty men coming into the country and replacing the more gambling element of the early camp.

The ultimate prosperity of the country depends largely, I think, upon the extent to which auriferous quartz may be discovered, and other resources developed.

But it is certain that Dawson has come with the intention of staying, and that the country is very far from played out. Not only is there a considerable quantity of ground yet to be worked in the Klondike creeks, but it must be remembered that much of the vast Yukon territory is auriferous, and that attention has only been distracted from other localities by the extraordinary wealth of the Klondike area.

Now that the district possesses a large town, inhabited throughout the year, now that communication is being facilitated, that freight rates are being lowered, and that the population is increasing, it ought to be possible to open up districts that could never have been attempted under the more adverse conditions of two or three years ago.

Coal is being mined at Cliff Creek, 55 miles below Dawson, and at Five Fingers, about 200 miles above Dawson; placer copper exists in large quantities on the White River; copper ores have been found near White Horse; the Atlin district promises well; horses, cattle, and sheep will shortly be supported in the country itself, and vegetables and other produce will be raised.

It only remains to be seen whether the cost of production can be so far diminished that this far northwestern Territory will be able to compete with other regions which are more favorably situated.

That the inhabitants have the necessary enterprise and energy I know from what I have seen of them. It is, in fact, most interesting to note how in this isolated country native grit and intelligence have brought the best men to the front. One naturally associates the element of luck with placer mining, and no doubt many fortunes were made and lost by sudden strokes of chance. But in no mining district have previous experience and knowledge been of less avail. The conditions were so strange, that the old and experienced miners sometimes made the worst mistakes, and the men who succeeded were those who were sufficiently alert and intelligent to adapt themselves to the new conditions. One finds among the leading miners—men who have come from all places and from all classes of society—men who two or three years ago were workmen, hotel clerks, store assistants, or farmers.

I cannot conclude without a word of tribute to the magnificent work which has been done by the Canadian Northwest Mounted Police, and the excellent way in which the inhabitants have settled

down under their rule. A mere handful of this fine military force have sufficed to introduce law and order into the country, from the time of the great rush in 1897. The perfect quiet which prevails, and has always prevailed, on the Canadian side of the frontier contrasts most favorably with the lawless scenes that took place till recently at Skagway and other places in American territory. Even the disorderly population which migrated into Klondike seemed to lose its character on Canadian territory, and the six-shooter was no more seen.

I doubt whether any better example exists of the manner in which, in any part of the world, the finest features of British character will prevail—the firmness, good temper, and love of order which are the dominant characteristics of our most successful colonists.



A STUDY OF TWENTIETH CENTURY SUCCESS.

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SOMEONE has said, with more or less philosophical insight, that all questions resolve themselves into three classes: those of the 'What,' the 'How,' and the 'Why.' In this paper it is primarily a question of the 'How' that is considered. How have the men and women, who in the opening year of this twentieth century are prominently in the public eye, achieved the success in their various vocations which has placed them there? What have been the stepping-stones to that success? How can we follow in their footsteps? The biographies of great men have done much to answer this question, still they leave much unsaid. The tow-path and the flat-boat do not furnish nowadays the shortest route to the eminence upon which the ambitious youth has fixed his eye, and he wants more guide posts by the way.

In an attempt to discover the general route to that goal, I have studied a few facts from the lives of many, rather than many facts from the lives of a few. The basis of the study is 'Who's Who in America' for 1900. This book, of which the edition of 1900 was the first, is for America what the English volume of the same name has been for England for more than half a century, namely, an address book of living celebrities—if we give this term considerable extension—containing a brief biographical sketch of each. This includes in most cases date of birth, particulars as to schooling, present profession and address, together with any unusual accomplishment or public service. The edition of 1900 contains 8,602 names and in my study of them the first three biographical facts mentioned were considered. I shall say nothing in defense of the criterion of success which I am here taking: that is, mention in 'Who's Who.' On what constitutes real success in life probably no two of us could agree. It would, however, be acceded by all who are familiar with the book, that although it fails to mention many who are as worthy a place in its pages as are some who appear there, it is nevertheless true that each whom it has mentioned has attained a degree of eminence which warrants the assertion that, at least before the public, success has crowned his efforts to a degree not achieved by the ordinary run of mankind.

Whatever success may mean, it would be safe to say that it depends upon two things: nature and nurture. On the nature side of the

problem, we find no help in 'Who's Who' since ancestry is not included. On the nurture side, which would mean education in its broadest sense, we find facts descriptive of certain phases only, namely those of the schools. How important a place they take in the education of the individual can never be determined with any degree of exactness, but even with a full recognition of the force of the home, the church, the state and the vocation, it must be conceded that their influence as an organized educational machine is very great. Facts bearing upon this influence are the ones principally furnished by 'Who's Who' and, together with those of age, the only ones considered here.

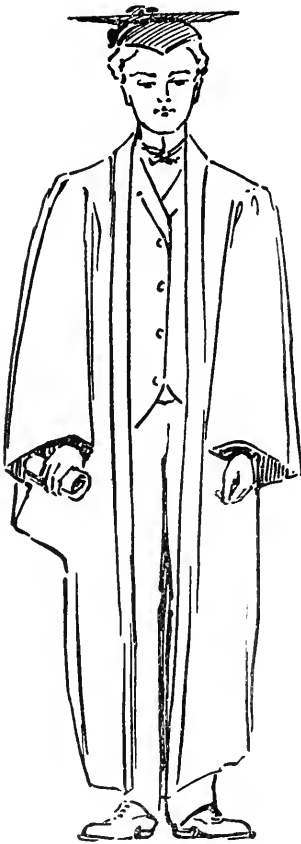


FIG. 1.

A mention of 8,602 names in the volume in question means, if we assume that every inhabitant of the United States above the age of twenty-one was eligible to such mention, that one in each six hundred was so honored. This then, would be our ratio of success for all degrees of education—good, bad and indifferent. We find, however, that of the whole number mentioned, 3,237 had received the bachelor's degree in arts, literature, science or philosophy at some college or university. But a study of the alumni lists of such institutions shows us that after the commencement season of 1899 there were 334,000 living graduates. A comparison of the number mentioned in the book (3,237) with this whole number alive shows us that one college graduate in each one hundred and six found a place. Here then we have the ratio of



success for college graduates. But to carry our process of comparison one step farther: taking 1:600 as the ratio of success (the 'Who's Who' kind) for the adult

American, and 1:106 as that for the college graduate, we find that the probability of success is increased more than 5.6 times by a college education. This relation is shown graphically in Fig. 1. This tremendous advantage can probably not be attributed entirely to the direct educational effect of such a training, but, to a considerable extent, to the selective influence of the course. Of the whole number of pupils who

enter the elementary schools, but a very small percentage continues to the completion of the college course. This comparatively small number of persisters does not fairly represent what our educational machinery could have done with the entire number who started at the bottom, but what that machinery can do with the kind nature had endowed with sufficient energy, determination and persistence to enable them to withstand the temptations to drop out one by one by the way and take a seemingly short cut to some *ignus fatuus* of success, but who continue to the end. There is here shown undoubtedly with considerable force the potency of the law of the survival of the fittest, if we take as our criterion of fitness mention in 'Who's Who.' This, however, does not invalidate the fact that the college course, either because of its educational or selective influence, increases largely, perhaps to the extent we have shown, the probability that the graduate will gain a favorable place in the public eye.

A classification of the names in the book which forms the basis of our study, in terms of the various professions and vocations, gives us the following numbers for the twenty-four which seem to form the most natural divisions. *Actor*: male 54, female 40. *Artist*, including illustrators: male 260, female 21. *Author*, including writer, historian, novelist and poet: male 528, female 272. *Business*, including the various mercantile pursuits: male 200. *Clergyman*, including bishop, rabbi, missionary, priest, salvation army and monk: male 655, female 7. *College professor*, including president, dean and chancellor: male 1,090, female 11. *Congressman* (both senate and house): 446. *Editor*, including journalist, critic, correspondent and reporter: male 509, female 13. *Educator*, including superintendent, teacher, philanthropist and reformer: male 188, female 30. *Engineer*, including architect and miner: male 284. *Financier*, including capitalist and banker: male 215. *Inventor*: male 26. *Lawyer*, including justice, judge and jurist: male 857, female 4. *Lecturer*: male 21, female 6. *Librarian*: male 362, female 9. *Musician*, including singer: male 111, female 21. *Physician*: male 540, female 7. *Railroad official*: male 102. *Sailor*: 103. *Scientist*, including naturalist: male 416, female 7. *Soldier*: 205. *Statesman*, including governor, diplomat, politician and mayor: 202. *U. S. official*: male, 98, female 1. *Miscellaneous*, running all the way from farmer to insurance president: male 53, female 2. The sum of these figures does not quite equal 8,602, the number which, as has already been stated, the book mentions, since a comparatively small number who failed to give the year of birth were not included in the study.

One question, among others, which the young person about to choose a profession is apt to consider is this: How long will it take to get a foothold? How many years of hard sledding before the

smooth road is reached? Both ambition and pocket are interested in the answer and without doubt many a young man has been influenced in his choice of profession by his conclusion on this matter. The data at my command throw light only indirectly on this question, but more directly on another. How long must I wait for eminence, if it ever comes, and in what profession may I expect it earliest? If there be any fixed relation between a foothold and success, then the former question may be answered by inference. A tabulation of the ages of each of the eight thousand and more individuals of both sexes for the vocations mentioned above (with the exception of a few less frequently chosen) is shown graphically in Figs. 2 and 3. The former is for males and the latter for females, though the gentler sex was a competitor of sufficient strength to warrant consideration in seven only. In each of the figures the vocations are indicated at the bottom. Of the two heavy vertical lines (ordinates) above each vocation, the one at the left indicates by its height the percentage of the whole number

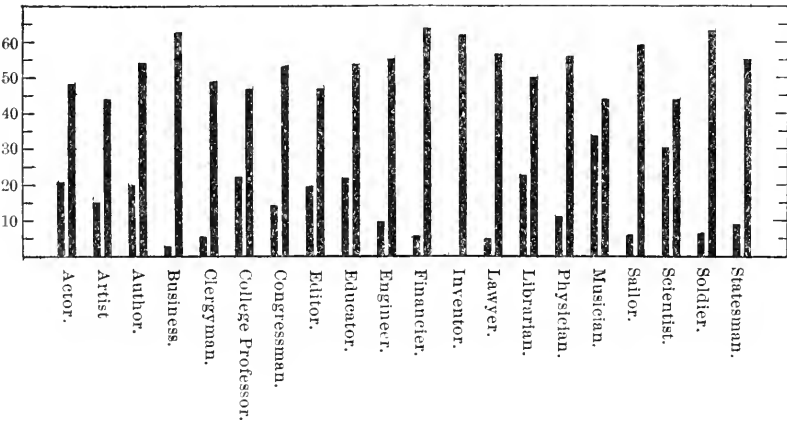


FIG. 2.

mentioned who were below forty years of age; in other words, the percentage of young men and women who had achieved eminence in it, if we may assume that a person is young until he is forty. The ordinate at the right of each pair shows in a similar manner by its height the average age in years of all those mentioned for the vocation indicated below. In each case the ordinates are to be read by means of the scales at the left and right of the figure: the *youth* ordinate in percentages and that for *age* in years, although the figure is so drawn that the same scales apply to both. These figures show then, as fully as an inductive study based upon a limited number of data will permit, (1) the relative probability of achieving early distinction in the various professions, (2) the average ages of persons of distinction in those professions, (3) a basis of comparison for the two sexes.

An inspection of Fig. 2 from the standpoint of the first of these possibilities (noting only the *left* of each pair of ordinates) shows at a glance that the musician distances all competitors in the race for distinction. This is not hard to understand when we recall the infant prodigies who frequently figure on our bill boards, or consider that nature has in most cases contributed more largely to his success than has nurture. Of those callings which presuppose a professional or at least an extended preparation, that of scientist seems from our figure to promise the earliest recognition. This is perhaps due to the fact that for him the actual work of life is entered with a completer intellectual equipment than by most of the others, and that the period of preparation offers opportunities for research and original investigation which may bring renown even before life work is begun. This would also apply to the college professor with perhaps fully as much force and in a lesser degree to the librarian and the educator. These four then might be included in a class in which the period of preparation is extended, but for which work of a high order might be expected immediately on its completion and positions of some prominence aspired to from the start. Next in the race for renown come the actor and the author, almost neck and neck. If we concluded that nature had most to do with the musician's success and nurture with the educator's we should be forced to place the author and the actor in a class in which those two forces divide the honors more evenly. No doubt one must be born an actor or an author to rise to a high rank, but after all, the making process is not to be despised as a factor, and this takes time. Except for the soldier and the sailor, whose ability to rise to prominence, at least in time of peace, is determined by the rapidity with which those above him are retired from service, and the congressman and the statesman, whose minimum limit is prescribed by law, the rest of the vocations shown upon the chart fall, it seems to me, into a class for which the schools, as organized means of education, provide no adequate preparation and for which that preparation must come, to a great extent, from the vocation itself. As an illustration of what I mean: the scientist, or even the college professor, who has devoted thirty years of life to study, can enter his profession from the top, while the business man and financier, for whom the accumulation of wealth is a desideratum, or the lawyer and the doctor, who must command a practice, or the minister, who needs a congregation, must, with the same period of intellectual infancy, enter it from the bottom and devote a few more years to the climbing process. In so far as the physician is an investigator the conditions of the scientist apply to him and no doubt the considerable number who are such accounts for the fact that his recognition comes earlier than that of his competitors in law and the pulpit. The surprising thing of the figure is perhaps the slowness with

which the inventor gains a foothold on the ladder to fame. Not one of those mentioned was below the age of forty, though not enough names were included to give this fact great weight.

A study of Fig. 2 from the standpoint of average ages of those mentioned (note only the *right* ordinate of each pair) discloses little which would not have been expected from the facts already stated. It will be seen that where recognition was early, the average age is comparatively small, while for those vocations in which the climb was a tedious one, the age is much greater. Certainly one whose ambition was early renown would not, from the showing of our figures, choose business or finance. Since, however, these professions are seldom entered for glory, we need not fear a lack of aspirants for the rewards which they bring. When nature has done most for the man as in the case of the actor, author and musician the laurel crown comes earliest. If one must depend upon nurture as most of us must, the scientist, the college professor, the editor, the educator and the clergyman may hope to wear it longest and in the order given.

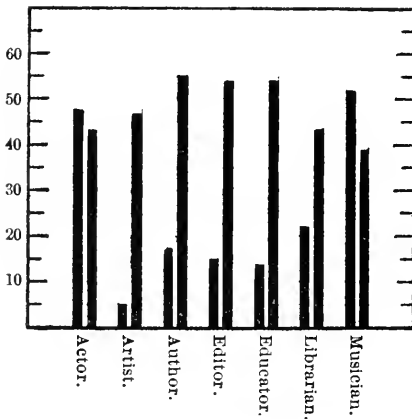


FIG. 3.

As has been stated, Fig. 3 shows for women the conditions which have just been discussed for men, for those callings in which they have been to any extent competitors. It shows that upon the stage and in musical circles recognition is much earlier for them, while in the other callings it is slower than for their brothers. In other words, nature works quicker with her and nurture slower, if our figures are to be accepted.

It is perhaps worthy of mention too, that the two professions in which she outstrips him are the only ones in which attractiveness of person would be at a premium; perhaps at so much of a premium as to make up for some other defects. When, however, this is outlived with youth the struggle seems to be a hard if not a losing one.

We have now to consider the educational preparation of the persons whose names are included under the several vocations. This so far as it has to do with the schools—the only data at our disposal—is shown by the somewhat complicated-looking Figs. 4 and 5, the former for the men and the latter for the women. Upon each of them the vocations are indicated at the bottom as in those just explained. Of the variously constructed ordinates above each name, that part which is wholly black

shows by its height the percentage of those named for that vocation who mentioned no schooling above the elementary or secondary grade. This would probably mean in most cases that the educational preparation was carried no farther. That portion of the ordinate which has heavy black lines at the sides shows in the same manner the percentage of those mentioned who had received the baccalaureate degree at some college or university; that portion having a heavy line in the center, the percentage who had completed a professional course; that portion which has the heavy lines both at the side and in the middle, the percentage who had pursued both the college and professional course; the portion between the top of the ordinate and the horizontal line at the top of the figure, the percentage educated entirely abroad, and the little line extending out from some of the ordinates, by its distance from the base line, the percentage who had taken some postgraduate degree. Honorary degrees are not included. In every case, the per-

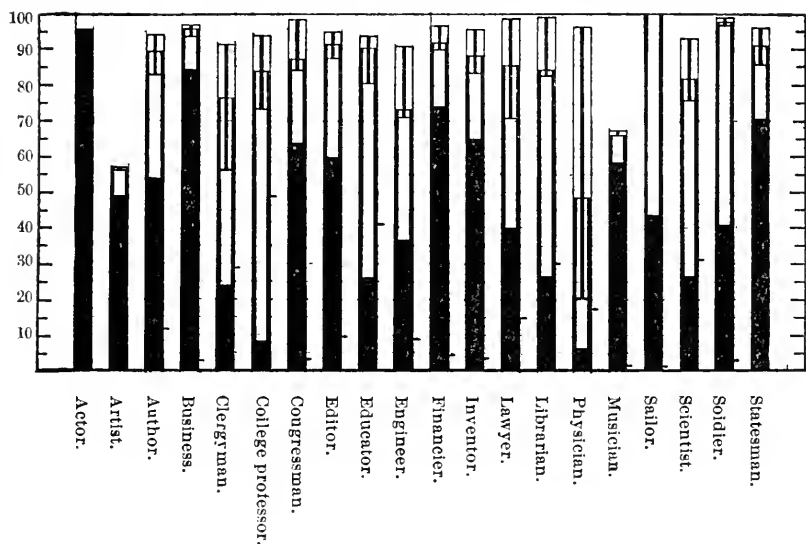


FIG. 4.

centages are to be read by means of the scale at the right and left of the figure. As an illustration of the interpretation of one of the ordinates I will take that for clergymen: 24 per cent. are shown to have no education above the high school (black portion), 52 per cent. have a college education (heavy side lines  $76 - 24 = 52$ ), 35 per cent. have a professional education, presumably, the divinity school (heavy middle line  $91 - 56 = 35$ ), 20 per cent. have both (heavy side and middle lines  $76 - 56 = 20$ ), 9 per cent. were educated entirely abroad and were presumably largely foreigners (distance between top of ordinate and top of figure,  $100 - 91 = 9$ ), 28 per cent. had taken a postgraduate degree

(distance between base line and small mark at right of ordinate). The ordinates for each of the other professions may be interpreted in the same manner. The data in my possession make possible the study of various other combinations of educational courses, as well as comparisons of them for persons of different ages showing the educational trend, but lack of space prevents a discussion of these facts in the present paper. I will say, however, that the figures do not show combinations of training abroad with that in our home institutions. The spaces on the figures which have to do with training abroad refer only to those persons who failed to make any use whatever of home institutions, at least above high school.

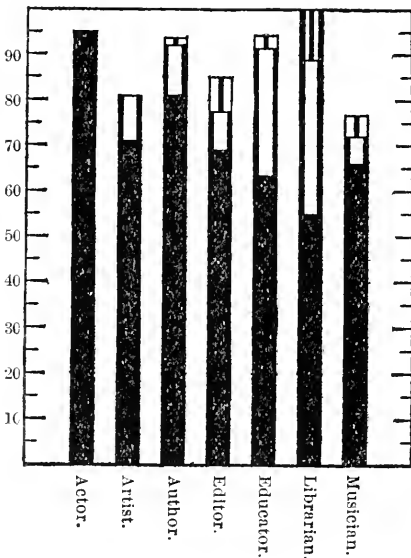


FIG. 5.

Figures 4 and 5 then show (1) the educational preparation of persons of both sexes for the various professions and (2) a basis of comparison between the two. They answer, too, a very important question: "What kind of preparation has proved most essential to that kind of success which mention in 'Who's Who' means?" They have nothing to do with the question, 'What kind of preparation must the doctor, or the lawyer, or the minister have to be a doctor, or a lawyer, or a minister,' but what kind is most likely to put him in the class of doctors, and lawyers, and ministers who achieve eminence.

In other words, we are studying selected persons in each profession, but since every man and woman of proper ambition who enters a profession hopes to be one of those selected, the problem has a wide bearing.

In the discussion of the figures which follows I shall, for the sake of directness and with full recognition of the fact that the two are not synonymous, speak of those under each profession whose education stopped with the high school (black portion of the ordinates) as *uneducated*. Of this class the actor shows by far the greatest number—so large that we could hardly advise the young person with histrionic ambition to go to college merely as an aid to public recognition in his art. There may be other inducements for him, but seemingly not that.

Business seems to offer the next largest inducement to the uneducated; 84 per cent. of its devotees belong to that class. Twelve per



cent. had, however, completed the college course, and this in my opinion is enough to invalidate the arguments of C. P. Huntington and others against such training for business men. We have no means of knowing just how many of our business men throughout the country have taken the college course, but computed roughly, one man in about 300 of all grades and stations in life has been so educated. Since this includes mill operatives and other classes in which such training is practically unknown, we must assume that the ratio would be much larger for the business man. Yet it seems to me that even a most generous estimate could not bring it up to one in eight—that of our business men of eminence—and we should be forced to conclude that the college course has even for him, remote as the connection seems to be, been a contributor to his success. This argument would also apply to the financier, who comes next with his 18 per cent. of college graduates. Our statesmen, the next class, and the congressmen, who differ but little, are hardly to be congratulated on their showing. Thus one may say that with our whole male citizenship eligible to those positions of honor—the boast of our republic—whose ratio of college training is one to 300, while that for the eminent man of these two classes is about one to five as shown by our figure, the probability of gaining such honorable mention is increased about sixty-fold for these our law-makers and diplomats by the college course, an increase which is not to be despised by those who aim at these high places at popular disposal. This too for college conditions in which departments of finance and special facilities for diplomatic training have not played so important a part as they are likely to in the future. Although artists and musicians seem to be uneducated classes we must not neglect the fact shown by the figure that large numbers (43 per cent. and 33 per cent. respectively) were educated abroad, where undoubtedly they were spending their time to better advantage than could have been done in any college at home. Next after the sailor and the soldier, whose heavy black lines upon the figure bear testimony to the efficiency of our national academies for the training of officers on land and sea, comes, in our descending scale of learnedness, the lawyer. His educational showing, when compared with that of the sister professions of medicine and theology, is not a favorable one. With 40 per cent. of the shining lights of our legal fraternity innocent either of professional training or of academic instruction beyond the high school, we wonder what the education of the lesser lights may be and whether really much education is essential to success. The records of the bar examination in the various states are so kept, or rather so not kept, as to make it impossible to ascertain the previous training of those admitted, so I am unable to show these facts for the rank and file of the profession. The reports of the U. S. Commissioner of Education, however, show that for the last twenty years 27 per cent.

of the students registered in the law schools of our country had already taken the bachelor's degree in some academic institution. This may then be taken as the percentage of lawyers throughout the country who have had the liberal training of the college course. But of our eminent lawyers the percentage so trained is forty-six, implying that the college educated lawyer's chances of being counted among the immortals of 'Who's Who' are nearly doubled. This relationship is more exactly shown in Fig. 6. Without discussing the engineer, the librarian, the scientist or the educator, whose educational conditions are shown and for whom no further comparisons can be made, the clergyman comes in for his share in the analysis. In his case we find about one fourth are uneducated, one half with college education and one third, that of

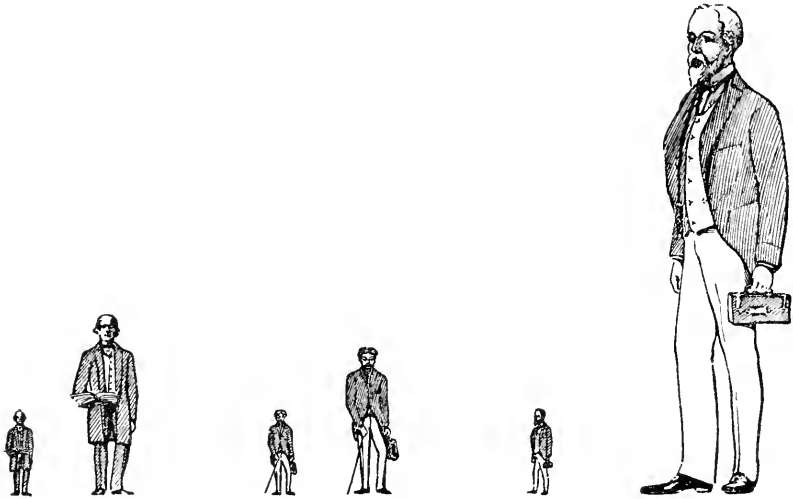


FIG. 6.

the professional school. For him too we have only the figures of the U. S. Commissioner as a basis of comparison. Of the divinity school students of our land we there find that 24.7 per cent. have taken a college degree. But of the 'Who's Who' clergy, 53.3 per cent. had been so rewarded. The premium which a comparison of these two puts upon the college bred minister is also shown in Fig. 6 and is one not to be disregarded by the aspirant for pulpit honor. On the score of post-graduate attainments the clergyman is shown to be an industrious worker.

The banner professions, so far as educational accomplishments are concerned, are seen to be those of college instruction and medicine, with the showing slightly in favor of the latter if we disregard post-graduate honor, in which the college men easily outrank all others. These, too, have made more extensive use of opportunities for study

abroad in connection with the home training, though this fact is not shown in the figure, nor is another fact of interest, namely, that they have made the most rapid improvements in their intellectual equipment as shown by a study by decades for the last sixty years. We have, however, no data upon which to base a comparison of the 'rank' with the 'file.'

For the physicians we can only rely once more upon the Commissioner of Education. He states that 7.5 per cent. of the medical students of the country have taken the academic degree. Yet we find—*mirabile dictu*—that 42 per cent. of the 'Who's Who' physicians have been recipients of that degree. Nearly six times as many of the 'rank' as of the 'file' (see Fig. 6). It seems hardly probable that the college training can be at such a premium in the actual practice of the medical man, so it seems to me we must conclude that it is as a scientist and a producer that such a training counts for most. The scientific societies of the physician undoubtedly stimulate more of their members to original research and investigation, and consequently to a greater productiveness, than do similar organizations among clergymen and lawyers, and it is here that the broader training would count for most. We must, in any event, from the facts disclosed by our study, conclude that of the three generally recognized learned professions, the medical leads in the breadth and perfection of its educational preparation.

A study of the education of women, based upon Fig. 5, is disappointing, and from it we are forced to one of two conclusions: either (1) that women can attain an eminence equal to that of men, with less dependence upon educational machinery, or (2) that the compilers of the book upon which our study is based have made use of a different and lower criterion in judging them. In the case of no one of the vocations shown upon the figure was her training so complete as was that of her male competitor for honors, and the same was true for the limited number of doctors, lawyers and ministers mentioned for the sex. In no one of the vocations, except that of the stage, was the difference so slight as to leave any doubt on the question. The most discouraging thing about it too, as disclosed by a study by decades but not shown upon any of the figures, is that for recent years, when institutions of nearly all classes have been as freely open to woman as to man, there seems to be no change for the better. Her educational inertia, due very naturally to centuries lacking in opportunity, is not easily thrown off, and, until it is—a time which seems not yet to have arrived—she can not take her place with man in the professional world, even should she consider it as properly her sphere.

## THE PANAMA ROUTE FOR A SHIP CANAL.\*

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THE Panama route as a line of transit across the isthmus was established, as near as can be determined, between 1517 and 1520. The first settlement, at the site of the town of old Panama, six or seven miles easterly of the present city of that name, was begun in August, 1517. This was the Pacific end of the line. The Atlantic end was finally established in 1519 at Nombre de Dios, the more easterly port of Acla, where Balboa was tried and executed, having first been selected but subsequently rejected.

The old town of Panama was made a city by royal decree from the throne of Spain in September, 1521. At the same time it was given a coat of arms and special privileges were conferred upon it. The course of travel then established ran by a road well known at the present time through a small place called Cruces on the River Chagres, about seventeen miles distant from Panama. It must have been an excellent road for those days. Bridges were even laid across streams and the surface was paved, although probably rather crudely. According to some accounts it was only wide enough for use by beasts of burden, but some have stated that it was wide enough to enable two carts to pass each other.

The harbor of the Atlantic terminus at Nombre de Dios did not prove entirely satisfactory and Porto Bello, westerly of the former point, was made the Atlantic port in 1597 for this Isthmian line of transit. The harbor of Porto Bello is excellent and the location was more healthful, yet Porto Bello itself was subsequently abandoned, largely on account of its unhealthiness.

As early as 1534 or soon after that date boats began to pass up and down the Chagres river between Cruces and its mouth on the Caribbean shore, and thence along the coast to Nombre de Dios and subsequently to Porto Bello. The importance of the commerce, which sprang up across the isthmus and in connection with this Isthmian route, is well set forth in the last paragraph on page 28 of the report of the Isthmian Canal Commission:

The commerce of the isthmus increased during the century and Panama became a place of great mercantile importance, with a profitable trade extending to the Spice Islands and the Asiatic coast. It was at the height of its

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\* The substance of this paper has been delivered as a lecture by the author and will soon be published in a series of lectures on civil engineering.

prosperity in 1585, and was called with good reason the toll-gate between western Europe and eastern Asia. Meanwhile the commerce, whose tolls only brought such benefits to Panama, enriched Spain, and her people were generously rewarded for the aid given by Ferdinand and Isabella in the effort to open a direct route westward to Cathay, notwithstanding the disadvantages of the isthmian transit.

This commercial prosperity suggested to those interested in it, and soon after its beginning, the possibility of a ship canal to connect the waters of the two oceans. It is stated even that Charles V. directed that survey should be made for the purpose of determining the feasibility of such a work as early as 1520.

The governor, Paseual Andagoya, reported that such a work was impracticable and that no king, however powerful he might be, was capable of forming a junction of the two seas or of furnishing the means of carrying out such an undertaking.

From that time on the city of Panama increased in wealth and population in consequence of its commercial importance. Trade was established with the west coast of South America and with the ports on the Pacific coast of Central America. In spite of the fact that it was made by the Spaniards a fortress second in strength in America only to old Cartagena it was sacked and burned by Morgan's buccaneers in February, 1671. The new city, that is the present city, was founded in 1673, it not being considered advisable to rebuild on the old site.

The project of a canal on this route was kept alive for more than three centuries by agitation, sometimes active, and sometimes apparently dying out for long periods until there was organized in Paris in 1876 a company entitled 'Société Civile Internationale du Canal Interocéanique,' with Gen. Etienne Turr as president, for the purpose of making surveys and explorations for a ship canal between the two oceans on this route.

The work on the isthmus for this company was prosecuted under the direction of Lieut. L. N. B. Wyse, a French Naval Officer, and he obtained for his company in 1878 a concession from the Columbian Government conferring the requisite rights and privileges for the construction of a ship canal on the Panama route and the authority to do such other things as might be necessary or advisable in connection with that project. This concession is ordinarily known as the Wyse concession.

A general plan for this transisthmian canal was the subject of consideration at an international scientific congress convened in Paris in May, 1879, and composed of 135 delegates from France, Germany, Great Britain, the United States and other countries with a majority from France. This Congress was convened under the auspices of Ferdinand de Lesseps, and after remaining in session for two weeks a decision, not unanimous, was reached that an interoceanic canal

ought to be located on the Panama route, and that it should be a sea level canal without locks. The fact was apparently overlooked that the range between high and low tides in the Bay of Panama, about twenty feet, was so great as probably to require a tidal lock at that terminus.

A company entitled 'Compagnie Universelle du Canal Interocéanique' was organized with Ferdinand de Lesseps as president, immediately after the adjournment of the international congress. The purpose of this company was the construction and operation of the canal, and it purchased the Wyse concession from the original company for the sum of 10,000,000 francs. An immediate but unsuccessful attempt was made to finance the company in August, 1879. This necessitated a second attempt, which was made in December, 1880, with success, as the entire issue of 600,000 shares of 500 francs each was sold. Two years were then devoted to examinations and surveys and preliminary work upon the canal, but it was 1883 before operations upon a large scale were begun. The plan adopted and followed by this company was that of a sea level canal affording a depth of 29.5 feet and a bottom width of 72 feet. It was estimated that the necessary excavation would amount to 157,000,000 cu. yds.

The Atlantic terminus of the canal route was located at Colon and at Panama on the Pacific side. The line passed through the low ground just north of Monkey Hill to Gatun, six miles from the Atlantic terminus, and where it first met the Chagres River. For a distance of twenty-one miles it followed the general course of the Chagres to Obispo, but left it at the latter point and passing up the valley of a small tributary cut through the continental divide at Culebra and descended thence by the valley of the Rio Grande to the mouth of that river where it enters Panama Bay. The total length of this line from 30 ft. depth in the Atlantic to the same depth in the Pacific was about 47 miles. The maximum height of the continental divide on the center line of the canal in the Culebra cut was about 333 ft. above the sea, which is a little higher than the lowest point of the divide in that vicinity. Important considerations in connection with the adjacent alignment made it advisable to cut the divide at a point not its lowest.

Various schemes were proposed for the purpose of controlling the floods of the Chagres River, the suddenness and magnitude of which were at once recognized as among the greatest difficulties to be encountered in the construction of the work. Although it was seriously proposed at one time to control this difficulty by building a dam across the Chagres at Gamboa that plan was never adopted, and the problem of control of the Chagres floods remained unsolved for a long period.

It was estimated by de Lesseps in 1880 that eight years would be required for the completion of the canal, and that its cost would be \$127,600,000. The company prosecuted its work with activity until

the latter part of 1887 when it became evident that the sea level plan of canal was not feasible with the resources at command. Changes were soon made in the plans, and it was concluded to expedite the completion of the canal by the introduction of locks, deferring the change to a sea-level canal until some period when conditions would be sufficiently favorable to enable the company to attain that end. Work was prosecuted under this modified plan until 1889, when the company became bankrupt and was dissolved by judgment of the French Court, called the Tribunal Civil de la Seine, on February 4, 1889. An officer called the liquidator, corresponding quite closely to a receiver in this country, was appointed by the court to take charge of the company's affairs. At no time was the project of completing the canal abandoned, but the liquidator gradually curtailed operations and finally suspended the work on May 15, 1889.

He determined to take into careful consideration the feasibility of the project, and to that end appointed a 'commission d'études,' composed of eleven French and foreign engineers, headed by Inspector-General Guillemain, director of the *École Nationale des Ponts et Chaussées*. This commission visited the isthmus and made a careful study of the entire enterprise, and subsequently submitted a plan for the canal involving locks. The cost of completing the entire work was estimated to be \$112,500,000, but the sum of \$62,100,000 more was added to cover administration and financing, making a total of \$174,600,000. This commission also gave an approximate estimate of the value of the work done and of the plant at \$87,300,000, to which some have attached much more importance than did the commission itself. The latter appears simply to have made the 'estimate' one half of the total cost of completing the work added to that of financing and administration, as a loose approximation, calling it an 'intuitive estimate'; in other words, it was simply a guess, based upon such information as had been gained in connection with the work done on the isthmus.

By this time, the period specified for completion under the original Wyse Concession had nearly expired. The liquidator then sought from the Colombian Government an extension of ten years, which was granted under the Colombian law dated December 26, 1890. This extension was based upon the provision that a new company should be formed and work on the canal resumed not later than February 28, 1893. The latter condition was not fulfilled, and a second extension was obtained on April 4, 1893, which provided that the ten-year extension of time granted in 1890 might begin to run at any time prior to October 31, 1894, but not later than that date. When it became apparent that the provisions of this last extension would not be carried out an agreement between the Colombian Government and the new Panama Company was entered into on April 26, 1900, which extended

the time of completion to October 31, 1910. The validity of this last extension of time has been questioned.

A new company, commonly known as the new Panama Canal Company, was organized on October 20, 1894, with a capital stock of 650,000 shares of 100 francs each. Under the provisions of the agreement of December 26, 1890, authorizing an extension of time for the construction of the canal, 50,000 shares passed as full paid stock to the Colombian Government, leaving the actual working capital of the new Panama Company at 60,000,000 francs, that amount having been subscribed in cash. The most of this capital stock was subscribed for by certain loan associations, administrators, contractors and others against whom suits had been brought in consequence of the financial difficulties of the old company, it having been charged, in the scandals attending bankruptcy proceedings, that they had profited illegally. Those suits were discontinued under agreements to subscribe by the parties interested to the capital stock of the new company. The sums thus obtained constituted more than two thirds of the 60,000,000 francs remaining of the share capital of the new company after the Colombian Government received its 50,000 shares. The old company had raised by the sale of stock and bonds not far from \$246,000,000, and the number of persons holding the securities thus sold has been estimated at over 200,000.

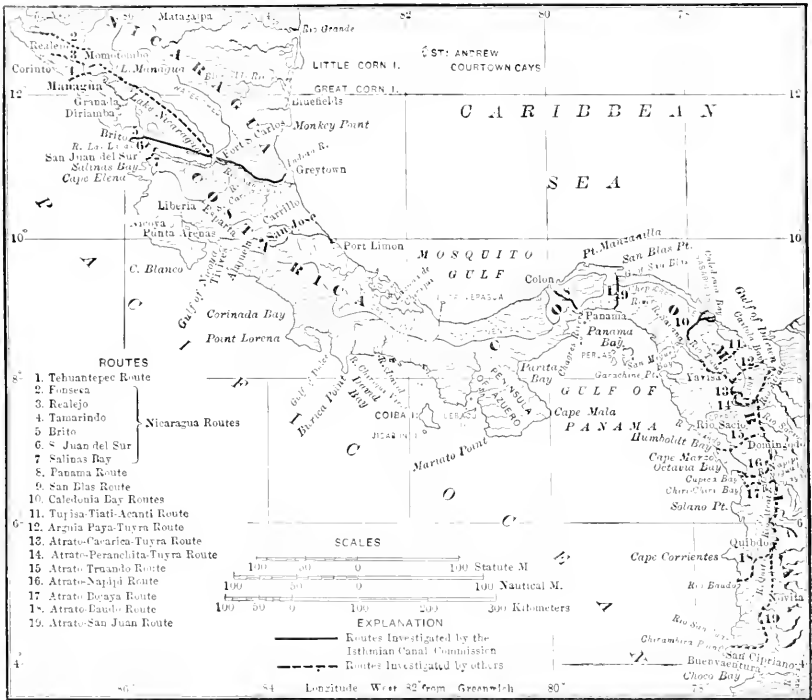
The Panama Railroad Company holds a concession from the Colombian Government, giving it rights prior to those of the Wyse Concession, so that the latter could not become effective without the concurrence of the Panama Railroad Company. This is shown by the language of Article III. of the Wyse Concession, which reads as follows:

If the line of the canal to be constructed from sea to sea should pass to the west and to the north of the imaginary straight line which joins Cape Tiburon with Garachine Point the grantees must enter into some amicable arrangement with the Panama Railroad Company or pay an indemnity, which shall be established in accordance with the provisions of law 46 of August 16, 1867, 'approving the contract celebration on July 5, 1867, reformatory of the contract of April 15, 1850, for the construction of an iron railroad from one ocean to the other through the Isthmus of Panama.'

It became necessary therefore in order to control this feature of the situation for the old Panama Company to secure at least a majority of the stock of the Panama Railroad Company. As a matter of fact the old Panama Canal Company purchased nearly 69,000 out of the 70,000 shares of the Panama Railroad Company, each such share having a par value of \$100. These shares of Panama railroad stock are now held in trust for the benefit of the new Panama Canal Company. A part of the expenditures of the old company therefore covered the cost of the Panama Railroad Company's shares, now held in trust for the benefit of the new company.



Immediately after its organization the new Panama Canal Company resumed the work of excavation in the Emperor and Culebra cuts with a force of men which has been reported as varying between 1,900 and 3,600. It also gave thorough consideration to the subject of the best plan for the completion of the canal. The company's charter provided for the appointment of a special engineering commission of five members by the company and the liquidator to report upon the work done and the conclusions to be drawn from its study. This report

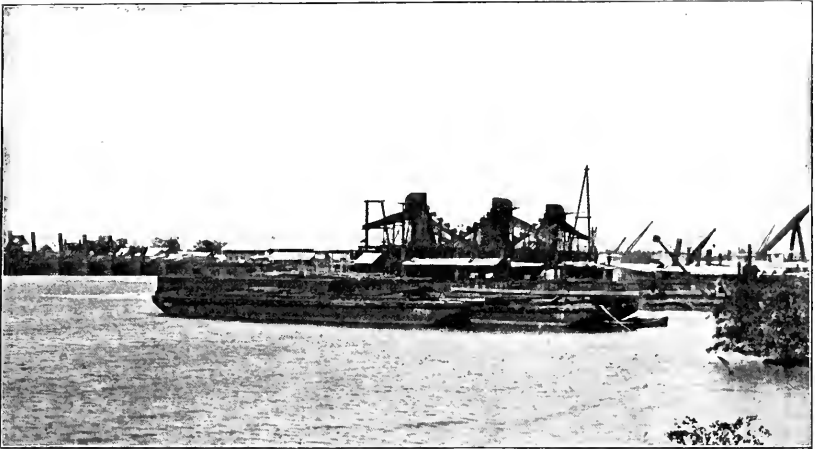


MAP OF CENTRAL AMERICA AND THE ISTHMUS.

was to be rendered when the amount expended by the new company should reach about one half of its capital. At the same time the company also appointed a 'Comité Technique,' constituted of fourteen eminent European and American engineers, to make a study of the entire project, which was to avail itself of existing data and the results of such other additional surveys and examinations as it might consider necessary. The report rendered by this committee was elaborate, and it was made November 16, 1898. It was referred to the statutory commission of five, to which reference has already been made, which commission reported in 1899 that the canal could be constructed within the limits of time and money estimated. On December 30, 1899, a

special meeting of the stockholders of the new company was called, but the liquidator, who was one of the largest stockholders, declined to take part in it, and the report consequently has not received the required statutory consideration.

The plan adopted by the company placed the minimum elevation of the summit level of the canal at 97.5 ft. above the sea and the maximum at 102.5 ft. above the same datum. It provided for a depth of 29.5 ft. of water and a bottom width of canal prism of about 98 ft., except at special places where this width was increased. A dam was to be placed near Bohio, which would thus form an artificial lake with its surface varying from 52.5 to 65.6 ft. above the sea. Under this plan there would be a flight of two locks at Bohio, about sixteen miles from the Atlantic end of the canal, and another flight of two locks at Obispo



OLD DREDGES NEAR COLON.

about fourteen miles from Bohio, thus reaching the summit level; a single lock at Paraiso, between six and seven miles from Obispo; a flight of two locks at Pedro Miguel, about 1.25 miles from Paraiso, and finally a single lock at Mira Flores, a mile and a quarter from Pedro Miguel, bringing the canal down to the ocean elevation. The location of this line was practically the same as that of the old company. The available length of each lock chamber was 738 ft., while the available width was 82 ft., the depth in the clear being 32 ft. 10 in. The lifts were to vary from 26 to 33 ft. It was estimated that the cost of finishing the canal on this plan would be \$101,850,000, exclusive of administration and financing.

In order to control the floods of the Chagres River, and to furnish a supply of water for the summit level of the canal, a dam was planned to be built at a point called Ahajuela, about twelve miles from Obispo,

from which a feeder about ten miles long, partly an open canal and partly in tunnels or pipe, would conduct the water from the reservoir thus formed to the summit level.

Although the plan, as described, was adopted, the 'Comité Technique' apparently favored a modification by which a much deeper excavation through Culebra Hill would be made, thus omitting the locks at both Obispo and Paraiso, and making the level of the artificial lake Bohio the summit level of the canal. In this modified plan the bottom of the summit level would be about 32 feet above the sea, and the minimum elevation of the summit level 61.5 feet above the sea. This modification of plan had the material advantage of eliminating both the Obispo and Paraiso locks. The total estimated cost of completing the canal under this plan was about \$105,500,000. Although the Alhajuela feeder would be omitted, the Alhajuela reservoir would be retained as an agent for controlling the Chagres floods and to form a reserve water supply. The difference in costs of these two plans was comparatively small, but the additional time required to complete that with the lower summit level was probably one of the main considerations in its rejection by the committee having it under consideration.

This brings the project up to the time when the Isthmian Canal Commission was created in 1899 and when the forces of the new Panama Canal Company were employed either in taking care of the enormous amount of plant bequeathed to it by the old company or in the great excavation at Emperador and Culebra. The total excavation of all classes, made up to the time when that commission rendered its report, amounted to about 77,000,000 cu. yds.

The work of the commission consisted of a comprehensive and detailed examination of the entire project and all its accessories, as contemplated by the new Panama Canal Company, and any modifications of its plans either as to alignment, elevations or subsidiary works, which it might determine advisable to recommend. In the execution of this work it was necessary among other things to send engineering parties on the line of the Panama route for the purpose of making such surveys and examinations as might be necessary to confirm estimates of the new Panama Canal Company as to quantities, elevations or other physical features of the line selected, or required in modifications of alignment or plans. In order to accomplish this portion of its work the commission placed five working parties on the Panama route with twenty engineers and other assistants and forty-one laborers.

The commission adopted for the purposes of its plans and estimates the route selected by the new Panama Canal Company, which is essentially that of the old company. Starting from the six-fathom contour in the harbor of Colon the line follows the low marshy ground adjoin-

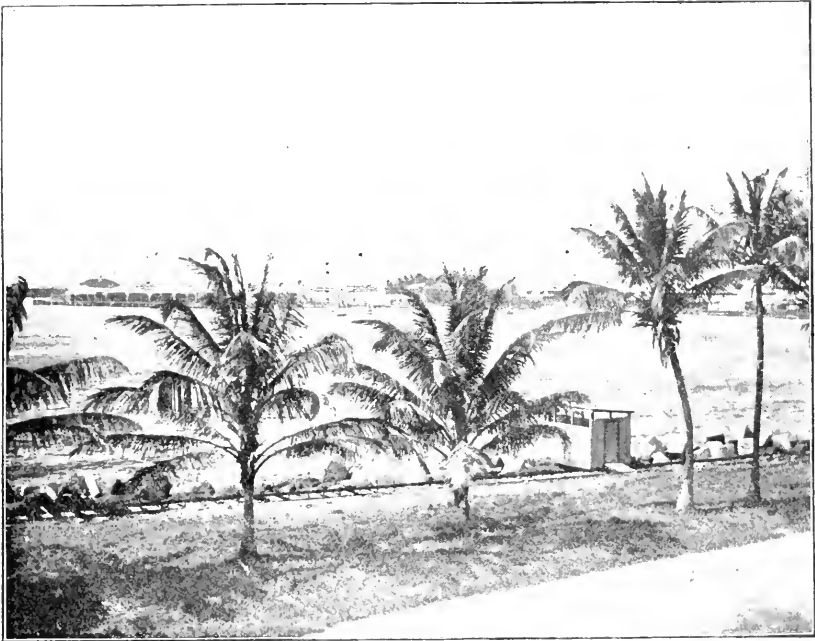
ing the Bay of Limon to its intersection with the Mindi River; thence through the low ground continuing to Gatun, about six miles from Colon, where it first meets the Chagres River. From this point to Obispo the canal line follows practically the general course of the Chagres River, although at one point in the marshes below Bohio it is nearly two miles from the farthest bend in the river at a small place called Ahorca Lagarto. Bohio is about seventeen miles from the Atlantic terminus and Obispo about thirty miles. At the latter point the course of the Chagres River, passing up stream, lies to the northeast, while the general direction of the canal line is southeast toward Panama, the latter leaving the former at this location. The canal route follows up the general course of a small stream, called the Camacho, for a distance of nearly five miles where the continental divide is found, and in which the great Culebra cut is located about thirty-six miles from Colon and thirteen miles from the Panama terminus. After passing through the Culebra cut the canal route follows the course of the Rio Grande River to its mouth at Panama Bay. The mouth of the Rio Grande where the canal line is located, is about a mile and a half westerly of the city of Panama. The Rio Grande is a small, sluggish stream throughout the last six miles of its course, and for that distance the canal excavation would be made mostly in soft silt or mud.

Although the line selected by the French company is that adopted by the Isthmian Canal Company for its purposes a number of most important features of the general plan have been materially modified by the commission, as will be easily understood from what has already been stated in connection with the French plans.

The feasibility of a sea-level canal but with a tidal lock at the Panama end was carefully considered by the commission, and an approximate estimate of the cost of completing the work on that plan was made. In round numbers this estimated cost was about \$250,000,000, and the time required to complete the work would probably be nearly or quite twice that needed for the construction of a canal with locks. The commission therefore adopted a project for the canal with locks. Both plans and estimates were carefully developed in accordance therewith.

The harbor of Colon has been fairly satisfactory for the commerce of that port, but it is open to the north and there are probably two or three days in every year during which northers blow into the harbor with such intensity that ships anchored there must put to sea in order to escape damage. The western limit of this harbor is an artificial point of land formed by material deposited by the old Panama Canal Company; it is called Christoph Colomb and near its extreme end are two large frame residences built for de Lesseps. The entrance to the canal is immediately south of this artificial point. The commission

projected a canal entrance from the six fathom contour in the Bay of Limon, in which the harbor of Colon is found, swinging on a gentle curve 6,560 feet radius to the left around behind the artificial point just mentioned and then across the shore line to the right into the low land southerly of Colon. This channel has a width of 500 ft. at the bottom, with side slopes of one on three, except on the second curve, which is somewhat sharper than the first, where the bottom width is made 800 ft. for a length of 800 ft. for the purpose of a turning basin. This brings the line into the canal proper, forming a well-protected harbor for nearly a mile inside of the shore line. The distance from



HARBOR OF COLON.

the six fathom line to this interior harbor is about two miles. The total cost of constructing the channel into the harbor and the construction of the harbor itself is \$8,057,707, and the annual cost of maintenance is placed at \$30,000. The harbor would be perfectly protected from the northers, which occasionally blow with such intensity in the Bay of Limon, and it could be made in all weathers by steam vessels seeking it.

The harbor at the Pacific end of the channel where it joins Panama Bay is of an entirely different character in some respects. The Bay of Panama is a place of light winds. Indeed it has been objected that the difficulties sometimes experienced by sailing vessels in finding

wind enough to take them out of Panama Bay are so serious as to constitute a material objection to the location for a ship canal on the Panama route. This difficulty undoubtedly exists at times, but the simple fact is to be remembered that Panama was a port for sailing ships for more than two hundred years before a steamship was known. The harbor of Panama, as it now exists, is a large area of water at the extreme northern limit of the bay, immediately adjacent to the City of Panama, protected from the south by the three islands of Perico, Naos and Culebra. It has been called a roadstead. There is good anchorage for heavy draft ships, but for the most part the water is shallow. With the commission's requirement of a minimum depth of water of 35 feet, a channel about four miles long from the mouth of the Rio Grande to the six-fathom line in Panama Bay must be excavated. This channel would have a bottom width of 200 feet with side slopes of one on three where the material is soft. Considerable rock would have to be excavated in this channel. At 4.41 miles from the six fathom line is located a wharf at the point called La Boca. A branch of the Panama Railroad Company runs to this wharf, and at the present time deep draft ships lie up alongside of it and take on and discharge cargo, as do the trains of the Panama Railroad Company. This wharf is a steel framed structure, founded upon steel cylinders, carried down to bedrock by the pneumatic process. Its cost was about \$1,284,000. The total cost of this excavated channel, leading from Panama Harbor to the pier at La Boca, is estimated by the commission at \$1,464,513. As the harbor at Panama is considered an open roadstead, it requires no estimate for annual cost of maintenance.

Starting from the harbor of Colon the prism of the canal is excavated through the low and for most part marshy ground to the little village called Bohio. The prism would cut the Chagres River at a number of points, and would require a diversion channel from that river for a distance of about five miles on the westerly side of the canal. Levees or protective embankments would also be required on the same side of the canal between Bohio and Gatun, the Chagres River leaving the canal line at the latter point on its way to the sea.

The principal engineering feature of the entire route is found at Bohio; it is the great dam across the Chagres River at that point, forming Lake Bohio, the summit level of the canal. The new Panama Canal Company located this dam at a point about seventeen miles from Colon, and designed to make it an earth structure suitably paved on its faces, but without any other masonry feature. Some borings had been made along the site and test pits were also dug by the French engineers. It was the conviction of the Isthmian Canal Commission, however, that the character of the proposed dam might be affected by

a further examination of the sub-surface material at the site. Consequently the boring parties of the commission sunk a large number of bore holes at six different sections or possible sites along the river in the vicinity of the French location. These borings revealed great irregularity in the character and disposition of the material below the bed and banks of the river. In some places the upper stratum of material was almost clear clay, and in other places clear sand, while all degrees of admixture of clay and sand were also found. At the French site the bedrock at the deepest point was found 143 ft. below sea level, with large masses of pervious and semi-pervious sand, gravel, and mixtures of those materials with clay. Apparently there is a geological valley in the rock along the general course of the Chagres River in this vicinity filled with sand, gravel and clay, irregularly distributed and with all degrees of admixture, large masses in all cases being of open texture and pervious to water. The site adopted by the commission for the purpose of its plans and estimates is located nearly half a mile down the course of the river from that selected by the new Panama Canal Company. The geological valley is nearly 2,000 ft. wide at this location, but the deepest rock disclosed by the borings of the commission is but 128 ft. below sea-level. The actual channel of the river is not more than 150 ft. wide and lies on the extreme easterly side of the valley. The easterly or right bank of the river at this place is clean rock and rises abruptly to an elevation of about 40 ft. above the river surface at ordinary stages. The left or westerly bank of the river is compact clay and sand and rises equally as abruptly as the rocky bank of the other side, and to about the same elevation. From the top of the abrupt sandy clay bank a plateau of rather remarkable uniformity of elevation extends for about 1,200 ft. in a southwesterly direction to the rocky hill in which the Bohio locks would be located. The rock slope on the easterly or northerly bank of the river runs down under the sandy river bed, but at such an inclination that within the limits of the channel the deepest rock is less than 100 ft. below sea-level.

After the completion of all its examinations and after a careful study of the data disclosed by them, the commission deemed it advisable to plan such a dam as would cut off absolutely all possible sub-surface flow or seepage through the sand and gravel below the river surface. It is to be observed that such a sub-surface flow might either disturb the stability of an earth dam or endanger the water supply of the summit level of the canal or both. The plan of dam finally adopted by the commission for the purposes of its estimates is shown by the accompanying plans and sections. A heavy core wall of concrete masonry extends from bed rock across the entire geological valley to the top of the structure, or to an elevation of 100 ft. above sea-level, thus absolutely closing the entire valley against any possible flow. The thickness of this wall

at the bottom is 30 ft., but at an elevation of 30 ft. below sea-level its sides begin to batter at such a rate as to make the thickness of the wall 8 ft. at its top. On either side of this wall are heavy masses of earth embankment of selected material properly deposited in layers with surface slopes of one on three. As shown by the plans the lower portions of the core wall of this dam would be sunk to bed rock by the pneumatic process, the joints between the caissons being closed and sealed by concrete and by cylinders sunk in recesses or wells, also as shown by the plans.

The profile of this route shows that the summit-level would have an ordinary elevation of 85 ft. above the sea, but it may be drawn down for uses of the canal to a minimum elevation of 82 ft. above the same datum. On the other hand, under circumstances to be discussed later, it may rise during the floods of the Chagres to an elevation of 90 or possibly 91 or 92 ft. above the level of the sea. The top of the dam therefore would be from 8 to 10 ft. above the highest possible water surface in the lake, which is sufficient to guard against wash or overtopping of the dam by waves. The total width of the dam at its top would be 20 ft., and the entire inner slope would be paved with heavy rip-rap suitably placed and bedded.

This dam would create an artificial lake having a superficial area during high water of about 40 sq. miles. The water would be backed up to a point called Alhajucla, about twenty-five miles up the river from Bohio. For a distance of nearly fourteen miles, *i. e.*, from Bohio to Obispo, the route of the canal would lie in this lake. Although the water would be from 80 to 90 ft. deep at the dam, for several miles below Obispo it would be necessary to make some excavation along the general course of the Chagres in order to secure the minimum depth of 35 ft. for the navigable channel.

The feature of Lake Bohio of the greatest importance to the safe and convenient operation of the canal is that by which the floods of the River Chagres are controlled or regulated. That river is but little less than 150 miles long, and its drainage area, as nearly as can be estimated, contains about 875 sq. miles. Above Bohio its current moves some sand and a little silt in times of flood, but usually it is a clear water stream. In low water its discharge may fall to 350 cubic feet per second.

As is well known, the floods of the Chagres have at times been regarded as almost if not quite insurmountable obstacles to the construction of a canal on this line. The greatest flood of which there is any semblance of a reliable record is one which occurred in 1879. No direct measurements were made, but it is stated with apparent authority that the flood elevation at Bohio was 39.3 ft. above low water. If the total channel through which the flood flowed at that time had been as large as at present, actual gaugings or measurements of subsequent floods



show that the maximum discharge in 1879 might have been at the rate of 136,000 cu. ft. per second. As a matter of fact the total channel section in that year was less than it is at the present time. Hence if it be assumed that a flood of 140,000 cu. ft. per second must be controlled an error on the safe side will be committed. Other great floods of which there are reliable records are as follows:

- 1885—Height at Bohio 33.8 ft. above low water.
- 1888—Height at Bohio 34.7 ft. above low water.
- 1890—Height at Bohio 32.1 ft. above low water.
- 1893—Height at Bohio 28.5 ft. above low water.

The maximum measured rate of the 1890 flood was 74,998 cu. ft. per second, and that of 1893, 48,975 cu. ft. per second. It is clear therefore that a flood flow of 75,000 cu. ft. per second is very rare, and that a flood of 140,000 cu. ft. per second exceeds that of which we have any record for practically forty years.

It is obvious that the dam, as designed by the commission, is of such a character that no water must be permitted to flow over its crest, or even in immediate proximity to the downstream embankment. Indeed it is not intended by the Commission that there shall be any waste way or discharge anywhere near the dam. At a point about three miles southwest of the site of the dam at Bohio is a low saddle or notch in the hills near the headwaters of a small stream called the Gigante River. The elevation of this saddle or notch is such that a solid masonry weir with a crest 2,000 ft. long may readily be constructed with its foundation on bed rock without deep excavation. This structure is called the Gigante Spillway, and all surplus flood waters from the Chagres would flow over it. The waters discharged would flow down to and through some large marshes, one called Pena Blanca and another Agua Clara before rejoining the Chagres. Inasmuch as the canal line runs just easterly of those marshes it would be necessary to protect it with the levees or embankments to which allusion has already been made. These embankments are neither much extended nor very costly for such a project. The protection of the canal would be further aided by a short artificial channel between the two marshes, Pena Blanca and Agua Clara, for which provision is made in the estimates of the commission. After the surplus waters from the Gigante Spillway pass these marshes they again enter the Chagres River or flow over the low, half-submerged country along its borders, and thence through its mouth to the sea near the town of Chagres about six miles northwest of Gatun.

The masonry crest of the Gigante Spillway would be placed at an elevation of 85 ft. above the sea, identically the same as that which may be called the normal summit level of the canal. It is estimated that the total uses of water in the canal added to the loss by evaporation taken

at six inches in depth per month from the surface of the lake will amount to about 1,070 cu. ft. per second if the traffic through the canal should amount to 10,000,000 tons per annum in ships of ordinary size. This draft per second is the sum of 406 cu. ft. per second for lockage, 207 for evaporation, 250 for leakage at the lock gates and 200 for power and other purposes, making a total of 1,063, which has been taken as 1,070 cu. ft. per second. The amount of storage in Lake Bohio between the elevations of 85 and 82 ft. above sea-level, as designed, is sufficient to supply the needs of that traffic in excess of the smallest recorded low-water flow of the Chagres River during the dry season of a low rainfall year. The lowest monthly average flow of the Chagres on record at Bohio is 600 cu. ft. per second for March, 1891, and for the purposes of this computation that minimum flow has been supposed to continue for three months. This includes a sensible margin of safety. In not even the driest year therefore can it be reasonably expected that the summit level of the canal would fall below the elevation of 82 ft. until the total traffic of the canal carried in ships of the present ordinary size shall exceed 10,000,000 tons. If the average size of ships continues to increase, as will probably be the case, less water in proportion to tonnage will be required for the purposes of lockage. This follows from the fact that with a given tonnage the greater the capacity of the ships the less the number required, and consequently the less will be the number of lockages made.

On the other hand it can be shown that with a depth of five feet of water on the crest of the Gigante Spillway the discharge of that weir 2,000 ft. long will be at the rate of 78,260 cu. ft. per second. If the flood water of the Chagres should flow into Lake Bohio until the head of water on the crest of the Gigante weir rises to 7.5 ft. the rate of discharge over that weir would be 140,000 cu. ft. per second, which, as already shown, exceeds at least by a little the highest flood rate on record. The operation of Lake Bohio as a flood controller or regulator is therefore exceedingly simple. The flood waters of the Chagres would pour into the lake and immediately begin to flow over the Gigante weir, and continue to do so at an increasing rate as the flood continues. The discharge of the weir is augmented by the increasing flood and decreases only after the passage of the crest of the flood wave. No flood even as great as the greatest supposable flood on record can increase the elevation of the lake more than 92 to 92.5 ft. above sea-level, and it will only be at long intervals of time that floods will raise that elevation more than about 90 ft. above sea level. The control is automatic and unfaillingly certain. It prevents absolutely any damage from the highest supposable floods of the Chagres, and reserves in Lake Bohio all that is required for the purposes of the canal and for wastage by evaporation through the lowest rainfall season. The floods

of the Chagres, therefore, instead of constituting the obstacle to construction and convenient maintenance of the canal heretofore supposed are deprived of all their prejudicial effects and transformed into beneficial agents for the operation of the waterway.

The highest floods are of short duration, and it can be stated as a general law that the higher the flood the shorter its duration. The great floods which it is necessary to consider in connection with the maintenance and operation of this canal would last but a comparatively few hours only. The great flood flow of 140,000 cu. ft. per second would increase the current in the narrowest part of the canal below Obispo to possibly 5 ft. per second for a few hours only, but that is the only inconvenience which would result from such a flood discharge. That velocity could be reduced by additional excavation.

Inasmuch as this system of control, devised and adopted by the Isthmian Canal Commission, is completely effective in regulating the Chagres floods, the reservoir proposed to be constructed, by the new Panama Canal Company at Alhajuela on the Chagres about twelve miles above Obispo, is not required, and the cost of its construction would be avoided. It could, however, as a project be held in reserve. If the traffic of the canal should increase to such an extent that more water would be needed for feeding the summit level the dam could be built at Alhajuela so as to impound enough additional water to accommodate, with that stored in Lake Bohio, at least five times the 10,000,000 annual traffic already considered. Its existence would at the same time act with substantial effect in controlling the Chagres floods and relieve the Gigante Spillway of a corresponding amount of duty.

The locks on the Panama route are designed to have the same dimensions as those in Nicaragua, as was stated in the lecture on that route. The usable length is 740 ft. and the clear width 84 ft. They would be built chiefly of concrete masonry while the gates would be of steel, and of the mitre type.

The great dam at Bohio raises the water surface in the canal from sea-level in the Atlantic maritime section to an ordinary maximum of 90 ft. above sea-level; in other words, the maximum ordinary total lift would be 90 ft. This total lift is divided into parts of 45 ft. each. There is therefore a flight of two locks at Bohio, indeed there are two flights side by side as the twin arrangement is designed to be used at all lock sites on both routes. The general dimensions and the arrangements of these locks with the requisite culverts and other features are shown in the accompanying plans and sections. They are not essentially different from other great modern ship canal locks. The excavation for the Bohio locks is made in a rocky hill against which the south-westerly end of the proposed Bohio dam rests and they are less than one thousand feet from it.

After leaving Bohio Lake, at Obispo, a flight of two locks is found at Pedro Miguel, about 7.9 miles from the former or 21.5 miles from Bohio. These locks have a total ordinary maximum lift of 60 ft., divided into two lifts of 30 ft. each. The fifth and last lock on the route is at Miraflores. The average elevation of water between Pedro Miguel and Miraflores is 30 ft. above mean sea-level. Inasmuch as the range of tide between high and low in Panama Bay is about 20 ft. the maximum lift at Miraflores is 40 ft. and the minimum about 20. The twin locks at Miraflores bring the canal surface down to the Pacific Ocean level, the distance from those locks to the six-fathom curve in Panama Bay being 8.45 miles. There are therefore five locks on the Panama route, all arranged on the twin plan, and, as on the Nicaragua route, all are founded on rock.

Near Obispo a pair of guard gates are arranged 'so that if it should become necessary to draw off the water from the summit cut the level of Lake Bohio would not be affected.'

An unprecedented concentration of heavy cutting is found between Obispo and Pedro Miguel. This is practically one cut although the northwesterly end toward Obispo is called the Emperador while the deepest part at the other end, about three miles from Pedro Miguel, is the great Culebra cut with a maximum depth on the center line of the canal of 286 ft. On page 93 of the Isthmian Canal Commission's report is the following reference to the material in this cut:

There is a little very hard rock at the eastern end of this section, and the western two miles are in ordinary materials. The remainder consists of a hard indurated clay, with some softer material at the top and some strata and dikes of hard rock. In fixing the price it has been rated as soft rock, but it must be given slopes equivalent to those in earth. This cut has been estimated on the basis of a bottom width of 150 feet, with side slopes of one on one.

When the old Panama Canal Company began its excavation in this cut considerable difficulty was experienced by the slipping of the material outside of the limits of the cut into the excavation, and the marks of that action can be seen plainly at the present time. This experience has given an impression that much of the material in this cut is unstable, but that impression is erroneous. The clay which slipped in the early days of the work was not drained, and like wet clay in numerous places in this country it slipped down into the excavation. This material is now drained and is perfectly stable. There is no reason to anticipate any future difficulty if reasonable conditions of drainage are maintained. The high faces of the cut will probably weather to some extent, although experience with such clay faces on the isthmus indicates that the amount of such action will be small. As a matter of fact the material in which the Culebra cut is made is stable and will give no sensible difficulty in maintenance.

(*To be continued.*)

## PRINCETON IN THE NATION'S SERVICE.\*

BY PRESIDENT WOODROW WILSON,  
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I HAVE no laboratory but the world of books and men in which I live; but I am much mistaken if the scientific spirit of the age is not doing us a great disservice, working in us a certain great degeneracy. Science has bred in us a spirit of experiment and a contempt for the past. It has made us credulous of quick improvement, hopeful of discovering panaceas, confident of success in every new thing.

I wish to be as explicit as carefully chosen words will enable me to be upon a matter so critical, so radical as this. I have no indictment against what science has done: I have only a warning to utter against the atmosphere which has stolen from laboratories into lecture rooms and into the general air of the world at large. Science—our science—is new. It is a child of the nineteenth century. It has transformed the world and owes little debt of obligation to any past age. It has driven mystery out of the Universe; it has made malleable stuff of the hard world, and laid it out in its elements upon the table of every classroom. Its own masters have known its limitations; they have stopped short at the confines of the physical universe; they have declined to reckon with spirit or with the stuffs of the mind, have eschewed sense and confined themselves to sensation. But their work has been so stupendous that all other men of all other studies have been set staring at their methods, imitating their ways of thought, ogling their results. We look in our study of the classics nowadays more at the phenomena of language than at the movement of spirit; we suppose the world which is invisible to be unreal; we doubt the efficacy of feeling and exaggerate the efficacy of knowledge; we speak of society as an organism and believe that we can contrive for it a new environment which will change the very nature of its constituent parts; worst of all, we believe in the present and in the future more than in the past, and deem the newest theory of society the likeliest. This is the disservice scientific study has done us: it has given us agnosticism in the realm of philosophy, scientific anarchism in the field of politics. It has made the legislator confident that he can create, and the philosopher sure that God cannot. Past experience is discredited, and the laws of matter are supposed to apply to spirit and the make-up of society.

\* Concluding part of the oration at the Princeton Sesquicentennial Exercises. Reprinted from *The Forum* for December, 1896.

Let me say once more, this is not the fault of the scientist; he has done his work with an intelligence and success which cannot be too much admired. It is the work of the noxious, intoxicating gas which has somehow got into the lungs of the rest of us from out of the crevices of his workshop—a gas, it would seem, which forms only in the outer air, and where men do not know the right use of their lungs. I should tremble to see social reform led by men who had breathed it; I should fear nothing better than utter destruction from a revolution conceived and led in the scientific spirit. Science has not changed the laws of social growth or betterment. Science has not changed the nature of society, has not made history a whit easier to understand, human nature a whit easier to reform. It has won for us a great liberty in the physical world, a liberty from superstitious fear and from disease, a freedom to use nature as a familiar servant; but it has not freed us from ourselves. It has not purged us of passion or disposed us to virtue. It has not made us less covetous or less ambitious or less self-indulgent. On the contrary, it may be suspected of having enhanced our passions, by making wealth so quick to come, so fickle to stay. It has wrought such instant, incredible improvement in all the physical setting of our life, that we have grown the more impatient of the un-reformed condition of the part it has not touched or bettered, and we want to get at our spirits and reconstruct them in like radical fashion by like processes of experiment. We have broken with the past and have come into a new world.

Can any one wonder, then, that I ask for the old drill, the old memory of times gone by, the old schooling in precedent and tradition, the old keeping of faith with the past, as a preparation for leadership in days of social change? We have not given science too big a place in our education, but we have made a perilous mistake in giving it too great a preponderance in method over every other branch of study. We must make the humanities human again; must recall what manner of men we are; must turn back once more to the region of practicable ideals.

Of course, when all is said, it is not learning, but the spirit of service, that will give a college place in the public annals of the Nation. It is indispensable, it seems to me, if it is to do its right service, that the air of affairs should be admitted to all its class-rooms. I do not mean the air of party politics, but the air of the world's transactions, the consciousness of the solidarity of the race, the sense of the duty of man toward man, of the presence of men in every problem, of the significance of truth for guidance as well as for knowledge, of the potency of ideas, of the promise and the hope that shine in the face of all knowledge. There is laid upon us the compulsion of the National life. We dare not keep aloof and closet ourselves while a nation comes

to its maturity. The days of glad expansion are gone; our life grows tense and difficult; our resource for the future lies in careful thought, providence and wise economy; and the school must be of the Nation.

I have had sight of the perfect place of learning in my thought, a free place and a various, where no man could be and not know with how great a destiny knowledge had come into the world—itsself a little world; but not perplexed, living with a singleness of aim not known without; the home of sagacious men, hard-headed and with a will to know, debaters of the world's questions every day and used to the rough ways of democracy; and yet a place removed—calm Science seated there, recluse, ascetic, like a nun, not knowing that the world passes, not caring, if the truth but come in answer to her prayer; and Literature, walking within her open doors, in quiet chambers, with men of olden time, storied walls about her, and calm voices infinitely sweet: here 'magic casements, opening on the foam of perilous seas, in fairy lands forlorn,' to which you may withdraw and use your youth for pleasure; there windows open straight upon the street, where many stand and talk, intent upon the world of men and business. A place where ideals are kept in heart in an air they can breath; but no fool's paradise. A place where to hear the truth about the past and hold debate about the affairs of the present, with knowledge and without passion: like the world in having all men's life at heart, a place for men and all that concerns them; but unlike the world in its self-possession, its thorough way of talk, its care to know more than the moment brings to light; slow to take excitement, its air pure and wholesome with a breath of faith; every eye within it bright in the clear day and quick to look toward heaven for the confirmation of its hope. Who shall show us the way to this place?

## THE ANTILLEAN VOLCANOES.

BY DR. W J MCGEE,

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IN all ages volcanoes have played a prominent rôle in human thought. The Vulcan of classic mythology was but the head of a family of earth-gods born of the polytechnic Mediterranean mind fertilized by the "burning mountains" of continents conjoined in the Levant; and in the still lower stages of human development represented by scores of surviving tribes, Fire-Earth deities head the primitive pantheons—indeed, the Vulcanian notion seems to run back to a pristine stage in which the forerunners of living races first stole Vulcan's torch, tamed capricious and ferocious fire even as other [to them] beasts were tamed, and thus took the initial step in that nature-conquest by which man rose above lower life. Certain it is that Vulcanian myths are most dominant in lower savagery, feebler albeit sharper-cut about the birth-time of writing, and decadent during the period of written history. Naturally a factor in the eclipse of Vulcan was the dispersion of mankind, largely in accordance with preconceived plans, from the volcanic centers in which fire was first enslaved over volcano-free regions in which the new servant was thrallied by new devices; and it is significant that not only the beast-gods of the prime but the later nature-deities, like Jove and Pluto, Thor and Odin, were swept away before the tide of self-confidence raised by nature-conquest. So Vulcan and the rest lost their terrors; they even fell into oblivion like the beast-gods before, save as the chaff of concepts caught in the meshes of scripture. Most of the mythic monsters are gone utterly; yet Vulcan dies hard—and now and then the nature power for which he stands rises above all human might, and tempts men to return to that early stage of thought marked by the personification of powers.

The latest Vulcanian throes have caught the attention of the reading world. Measured by volume of material cast out, or by force of explosions, the recent Antillean outbreaks rank below many others on record—far below the stupendous outbursts of later geologic periods; yet measured by mortality, the eruption of Mont Pelee on the morning of May 8, 1902, ranks among the most appalling catastrophes of history. And never before was news of disaster so quickly spread; quick thinkers jotted the details, and cables and swift ships carried them to every country within a few hours—yet not so speedily but that history's brightest example of practical sympathy overtook the echoes



of calamity. The prompt charity was not emotional merely, but a material outpouring of national substance; and it was no less rational, as attested by the presence on the relief ships of a corps of scientific students whose aim was to dispense knowledge with food and apparel, and to acquire better knowledge against future emergencies. Measured merely by mortality, Mont Pelee marks one of the darkest chapters in human history; measured by the upwelling of human sympathy, it stands for one of the brightest chapters; and measured by the prompt and effective inauguration of research, it must be said to open a new chapter in vulcanology.

The destruction of St. Pierre on the morning of May 8 was one of a series of episodes closely connected in time if not in cause. The chain began with eruptions from the long quiescent crater of Colima (western Mexico) late last year; then followed a series of earthquakes in Mexico and Central America, culminating in the shocks which wrecked Guatemala City and ruined Quetzaltenango on April 18; this shock was apparently followed immediately by steam spits from the crater of Mont Pelee (the culminating mountain mass of Martinique), which had been quiet since 1851, and also from La Souffriere, the commanding crater of the island of St. Vincent, which had rested since 1812. The steam puffs grew in magnitude, and before the end of April there were several explosions, accompanied by rumblings and tremblings of the earth, in which jets of mud were shot into the air and swept far a-sea by the trade-winds; while the warm springs and solfataras (or souffrieres) on Martinique and other islands displayed unwonted activity. The manifestations increased during the early days of May, and Professor Landes, of the Lycée de St. Pierre, detected gases of subterranean origin in the air and erupted material, and sent a note of danger to the Colonial Governor of Martinique. Most unhappily lulled by the memory of the innocent eruption of 1851, the official enjoined secrecy, and appointed a commission of inquiry, whose report did much to allay apprehension and keep St. Pierre crowded for the approaching holocaust. On May 5 there was a destructive eruption from Mont Pelee; clouds of rock-powder were blown high in the air, the rivers overflowed with scalding floods and a stream of hot mud engulfed a sugar factory—L'Usée Guerin—with a score of attachés. Still the Governor forbade the evacuation of St. Pierre; and when, on May 7, the great Souffriere on St. Vincent exploded with a violence exceeding all record, cables were broken and other means of communication interrupted, so that St. Pierre continued to await her doom with hardly ruffled composure. On the morning of May 8, Mont Pelee burst at top and side with a terrific detonation; the earth trembled, and for a few moments the people of the city and the sailors on the shipping in

the roadstead began to seek safety; then a gale of burning gas and a rain of red-hot rock fell, and all St. Pierre, with fifteen of the seventeen vessels at anchor, were destroyed in an instant. Neighboring villages were blotted out; all Martinique was shaken; the detonation rolled out over the waves two hundred miles in every direction; the column of steam and rock-powder rose miles in height, and the dust was scattered over more than a hundred thousand square miles of isle-dotted ocean. This outbreak was not the end, nor even the culmination; La Souffriere continued to belch steam and mud, and Mont Pelee to erupt daily if not hourly, the explosion of May 20 exceeding in violence those of all earlier dates; and the magnetic disturbances accompanying the severer shocks were recorded in Maryland and Kansas, in Paris, and according to one report in Honolulu. The long quiescent crater of Tacana (Guatemala) was stirred into explosive activity; the warm springs of New Mexico resumed the long-past geyser form, and the crater near Grant, dead for five centuries, steamed anew; Mount Redoubt and neighboring craters in Washington State resumed alarming activity, and rumors of fresh outbreaks in Alaskan volcanoes gained currency; and the latest reports indicate that Kilauea, in Hawaii, has joined the concert. These are but the best-known links in the chain of sequence; it may not yet be affirmed that this succession is more than one of time, yet it is significant that the localities swept by the chain are all within reach of the magnetic disturbances extending for thousands of miles from Mont Pelee.

The eruption of Colima cost a number of lives not yet counted; the mortality at Quetzaltenango and neighboring places is estimated at 2,000 or more; the outbreak of Tacana is reported to have cost over a thousand lives; La Souffriere slew some two thousand; St. Pierre lost all of her 25,000, and other villages on Martinique some seven thousand more; so that Vulcan's victims in a single province during April and May, 1902, must approach 40,000. The number will never be accurately known; for there are no censuses covering certain Central American districts and some others in which the fatalities were numerous.

The lesson of Mont Pelee and St. Pierre is especially instructive. The researches of Hill, Russell, Heilprin, Jaggard, Borchgrevink, Hovey and Kennan have already made fairly clear the external aspects of the great eruption. Northern Martinique, like other West Indian islands, is a labyrinth of *mornes* and *pitons*, *i. e.*, of singularly steep peaks and ridges (partly volcanic cones, partly erosional forms), densely clothed with forests and herbage; it culminates in the crater rim of Mont Pelee a little less than 5,000 feet in altitude, with a sinuous divide extending southward and minor *arettes* stretching sea-

ward between the gorges of radiating waterways. In general, the mass of northern Martinique bulges upward and outward, a great dome convex toward the sky; but west and southwest of the summit crater there is an irregularly triangular amphitheater, of a form suggesting that a segment of the mountain has dropped several hundred feet below the general contour. At the coast line this depression forms the shallow bay of St. Pierre roadstead; and thence to the crest the depressed segment is bounded by rocky walls—sharp divides, cliffs, and lines of mornes, in different places. Almost in the center of this triangular trough sloping down from Pelee crater to the sea stood the city of St. Pierre, the metropolis of Martinique—that gem of the Antilles which must always live in history as the birthplace of Josephine, the early home of Bernardin de St. Pierre and the real scene (through youthful associations) of the epic of Paul and Virginia. St. Pierre was, indeed, an Antillean metropolis, the abode of culture and refinement, a mart of trade and shipping, the site of educational institutions of no mean grade, a city whose strong and distinctive characters were well worthy the gifted pen of its best chronicler, Lafcadio Hearn. Up the steep slopes toward the idly gaping crater four miles away, ran well beaten footpaths (for horses and wheels are alien to the precipitous slopes of the Antilles) leading to plantations and on to suburban villages, Carbet on the south, Precheur on the northern boundary of the amphitheater, Morne Rouge on the divide stretching away from the crater. The colonial Jardin Botanique lay in the rear, some hundred feet above the city; luxuriant cane-fields covered every available spot, groves and rows of palms skirted streets and pathways, legion brooks carried living water from the upper slopes to the sea, and thick native verdure mantled all the surface save fields and paths. Some half-way down the trough from Pelee to St. Pierre stood a minor crater, with traces of fumaroles; but they were covered from sight and memory by the prevailing verdure. A picturesque pond lay at the bottom of the great crater; and much of the water flowing seaward from the verdure-clad hills of the trough gathered into a central stream, La Riviere Blanche. Such was the area of destruction.

It is probable that the explosion of May 5 vaporized the water of the crater-set pond, and blew it into the air; it is also probable that the minor crater half-way down the slope toward St. Pierre was at least partially opened. More certain it is that on the morning of May 8 a mass of molten rock in the throat of the great crater exploded by the flashing into gas of the water and other volatile substances approaching the surface and so escaping subterranean pressure; and that immediately afterward (probably timed by the disturbed air pressure due to the first discharge) the minor crater fired a smaller

blast. In any event, steam, smoke, rock-dust, pumice bombs, and great blobs of half-liquid rock shot skyward from the main crater, with an earth-tremor of startling but not wrecking severity—and this discharge, extending miles into the upper air, must have initiated a series of atmospheric pressure waves; and about the time the heavier dust and bombs began to fall, or just in time to meet the recurrent wave of atmospheric pressure, the discharge of steam and other gases from the minor crater occurred. Some at least of these gases were heavier than air, and formed a black cloud which rolled down the amphitheater toward St. Pierre; according to several witnesses cross-examined by Hill, it was dense and black in front, aflame in the rear; and under the shock of the recurrent air-waves above, it was driven down on St. Pierre with such velocity that roofs flew before it like chaff, the lighthouse tower was twisted and rent into débris, heavy cannon were lifted from their carriages, and a 7-ton metal monument was blown forty yards; every vessel at anchor was careened and most of them capsized, anchor-chains were broken, and an off-shore wave was driven out of the roadstead to return in a destructive debacle. Disturbed by the initial quake, the people of the city fled to the cathedral or local shrines, sought refuge in fancied strongholds, or ran aimlessly about; when caught by the black cyclone, they were thrown against walls and amidst wreckage, bruised and burned by the red-hot rocks pouring from above, and suffocated by sulphurous fumes; then, when the gas-cloud caught fire from its own lightning or from molten rock, every living thing was scorched, seared or baked according to the local conditions of the burning. Such is the picture painted by Hill from the testimony of survivors of the *Roddam* and the *Roraima*, and of the parish priest and others who looked down on the holocaust from the cliffs flanking the St. Pierre amphitheater; Russell ascribes less effect to burning gas and more to scorching rock-powder; Borchgrevink emphasizes the evidence of electro-magnetic disturbance; but all agree that the scourge of St. Pierre was fire rather than earthquake or Pompeiian burial. The tragedy was not absolutely instantaneous; yet within three to ten minutes, the thirty thousand of St. Pierre and environs—Professor Landes, the prophetic scientist, and the misguided Governor among the rest—were no more. Thousands of bodies cumbered the debris-strewn streets or lay in the shattered houses until May 20, when Pelee again thundered—and then buried the reeking wreckage beneath a fresh layer of rock-powder. The later eruptions, like the initial one, usually combined an explosion from the main crater with an immediately subsequent one from the subordinate crater; and they sent out clouds whose movements helped to interpret those of earlier date. Thus, on May 23 Hill was able to study from below a gas-cloud like that which fell on St. Pierre; and he was even able (after realizing

the futility of attempting escape) to photograph the swirling tongue of flame by which the cloud was rent, and this picture must some day tell whether the fire was lightning or the combustion of inflammable gas.

Other external features of the Vulcanic throes, especially in Mont Pelee, were the detonations heard 200 miles away (those of Krakatoa were audible over 1,000 miles in all directions, almost 3,000 in one); the seismic tremors felt throughout most of the Lesser Antilles; the magnetic shock noted by suitably equipped laboratories from Paris to Honolulu, or a full third of the way about the globe; and especially the solid and gaseous ejectamenta discharged skyward and distributed hundreds of miles in every direction. At Fort de France it was estimated that the greater discharges rose six miles from the crater, seven miles above the level of the sea; by triangulation Bernadou determined the height of the minor discharge of May 30 at 15,500 feet, or something less than three miles (the mean estimate of the height of the Krakatoan discharge in 1883 was 17 miles). The cloud of steam and other gases, with their burden of rock-powder, spread in typical mushroom shape with such rapidity that neighboring islands up to a hundred miles away were darkened, and the dust-rain began to fall within three hours; on Barbados, 100 miles from La Souffriere and 125 from Mont Pelee, the dust-rain reached a depth of a quarter of an inch, and brought down sulphurous gases. The early analyses indicate that the greater part of this material is a crystalline hypersthene-andesite, *i. e.*, the heavier portion of a rather acidic lava of which the more glassy portions are thought by Teall 'to have been vanned away and deposited elsewhere' (*Nature*, Vol. 66, p. 130); while according to Diller and Steiger some of the grains collected 275 miles southeast of St. Vincent have the astonishingly high specific gravity of 3.3, and the insoluble dust contained .11 per cent. of sulphur, while the dust collected on Barbados was notable for the abundance of magnetite (*Science*, Vol. XV., pp. 947-950). Nearer the crater of Mont Pelee, the dust—'ashes' of the press reports, 'lapilli' of the books—lies like snow in drifts and sheets sometimes several feet in depth, and is mingled with fragments of pumice or bombs of denser rock, perhaps torn from the throat of the crater. Naturally the rock-rain was cool at Barbados and other remote stations; on St. Vincent, after the outbreak of La Souffriere, and on Martinique under each eruption of Mont Pelee, the falling rock was warm, even hot; an officer of one of the vessels wrecked in the roadstead of St. Pierre escaped the first shock only to be smitten down by a falling mass of half-molten rock; Russell found indications that some of the falling dust was hot enough to scorch the skin of victims but not to fire cotton garments; and a correspondent of *Nature* reiterates the incredible report that the sand

falling on St. Pierre, miles from the nearest crater, was still 'white hot.' All accounts agree as to the immensity and blackness of the clouds cast out from Mont Pelee with each explosion; and all agree in indicating that an important constituent of these clouds was gas, at least in part heavier than air, and at least in part inflammable. These eruptions are especially notable for the extravasation of material in gaseous form; but the gases have not yet been measured or even identified with any approach to precision. Thus far no quantitative estimates have been made of the aggregate amount of matter erupted from either Antillean volcano; but it seems probable that the total from both will not exceed one or two cubic miles, *i. e.*, probably less than a third of that thrown out by Krakatoa alone in the memorable outbreak of 1883. No decisive indications of subsidence of the coasts or of deformation of either insular masses or sea-bottom, such as might be expected to accompany the transfer of so vast a mass of material, have yet been detected—indeed, the geographic effects of the eruptions seem to be inconsiderable. Nor were there notable tidal waves anywhere in the Antillean region, save the outflows and subsequent inrushes in the St. Pierre harbor, ascribed by Hill to the atmospheric disturbance; and even these air-waves were of but limited extent, as indicated by the absence of records at meteorologic stations more remote than that on St. Kitt's, some 200 miles north of Martinique.

The most impressive part of Pelee's lesson is the tale of terrible mortality due to the ill-chosen site of St. Pierre. The convex slopes of the great dome stretching northward and eastward from the crater are still clad in verdure; Morne Rouge, the high-lying suburb on the principal salient stretching out from the crater, suffered nothing more serious than startling tremors and disagreeable dust-showers; it was only in the topographic funnel leading from the crater to the indented roadstead that the destruction was complete. Looking back over her history, it is easy to see that St. Pierre was founded with no more foresight than that of the spider spinning her web across a frequented path; the sacrifice of the city was but the necessary price of shortsight; yet if future dwellers on the Antilles, and the folk of other volcano-ridden regions, but profit by the experience of St. Pierre, the sacrifice may not be wholly vain.

So far as indicated by external manifestations, the internal mechanism of the Antillean volcanoes was in no way unprecedented or even peculiar, save, perhaps, in the high ratio of gaseous ejetamenta and the vast extent of magnetic disturbance and even these features may not be new, but only the outcome of more refined observations than those of earlier generations.

The internal mechanism of Mont Pelee and La Souffriere is fairly

clear in the light of what may be called the natural history of vulcanism; for, just as the life history of organic orders and genera is traced only by aid of fossils, so the ontogeny of the volcano may be viewed in the light of the phylogeny traced through its fossil remains—lava sheets, tuff beds, laccolites, volcanic necks like those of the Mount Taylor plateau, and other products of organic action during the ages past.

Naturally the first question concerning the volcano relates to its character; and this is answered partly by such dynamic facts as those recently observed in the Antilles, partly by the static records of the rocks. In the light of the various phenomena, it is convenient to recognize three types of eruption, viz: (1) the Stromboli type, or that of quiet outflow of highly fluent lava; (2) the type of Vesuvius, or that of explosive eruption usually followed by quieter flows of lava; and (3) the Krakatoa type, represented by violent explosions with little, if any, extravasation of lava. In some measure the types intergrade, the middle one, indeed, approaching the extremes; yet they are so connected with the character of the erupted material and other factors as to demand recognition.

The second inquiry concerning the world's volcanoes relates to geographic distribution; and this is well answered by any convenient map, such as that of Bonney (reproduced in the June number of this journal, page 187), from which it appears that nearly all of the living and recently extinct craters are arranged in lines, or zones, coinciding approximately with continental boundaries. Two of the most striking volcanic belts of the globe are those following the chain of Aleutian islands, and that of the Lesser Antilles from Porto Rico southward to the mouth of Orinoco river; several of the world's largest volcanoes occur in the interlacing zones lying off southeastern Asia; and the world's longest belt begins with the Aleutian chain, follows the coastwise mountains of western North America, traverses Central America, takes in the great Andean volcanoes of western South America, and stretches thence to Terra del Fuego, if not across to Antarctica to end with Mounts Erebus and Terror. The volcanic belts of the globe are sometimes styled 'lines of weakness' in the earth-crust, though a sufficient number of live or recently dead craters lie apart on oceanic islands or in continental interiors to caution conservative geologists against too simple groupings; yet all the facts seem to fall into the generalization that volcanic regions coincide with zones of exceptional activity in continent-making agencies.

A third inquiry concerning volcanoes relates to their geologic distribution, or—in ultimate analysis—to their connection with other geologic agencies and processes. The observations of numberless geologists in the different countries of the globe seem to answer this inquiry in general terms, by indicating that the agency of vulcanism is deca-

dent—that it culminated before the beginning of that definite world-growth recorded in the stratified rocks, revived locally during various periods down to the later Tertiary, and is probably less vigorous to-day than during any earlier eon of geologic time. Going further into detail, Powell has defined what may be called the normal sequence of vulcanism in any particular geologic province: The first stage in this sequence is that of loading, or accumulation of sediments in areas of deposition; the second is that of baking, compression, and metamorphosis of the lower sediments by the rise of the isogeotherms (measuring proper terrestrial heat); the third stage is that of uplift, partly by reason of the expansion and crumpling consequent on the heating from below; the fourth stage is that of unloading, or degradation by rain and rivers; and the final stage is that of vulcanism, supervening as the degradation proceeds and sometimes continuing until the province is once more submerged.

The distribution of volcanoes, both on the present earth-face and throughout the periods of earth-growth, covers essential phases of the natural history of vulcanism; yet the mechanism of the volcano remains to be traced through specific interpretation of both processes and products, so far as these lie within reach of observation. An epoch-marking step towards the interpretation of volcanic products was made by Baron von Richthofen a third of a century ago, when he recognized a natural system of volcanic rocks; and the goal was attained when Dutton, in a flash of genius, saw ‘the double function of density and fusibility’ (*‘Geology of the High Plateaus of Utah,’* 1880, p. 137) which conditions the extrusion of molten rock-matter. Diller, Iddings, Lawson and others have extended the interpretation; yet the later researches have but established the inference that density, or specific gravity, and fusibility (itself affected by wetness) are leading factors in determining the mechanism of volcanic action. Briefly, it may be said (1) that the seat of normal volcanic action is deep in the earth-crust, so deep that the vertical column of denser sea-bottom rocks is heavier than the longer column of mountain rocks rising thence to the cratered crest; (2) that here the rock-matter is subjected to the enormous pressure of superincumbent miles of rock, yet so highly heated as to become mobile with any relief from pressure; (3) that by reason of the variable strains due to unloading or other causes, some portion of this confined rock-matter is sufficiently relieved from pressure to become mobile, whereupon it seeks the level determined by its density, and forces itself upward through any overlying strata of greater density in channels or vents enlarged by continuous flow; (4) that the molten rock arranges itself in the vent in the order of specific gravity, the lighter above, the heavier (and generally wetter) below; (5) that sometimes the upwelling stream of molten rock reaches



a hydrostatic equilibrium and spreads out in laccolites without ever reaching the surface, though normally it forces its way upward through the lightest rocks (and these are those of mountains) well toward the surface; and (6) that as the mass approaches the surface so closely as to find relief from the subterranean pressure, its volatile constituents (chiefly occluded water) flash into gas, usually with explosive violence. Now if the lava column is of exceptionally viscous material, either because exceptionally dry or because exceptionally acidic in composition, the explosively expanding steam and other gases inflate it into pumice, or even blow it into dust; while if exceptionally fluent, by reason either of wetness or of basic composition, the explosion is less violent, the steam bubbles out as from boiling liquid, and the lava flows over the crater-rim, or through some chasm rent by its own enormous weight, in streams extending perhaps for many miles—as in Kilauea in 1841, and in the New Mexican volcano near Grant shortly before the Columbian discovery. Commonly it happens that the lighter lavas first extruded are the more viscous, the later and heavier material more fluent; so that the initial manifestation is commonly more decidedly explosive, the action then running down to relatively quiescent outflow; and their other relations depending on composition of the lava, etc., too complex for ready summing.

In the light of the natural history of vulcanism, and of the mechanism traced through the phylogeny of the volcano, the Antillean eruptions may readily be placed in the general scheme of knowledge. Both Mont Pelee and La Souffriere lie in a volcanic province in which the activity culminated ages ago, so that their activity may be likened to the dying throes of a Vulcanian giant; and this fact, while by no means to be interpreted in definite prophecy, is one of some promise to future generations. Again, both volcanoes approach the Krakatoan character rather than the innocent type of Stromboli; this character is destructive in itself; moreover, in view of the normal passage from initial explosion to final outwelling of quiet lava streams, it is to be regarded as an indication either (1) that the crisis of the spasm is not yet passed, or (2) that the andesitic lavas thus far outcast are precursors of more completely differentiated matter to be erupted during coming millenniums. In either case the outlook is less roseate than the humanitarian student would wish; for the fact that the region is one in which vulcanism is decadent when it is measured by geologic ages is of far less immediate interest than the prospect measured either in days of the single vulcanian spasm, or in millenniums of the life history of particular vents.

## SCIENTIFIC LITERATURE.

## ZOOLOGY.

A PLAUSIBLE explanation of the occurrence of peculiarities of structure and coloration in the males of many animals, both vertebrate and invertebrate, was first given by Darwin in his theory of sexual selection. Objections have been raised, however, to that portion of the theory which concerned ornamental peculiarities on the ground that the existence of an esthetic sense sufficiently acute to account for the minute and complex details of coloration is in many cases improbable, and from time to time other theories have been advanced which sought to avoid this difficulty. Among these may be mentioned the theory of Wallace, to the effect that the greater ornamentation of the male is due to his 'surplus of vitality'; that of von Kennel, which is essentially a negative statement of Wallace's, holding that the drain upon the vitality of the female in the production of ova prevents the full fruition of development seen in the males; and the sacrificial theory of Jäger and Stolzmann, according to which the brilliancy or excessive development of the male conduces to his destruction whereby the female is indirectly protected and the male is removed from competition with her in the struggle for nourishment.

But all these theories are open to the criticism either that they are too general or that they fail to explain the origin of the sexual peculiarities, and,

recently, Professor J. T. Cunningham, in his 'Sexual Dimorphism in the Animal Kingdom' (A. and C. Black, 1900), has endeavored to avoid both these objections by discarding natural selection in all its forms and relying upon the Lamarckian hypothesis. He regards secondary sexual characters as being due to the inheritance of the effects of definite mechanical and physiological irritations, and endeavors to correlate the peculiarities of various species with their habits. Thus he explains the mane of the lion not as a protection, but as the result of the local irritation of the skin due to the habit possessed by fighting lions of seizing one another by the nape of the neck; the coloration and furlrowing of the cheek of the mandrill are due to the inheritance of irritations and injuries inflicted by the males in combat; the plumes of the birds of paradise have reached their extensive development by having been erected during sexual excitement and so stimulated to special growth through many generations, and the naked head and neck of the turkey-cock and his wattles represent 'the inherited scars of a long line of pugnacious ancestors.' These examples, and they are by no means extreme, may serve to indicate the general tenor of Professor Cunningham's argument, and it seems more than doubtful if he has strengthened the Lamarckian position or provided valid evidence for the overthrowal of the theory of sexual selection.

## THE PROGRESS OF SCIENCE.

## THE AMERICAN ASSOCIATION.

THE American Association for the Advancement of Science will hold its fifty-first annual meeting at Pittsburgh, beginning with a session of the council on June 28 and with the first regular session of the Association on June 30. The time and place of meeting seem to be favorable to a large attendance and a good program. There is reason to suppose that the first of July is more satisfactory than the usual date, the middle of August, as men of science are then so widely scattered that it is difficult for them to come together. Pittsburgh is certainly a central point, as easily reached by railways from all parts of the country as any in America. An unusual concession has been made by some of the railways in extending the return limit of tickets until the end of August, thus accommodating those who wish to make the meeting at Pittsburgh the opening of their summer holidays. Under the direction of the chairman of the local committee, Dr. W. J. Holland, and the local secretary, Mr. George A. Wardlaw, an elaborate announcement has been published; and it appears that excellent arrangements have been made for the success of the meeting.

The address of the retiring president, Professor C. S. Minot, of the Harvard Medical School, which we hope to have the privilege of publishing in this journal, will set a high standard for the addresses of the vice-presidents which they will undoubtedly meet, for they are among our leading men of science—Professor James MacMahon in mathematics; Professor D. B. Brace in physics; Professor H. S. Jacoby in engineering; Professor C. R.

Van Hise in geology; President David Starr Jordan in zoology; Mr. B. T. Galloway in botany; Dr. J. Walter Fewkes in anthropology, and Mr. John Hyde in social science.

The American Association has become a center of affiliation for a large number of special scientific societies. Thus it is expected that there will meet at Pittsburgh, either at the same time as the association, or just before or after, the national societies devoted to chemistry, geology, botany, agricultural science, microscopy, entomology, folk-lore, engineering education and physics. These and other societies that will join with the association at its next meeting are represented on its council, which thus becomes a representative body competent to legislate on behalf of the interests of science and scientific men. The special papers tend increasingly to be presented before the societies affiliated with the association, while the association itself retains the function of representing science before the general public. Only men of science belong to the special societies, but all those interested in science are eligible for membership in the association. As a matter of fact, its three thousand members are nearly equally divided between those who are professionally engaged in scientific work and those who take an interest in and wish to assist in such work. Members have the privilege of attending the meetings of the association and of its affiliated societies, enjoying the reduced fares on the railways and the arrangements for entertainment, this being much more than a return for the small annual membership fee (\$3). Even those unable to attend the meetings have now a full

return, as they not only receive the volume of the proceedings, but also the weekly journal *Science*. But even apart from these practical advantages, it is desirable that all those who wish to further the advancement of science in America should ally themselves with the association. Information in regard to the conditions of membership may be obtained from the permanent secretary, Dr. L. O. Howard, Cosmos Club, Washington, D. C.

#### PRESIDENT ASAPH HALL.

ONE of the greatest of the world's astronomers will preside over the Pittsburgh meeting of the American Association. Dr. Hall has obtained a wide reputation by the discovery of the satellites of Mars, and among astronomers his continuous observations at the Naval Observatory from 1863 onward are recognized as of the highest value. He has also taken part in a number of important government expeditions, including one to Bering Straits in 1869 to observe the eclipse of the sun—to Sicily in 1870, and to Colorado in 1878 for the same purpose; and to observe the transit of Venus in Siberia in 1874 and in Texas in 1882. While the life of a man of science is usually uneventful, Dr. Hall's early career is full of interest. His father died when he was thirteen years old, and he took charge of the farm. He then became a carpenter; and, having saved a little money, at the age of twenty-five years went to a small college in New York State. There he married one of his fellow students. He taught school and studied at the University of Michigan, where he became interested in astronomy under Professor Brünnow. In 1857, when he was twenty-eight years old, he obtained a position in Harvard College Observatory under Professor Bond, with a salary of \$3 a week. Appointed professor of mathematics in the U. S. Navy at the beginning of the year 1863, he worked first with the 9½-

inch equatorial; from 1868 to 1875 he was in charge of the small equatorial, and from 1875 until his retirement in 1891 he was in charge of the 26-inch equatorial. Dr. Hall was professor of astronomy at Harvard University from 1895 until last year. He is vice-president of the National Academy of Sciences and a member of many foreign scientific academies. He has received the gold medal of the Royal Astronomical Society, and the Lalande prize and the Arago medal of the Paris Academy of Sciences; he has received the degree of LL.D. from Yale and Harvard Universities and many other honors. A recent portrait of Dr. Hall is given as a frontispiece; an earlier portrait and an extended biographical sketch will be found in the issue of THE POPULAR SCIENCE MONTHLY for October, 1894.

#### AN AMERICAN ANTHROPOLOGICAL SOCIETY.

WHILE we have in this country societies for nearly all the sciences, a society for anthropology has not hitherto been established. The section of the American Association representing anthropology has to a certain extent filled the function of a special society, having in recent years held a separate meeting in mid-winter. The time, however, appears to have come when a national anthropological society can be established to advantage, and the formation of such a society is now under discussion. Professor Franz Boas, in a paper read before the Anthropological Society of Washington, presented very clearly the need of such a society and the precautions that should be taken in its establishment. He points out that anthropology is one of the subjects in which there is a considerable popular interest, without a very large body of well-trained specialists, and that there would be some danger in establishing a society to which every one would be admitted. Not only might the meetings of such

a society assume the character of popular lectures, but it might interfere with the proper work of the American Association for the Advancement of Science. Professor Boas proposes that a national society be established in cooperation with the American Association, and the council of the association has appointed a committee to consider the plan. It contemplates all members of the Anthropological Society being members of the American Association, assuming for the special society the conduct of the special papers and discussions, and leaving to the general association such steps as may be desirable for the popularization of the science. This plan appears to be in the line of development. We need in each center societies composed of specialists in a given department. These societies should unite, on the one hand, to form a local academy and on the other to form a national scientific society. Then, in addition to these special students, it is important that all those who wish to ally themselves with science and to assist in its development should be permitted to become members both of the local academy and of the national association.

#### THE ROYAL SOCIETY'S CON- VERSAZIONE.

It is an open question whether it is for the interests of science that there should be in a country a number of small centers or one chief capital where its intellectual life is gathered. The civilizations of Greece, Italy and Germany seem to have been advanced by their competing cities and principalities, whereas France and England seem to have profited by the great concentration in Paris and in London. The Paris Academy of Sciences and the London Royal Society occupy positions unrivaled by the societies of other countries; and there are certainly very great advantages in the intimate union of all the men of science of a country in a single society. These advantages

are illustrated by the conversazioni annually held by the Royal Society at which are exhibited the scientific advances of the year. A similar exhibition and reception was for several years held by the New York Academy of Sciences, and it is to be hoped that this may be resumed. It can not be expected, however, that the scientific advances made in a single city of the United States will compare with those of London which represent in large measure those of the whole kingdom.

It appears from the descriptive catalogue that there were fifty-six exhibits at the conversazione of the Royal Society held on May 14. They all represent valuable scientific advances, but without any really noteworthy discovery, so that it is somewhat difficult to select any of the exhibits for special mention. The new fields opened up by the discoveries of the X-rays and of the inert gases of the atmosphere, have ever since furnished material for the exhibits. This year, for example, Mr. Davidson showed an X-ray stereoscope, Mr. Cossor a new tube and Mr. Pidgeon a new electrical influence machine for X-ray work, while Professor Ramsay exhibited a vacuum tube containing crypton, the color of which appears to some observers to be lilac and to others green. Other physical exhibits were a kymograph in which the writing pen is moved instead of the drum, an improved coal calorimeter and an electricity meter. Color photography was well represented, apparatus being shown and exhibits made, those of special interest being in photomicrography. The methods of manufacture of synthetic indigo, now threatening to supersede the use of the indigo plant, were exhibited. The Marine Biological Association presented an exhibit showing how the age of fishes is indicated by the growth of layers of scales somewhat similar to the eccentric lines on the section of the trunk of a tree. The School of Tropical Medicine exhibited a parasite from

human blood resembling that found in animals suffering from the tsetse fly disease. Several of the exhibits were more or less connected with America. Thus Dr. Roberts showed lantern slides in natural colors of the Canyon of the Colorado and the Yellowstone Park, and similar American scenes painted by Miss Breton were exhibited. Professor Schuster exhibited a Rowland grating of one meter focus arranged to show the lines of iron in the flame of a Bunsen burner. Professor Lankester exhibited models of deep-sea fishes, based in part on the figures and text of Goode and Bean's 'Oceanic Ichthyology,' while the Royal Astronomical Society exhibited photographs of the nebula surrounding Nova Persei taken at the Yerkes Observatory.

#### PRINCETON UNIVERSITY.

THE Rev. Dr. Francis L. Patton, who succeeded the Rev. Dr. James McCosh as president of the College of New Jersey in 1888, resigned the presidency of Princeton University on June 9, and the trustees immediately elected as his successor Dr. Woodrow Wilson, McCormick professor of jurisprudence and politics. It would be pleasant to join in the general expression of surprise at President Patton's resignation, of admiration for his administration and of eulogy of his successor. But principles are more important than men; and this journal represents certain principles at variance with the policy of the authorities of Princeton University. President Patton's resignation was not a surprise to those familiar with the inside history of the university, nor do they regard the material growth of Princeton in money and men during the past fourteen years as due to him. Dr. McCosh was in advance of his church and his college; he did much to forward the teaching of organic evolution and of psychology as a science. Dr. Patton was once a hunter down of heretics in his church; the ethics that he

teaches are but little concerned with the principles of evolution or of psychology. He has an acute mind of a scholastic turn and an attractive individuality; but his influence at Princeton has not been great.

Through the loyalty of its alumni, Princeton has increased in wealth and in numbers under President Patton's administration; but nothing has been done to justify the change of name from college to university. Fourteen years ago Harvard, Yale and Princeton might with some reason have been mentioned as our leading institutions of learning; now Princeton can be ranked with Harvard, Columbia and Chicago only by those who gain their information from the pages of the daily press devoted to athletic sports. Princeton has no school of law or of medicine. The theological seminary in the village represents the least progressive elements in the Presbyterian church. The last catalogue of Princeton University contains the names of 117 graduate students, but sixty-eight of them live in the halls of the theological seminary. Princeton has a school of science; but its students must take thirteen and a half hours in language (including Latin) as compared with eight hours in science; they are not permitted to begin the study of physics until the junior year.

There is reason to doubt whether President Wilson will accomplish at Princeton what President Hadley may be expected to accomplish at Yale. Dr. Wilson is a brilliant essayist; like his predecessor, he is one of the few college presidents who can speak with credit on the same platform as President Eliot. But from the scientific point of view, there is not a great difference between the literary-theological and the literary-legal mind. When Dr. Eliot in 1869 resigned the professorship of chemistry in the Massachusetts Institute of Technology and was installed as president of Harvard University, he laid down a program of

progress to which his administration has been devoted. The recently installed presidents of Yale, Johns Hopkins and Columbia have thought it wiser to confine their inaugural addresses to generalities, and there is reason to suppose that the president of Princeton will follow their example. We therefore reprint above the concluding part of the official oration given by him on the occasion of the Sesquicentennial Celebration of Princeton University. President Wilson's attitude toward science might be misstated; it is better to let him speak for himself.

#### THE ABUSE OF ALCOHOLIC TEACHING.

THE success of certain well-meaning but intemperate women in securing the enactment of laws requiring the teaching in the public schools of the injurious effects of alcoholic beverages, etc., is now receiving serious attention. Professor W. T. Sedgwick, in his presidential address before the Chicago meeting of the American Society of Naturalists, and the New York State Science Teachers Association, through the report of its committee, give the subject the attention it deserves. The question is certainly complicated, opening up many problems in sociology, education, psychology and morals which can not be settled off-hand. Whether the moderate use of alcohol is injurious, whether the attempt should be made to prevent its excessive use by law, whether its dangers should be taught to children, are questions to which science can not give a definite answer. On the other hand, there is substantial agreement on the part of educators and scientific men that the existing laws prescribing the constant teaching of the dangers of alcohol as part of the science of physiology are undesirable. In the state of New York, for example, all children below the second year of the high school and above the

third year of school work—say from the ages of nine or ten to fifteen or sixteen years—must have thirty lessons a year on the effects of alcohol, etc. The lessons must be one fifth of the work in physiology and hygiene and the subject must be treated in connection with the various chapters. Further the text-books in physiology are practically supervised by Mrs. Mary H. Hunt, who calls herself 'World and National Superintendent of the Department of Scientific Temperance of the Woman's Christian Temperance Union.' Now it is evident that all that is known in regard to the effects of alcohol on the tissues can be told in an hour or two; the arguments against its use are economic and moral. If morals are to be taught in the public schools, as is the case in France, the issue should be fairly met. If temperance is a proper subject for instruction, it is reasonable to assume that the abuse of alcohol should not receive more attention than the abuse of legislation and physiology, as exemplified by what Mrs. Hunt calls 'organized motherhood.'

#### SCIENTIFIC ITEMS.

WE note with regret the death of Professor Adolf Kussmaul, of Heidelberg, eminent for his work on aphasia and other forms of nervous disease; of Mr. George Griffith, assistant general secretary of the British Association for the Advancement of Science, and of Professor Emmett S. Goff, who held the chair of horticulture at the University of Wisconsin.

THE Geological Society of London has elected as foreign correspondents Professor T. C. Chamberlin, of the University of Chicago; Professor S. W. Williston, just called to the University of Chicago, and Dr. T. Thoroddsen, of Iceland.—The Linnean Society of London has elected among four foreign members Professor C. S. Sargent, of Harvard University.—Dublin University will confer the degree of

Doctor of Science on Professor J. Willard Gibbs, of Yale University.—The Hon. James Wilson, Secretary of Agriculture, and Dr. B. F. Galloway, chief of the Bureau of Plant Industry, have received the degree of LL.D. from the Missouri State University.—Dr. Carlos Finlay, of Havana, eminent for his work on yellow fever, has been given the degree of Doctor of Science by Jefferson Medical College, from which he graduated in 1855.

THE Senate has passed a bill authorizing the Commissioner of Fish and Fisheries to establish a biological station on the Great Lakes.—Plans have been prepared for the erection of a bacteriological laboratory in Washington, under the control of the Marine Hospital service.—Yale University has received for the Sheffield Scientific School a new building for mineralogy, geology and physiography.—A new building, chiefly for surgery, is to be erected for the Johns Hopkins Medical School at a cost of \$100,000.—Friends of Columbia University have purchased from the New York Hospital for \$1,900,000 the two blocks of land facing the University. It is hoped that this land may be ultimately acquired for the use of the University.—The final appraisal of the estate of the late Jacob S. Rogers shows a value of \$6,063,173. After deducting the costs of administration and the legacies it is estimated that the residuary estate which will go to the Metropolitan Museum of Art under the will is \$5,547,922.60.—According to an official statement recently issued the endowment of the Nobel Foundation is about \$7,500,000, and the value of each of the five prizes to be awarded at the close of

the present year will be nearly \$40,000.

At the annual meeting of the American Academy of Arts and Sciences, held on May 14, it was voted to award the 'Rumford Premium' to Professor George Ellery Hale, of the Yerkes Observatory, 'for his investigations in solar and stellar physics, and in particular for the invention and perfection of the spectro-heliograph.' It was also voted to appropriate the sum of \$750 from the income of the Rumford Fund to be expended for the construction of a mercurial compression pump designed by Professor Theodore W. Richards and to be used in his research on the Thomson-Joule effect. An appropriation from the Rumford Fund was also made to Professor Arthur A. Noyes in aid of his research upon the effect of high temperatures upon the electrical conductivity of aqueous solutions.

IN connection with the proposal to enlarge the Royal Society so as to include representatives of the historical, philological and moral sciences, or to establish a new academy for these sciences, Mr. Charles Waldstein, of King's College, Cambridge, has proposed the establishment of an Imperial British Academy of Arts and Sciences, which would include four sections as follows: The Royal Society for the natural and mathematical sciences, a new Royal Society of Humanites for the historical, philological and moral sciences, the present Royal Academy for painting, sculpture, architecture and the decorative arts, and a new Royal Academy of literature and music.



# THE POPULAR SCIENCE MONTHLY.

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## THE PROBLEM OF CONSCIOUSNESS IN ITS BIOLOGICAL ASPECTS.\*

BY PROFESSOR CHARLES SEDGWICK MINOT,  
HARVARD MEDICAL SCHOOL.

OUR Association meets in Pittsburgh for the first time. We are glad to indicate by our assembling here our appreciation of the immense work for the promotion of education and science which has begun in this city and already is of national value. It has been initiated with so great wisdom and zeal that we expect it to render services to knowledge of the highest character, and we are glad to be guests of a city and of institutions which are contributing so nobly to the cause of science.

We may congratulate ourselves on the bright prospects of the Association. Our membership has grown rapidly, and ought soon to exceed four thousand. Every member should endeavor to secure new adherents. For our next meeting we are to break with the long tradition of summer gatherings and assemble instead at New Year's time, presumably at Washington. To render this possible it was necessary to secure the cooperation of our universities, colleges and technical schools, to set aside the week in which the first of January falls, as *Convocation Week*, for the meeting of learned societies. The plan, owing to the cordial and almost universal support given by the higher educational institutions, has been successfully carried through. For the winter meetings we have further succeeded in securing the cooperation of numerous national societies. The change in our time of meeting is an

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\* Address of the President of the American Association for the Advancement of Science. Pittsburgh Meeting, June 28 to July 3, 1902.

experiment which we venture upon with the greater confidence, because of the success of our present meeting in Pittsburgh.

For my address this evening I have chosen the theme: 'The Problem of Consciousness in its Biological Aspects.' I hope both to convince you that the time has come to take up consciousness as a strictly biological problem, and also to indicate the nature of that problem, and some of the actual opportunities for investigating it. It is necessary to begin with a few words on the philosophical interpretation. We shall then describe the function of consciousness in animal life, and consider its part in the evolution of animals and of man. The views to be stated suggest certain practical recommendations, after presenting which I shall conclude by offering an hypothesis of the relation of consciousness to matter and force.

Consciousness is at once the oldest problem of philosophy and one of the youngest problems of science. The time is not yet for giving a satisfactory definition of consciousness, and we must fain content ourselves with the decision of the metaphysician, who postulates consciousness as an ultimate datum or concept of thought, making the brief dictum *cogito, ergo sum* the pivot about which his system revolves. I have endeavored vainly to discover by reading and by questioning those philosophers and psychologists whom I know, some deeper analysis of consciousness, if possible, resolving it into something more ultimate.

Opinions concerning consciousness are many and often so diverse as to be mutually exclusive, but they may be divided into two principal classes. The first class includes all those views which make of consciousness a real phenomenon; the second, those views which interpret it as an epiphenomenon. We are, I think practically all, agreed that the fundamental question is: Does or does not consciousness affect directly the course of events?—or, stated in other words, is consciousness a true cause? In short, we encounter at the outset the problem of free-will; of which more later.

The opinion that consciousness is an epiphenomenon has gained renewed prominence in recent times, for it is, so to speak, a collateral result of that great movement of European thought which has culminated in the development of the doctrine of monism. Monism itself is postulated chiefly upon the two greatest discoveries of the nineteenth century—the law of the conservation of energy, and the law of the evolution of species. Both laws establish a greater unity in the phenomena of the universe than mankind had previously been able to accept. In the physical world, instead of many forces, we now recognize only one force, which assumes various forms of energy; and in the living world we recognize one life, which manifests itself in many types of form. With these two unities in mind, what could be nearer than the thought that the unity goes still deeper, and that the phe-

nomena of the inanimate or physical, and of the living world are fundamentally identical? The progress of physiological science has greatly increased the impetus towards the adoption of this thought as the cardinal dogma of the new faith, because the work of physiologists has been so devoted to the physical and chemical phenomena of life, that the conviction is widespread that all vital phenomena are capable of a physical explanation. Assuming that conviction to be correct, it is easy to draw the final conclusion that the physical explanation suffices for the entire universe. As to what is, or may be, behind the physical explanation, complete agnosticism is of course the only possible attitude. Such in barest—but I believe correct—outline is the history of modern monism—the doctrine that there is but one kind of power in the universe.

It is evident that monism involves the elimination of two concepts, God and consciousness. It is true that monists sometimes use these words, but it is mere jugglery, for they deny the concept for which the words actually stand. Now, consciousness is too familiar to all men to be summarily cast aside and dismissed. Some way must be found to account for it. From the monistic standpoint there is a choice between two possible alternatives; either consciousness is a form of energy, like heat, etc., or it is merely a so-called epiphenomenon. As there is no evidence that consciousness is a form of energy, only the second alternative is in reality available, and in fact has been adopted by the monists.

It is essential to have a clear notion of what is meant by an epiphenomenon. Etymologically the word indicates something which is superimposed upon the actual phenomenon. It designates an accompanying incident of a process which is assumed to have no causal relation to the further development of the process. In practice it is used chiefly in regard to the relation of the mind or consciousness to the body, and is commonly employed by those philosophers who believe that consciousness has no causal relation to any subsequent physiological process.

For many years I have tried to recognize some actual idea underneath the epiphenomenon hypothesis of consciousness, but it more and more seems clear to me that there is no idea at all, and that the hypothesis is an empty phrase, a subterfuge, which really amounts only to this—we can explain consciousness very easily by merely assuming that it does not require to be explained at all. Is not that really the confession made by the famous assertion that the consciousness of the brain no more requires explanation than the aqosity of water?

Monism is not a strong system of philosophy, for it is not so much the product of deep and original thinking as the result of a contemporary tendency. It is not the inevitable end of a logical process, because it omits consciousness, but rather an incidental result of an

intellectual impulse. Its very popularity betokens its lack of profundity, and its delight in simple formulæ is characteristic of that mediocrity of thought which has much more ambition than real power and accepts simplicity of formularization as equivalent to evidence. It would seem stronger too, if it were less defended as a faith. Strong partizans make feeble philosophers.

Consciousness ought to be regarded as a biological phenomenon, which the biologist has to investigate in order to increase the number of verifiable data concerning it. In that way, rather than by speculative thought, is the problem of consciousness to be solved, and it is precisely because biologists are beginning to study consciousness that it is becoming, as I said in opening, the newest problem of science.

The biologist must necessarily become more and more the supreme arbiter of all science and philosophy, for human knowledge is itself a biological function which will become comprehensible just in the measure that biology progresses and brings knowledge of man, both by himself and through comparison with all other living things. We must look to biologists for the mighty generalizations to come rather than to the philosophers, because great new thoughts are generated more by the accumulation of observations than by deep meditation. To know, observe. Observe more and more, and in the end you will know. A generalization is a mountain of observations; from the summit the outlook is broad. The great observer climbs to the outlook, while the mere thinker struggles to imagine it. The best that can be achieved by sheer thinking on the data of ordinary human experience we have already as our glorious inheritance. The principal contribution of science to human progress is the recognition of the value of accumulating data which are found outside of human experience.

Twenty-three years ago, at Saratoga, I presented before the meeting of this Association—which I then attended for the first time—a paper, ‘On the Conditions to be filled by a Theory of Life,’ in which I maintained that, before we can form a theory of life, we must settle what are the phenomena to be explained by it. So now, in regard to consciousness it may be maintained that, for the present, it is more important to seek additional positive knowledge than to hunt for ultimate interpretations. We welcome therefore especially the younger science of experimental psychology, which, it is gratifying to note, has made a more auspicious start in America than in any other country. It completes the circle of the biological sciences. It is the department of biology to which properly belongs the problem of consciousness. The results of experimental psychology are still for the most part future. But I shall endeavor to show that we may obtain some valuable preliminary notions concerning consciousness from our present biological knowledge.

We must begin by accepting the direct evidence of our own consciousness as furnishing the basis. We must further accept the evidence that consciousness exists in other men essentially identical with the consciousness in each of us. The anatomical, physiological and psychological evidence of the identity of the phenomena in different human individuals is, to a scientific mind, absolutely conclusive, even though we continue to admit cheerfully that the epistemologist rightly asserts that no knowledge is absolute, and that the metaphysician rightly claims that *ego* is the only reality and everything else exists only as *ego's* idea, because in science as in practical life we assume that our knowledge is real and is objective in source.

For the purpose of the following discussion we must define certain qualities or characteristics of consciousness. The most striking distinction of the processes in living bodies, as compared with those in inanimate bodies, is that the living processes have an object—they are teleological. The distinction is so conspicuous that the biologists can very often say *why* a given structure exists, or *why* a given function is performed, but *how* the structure exists or *how* the function is performed he can tell very imperfectly, more often not at all. Consciousness is only a particular example, though an excellent one, of this peculiarity of biological knowledge—we do not know what it is, we do not know how it functions, but we do know why it exists. Those who are baffled by the elusiveness of consciousness when we attempt to analyze it will do well to remember that all other vital phenomena are in the last instance equally and similarly elusive.

In order to determine the teleological value of consciousness, we must endeavor to make clear to ourselves what the essential function is which it performs. As I have found no description or statement of that function which satisfied me, I have ventured, perhaps rashly, to draw up the following new description:

The function of consciousness is to dislocate in time the reactions from sensations.

In one sense this may be called a definition of consciousness, but inasmuch as it does not tell what consciousness is, but only what it does, we have not a true definition, but a description of a function. The description itself calls for a brief explanation. We receive constantly numerous sensations, and in response to these we do many things. These doings are, comprehensively speaking, our reactions to our sensations. When the response to a stimulus is obviously direct and immediate we call the response a reflex action, but a very large share of our actions are not reflex but are determined in a far more complicated manner by the intervention of consciousness, which may do one of two things: (1) Stop a reaction, as, for example, when something occurs, calling, as it were, for our attention and we do not give our

attention to it. This we call conscious inhibition. It plays a great rôle in our lives; but it does not mean necessarily that inhibited impressions may not survive in memory and at a later time determine the action taken; in such cases the potential reaction is stored up. (2) Consciousness may evoke a reaction from a remembered sensation and combine it with sensations received at other times. In other words, consciousness has a selective power, manifest both in choosing from sensations received at the same time and in combining sensations received at different times. It can make synchronous impressions dyschronous in their effects, and dyschronous impressions synchronous. But this somewhat formidable sentence merely paraphrases our original description: The function of consciousness is to dislocate in time the reactions from sensations.

This disarrangement and constant rearrangement of the sensations, or impressions from sensations, which we gather, so that their connections in time are altered seems to me the most fundamental and essential characteristic of consciousness which we know. It is not improbable that hereafter it will become possible to give a better characterization of consciousness. In that case the opinion just given may become unsatisfactory, and have to yield to one based on greater knowledge. The characteristic we are considering is certainly important, and so far as the available evidence goes it belongs exclusively to consciousness. Without it life would have no interest, for there would be no possibility of experience, no possibility of education.

Now, the more we have learned about animals, the better have we appreciated the fact that in them only such structures and functions are preserved as are useful, or have a teleological value. Formerly a good many organs were called rudimentary or vestigial and supposed to be useless survivals because they had no known function. But in many cases the functions have since been discovered. Such, for example, were the pineal gland, the pituitary body, the suprarenal capsules and the Wolfian body of man, all of which are now recognized to be functionally important structures. Useless structures are so rare that one questions whether any exist at all, except on an almost insignificant scale. It has accordingly become well-nigh impossible for us to imagine consciousness to have been evolved, as it has been, unless it had been bionomically useful. Let us therefore next consider the value of consciousness from the standpoint of bionomics.\*

We must begin with a consideration of the nature of sensations and the object of the reactions which they cause. In the simpler forms of nervous action a force, usually but not necessarily external to the

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\* A convenient term, recently gaining favor, for what might otherwise be called the economics of the living organism. Bionomics seems preferable to *ecology*, which some writers are adopting from the German.

organism, acts as a stimulus which causes an irritation; the irritation produces a reaction. Within the ordinary range of the stimuli to which an organism is subjected, the reaction is teleological, that is, it tends to the benefit of the organism. A familiar illustration is the presence of food in the stomach, which produces a stimulus, the reaction to which is manifested by the secretion of the digestive fluid for the purpose of digesting the food. An organism might conceivably be maintained solely by this mechanism in cooperation with the physical laws which govern all matter. Life in such an organism would be a succession of teleological processes, essentially mechanical and regulated automatically by the organism. By far the majority of biologists regard plants as essentially conforming to this type of life. Whether they absolutely so conform we do not, of course, yet know.

A sensation involves the interpolation of consciousness between the stimulation and the reaction, and in consequence there is established the possibility of a higher order of adjustment to the external world than can be attained through the teleological reaction to a stimulus. This possibility depends upon the fact that the intervention of consciousness permits an adjustment in accordance not merely with the immediate sensation, but also, and at the same time, in accordance with earlier sensations. Thus, for example, the child sees an object, and its reaction is to take hold of the object, which is hot and hurts the child. Later the child sees the object again and its natural reaction is to take hold of it again, but the child now reacts differently because its consciousness utilizes the earlier as well as the present sensation; the previous sensation is dislocated in time and fused with the present sensation and a new reaction follows. No argument is necessary to establish the obvious conclusion that an organism which has consciousness has an immensely increased scope for its adjustments to the external conditions; in other words, consciousness has a very high value for the organism. It is unnecessary to dwell upon this conclusion, for it will be admitted by every one, except perhaps those who start with the *a priori* conviction that consciousness is an epiphenomenon.

A sensation gives information concerning the external world. Perhaps science has achieved nothing else which has done so much to clarify philosophy as the demonstration that the objective phenomena are wholly unlike the subjective sensations. Light is a series of undulations, but we do not perceive the undulation as such, but as red, yellow and green, or as we say colors; the colors give us available information, and we use them as so many labels, and we learn that reactions to these labels may be helpful or hurtful, and so we regulate our conduct. Objectively red, yellow and green do not exist. Similarly with the vibrations of the air, certain of which cause the sensation of sound, which is purely subjective. But the sound gives us information con-

cerning our surroundings, which we utilize for our teleological needs, although in nature external to us there is no sound at all. Similarly all our other senses report to us circumstances and conditions, but always the report is unlike the external reality. Our sensations are symbols merely, not images. They are, however, bionomically sufficient because they are constant. They are useful not because they copy the external reality or represent it, but because, being constant results of external causes, they enable consciousness to prophesy or foresee the results of the reactions of the organism, and to maintain and improve the continual adjustment to the external reality.

The metaphysicians have for centuries debated whether there is any external objective reality. Is it too much to say that the biological study of consciousness settles the debate in favor of the view that the objective world is real?

Consciousness is not only screened from the objective world from which it receives all its sensations, but also equally from immediate knowledge of the body through which it acts. As I write this sentence I utilize vaso-motor nerves, regulating the cerebral blood currents, and other nerves which make my hand muscles contract and relax, but of all this physiological work my consciousness knows nothing though it commands the work to be done. The contents of consciousness are as unlike what is borne out from it as they are unlike what is borne in to it.

The peculiar untruthfulness to the objective which consciousness exhibits in what it gets and gives would be perplexing were it not that we have learned to recognize in consciousness a device to secure better adjustment to external reality. For this service the system of symbols is successful, and we have no ground for supposing that the service would be better if consciousness possessed direct images or copies instead of symbols of the objective world.

Our sensory and motor\* organs are the servants of consciousness; its messengers or scouts; its agents or laborers; and the nervous system is its administrative office. A large part of our anatomical characteristics exists for the purpose of increasing the resources of consciousness, so that it may do its bionomic function with greater efficiency. Our eyes, ears, taste, etc., are valuable, because they supply consciousness with data; our nerves, muscles, bones, etc., are valuable, because they enable consciousness to effect the needed reactions.

Let us now turn our attention to the problem of consciousness in animals. The comparative method has an importance in biology which it has in no other science, for life exists in many forms which we commonly call species. Species, as I once heard it stated, differ from one

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\* And other organs in efferent relations to consciousness.



another with resemblance. The difference which resembles we term an homology. Our arm, the bird's wing, the lizard's front leg are homologous. The conception of homology both of structure and of function lies at the basis of all biological science, which must be and remain incomprehensible to any mind not thoroughly imbued with this conception. Only those who are deficient in this respect can fail to understand that the evidence is overwhelming that animals have a consciousness homologous with the human consciousness. The proof is conclusive. As regards at least mammals—I think we could safely say as regards vertebrates—the proof is the whole sum of our knowledge of the structure, functions and life of these animals.

As we descend the animal scale to lower forms there is no break and therefore no point in the descent where we can say here animal consciousness ends, and animals below are without it. It seems inevitable therefore to admit that consciousness extends far down through the animal kingdom, certainly at least as far down as there are animals with sense organs or even the most rudimentary nervous system. It is unsatisfactory to rely chiefly on the anatomical evidence for the answer to our query. We await eagerly results from psychological experiments on the lower invertebrates. A sense organ however implies consciousness, and since such organs occur among cœlenterates we are led to assign consciousness to these animals.

The series of considerations which we have had before us lead directly to the conclusion that the development and improvement of consciousness has been the most important, really the dominant, factor in the evolution of the animal series. The sense organs have been multiplied and perfected in order to supply consciousness with a richer, more varied and more trustworthy store of symbols corresponding to external conditions. The nervous system has grown vastly in complexity in order to permit a constantly increasing variety in the time dislocations of sensation. The motor and allied apparatus have been multiplied and perfected in order to supply consciousness with more possibilities of adjustment to external reality which might be advantageous.

If we thus assign to consciousness the leading rôle in animal evolution we must supplement our hypothesis by another, namely, that conscious actions are primary; reflex and instinctive actions secondary, or, in other words, that, for the benefit of the organism, conscious actions have been transformed into reflexes and instincts. Unfortunately we must rely chiefly on future physiological and psychological experiments to determine the truth of this hypothesis. Its verification, however, is suggested by certain facts in the comparative physiology of the vertebrate nervous system, which tend to show that in the lower forms (amphibia) a certain degree of consciousness presides over the

functions of the spinal cord, which in mammals is devoted to reflex actions. Its verification is further suggested by the natural history of habits. As we all know, new actions are performed with difficulty and slowly, but if often repeated they are soon easier and more rapid. If a given reaction to a sensation or group of sensations through consciousness is advantageous to the organism and the environment is such that the sensation is often repeated, then a habit is formed and the response becomes more rapid, and often in ourselves we see habits which arose from conscious action working almost without the participation of consciousness, and moreover working usefully because rapidly. The usefulness of conscious reactions is that they are determined not merely by the present sensation but also by past sensations, but they have the defect that they are slow. We can readily understand that it would aid an organism to have the quicker reaction substituted, and we thus recognize a valid teleological reason for the replacement of conscious action by habits in the individual, by instincts in the race. The investigation of the evolution of reflexes and instincts is one of the important and most promising tasks of comparative psychology.

A frank unbiased study of consciousness must convince every biologist that it is one of the fundamental phenomena of at least animal life, if not, as is quite possible, of all life. Nevertheless its consideration has barely a place in biological science, although it has long occupied a vast place in philosophy and metaphysics. If this address shall contribute to a clearer appreciation of the necessity of treating consciousness as primarily a problem for biological research to solve, my purpose will be achieved. In an ideal world philosophers and scientists would be identical; in the actual world there are philosophical scientists and scientific philosophers, but in the main the followers of the two disciplines pursue paths which are unfortunately distinct. The philosophical mind is of a type unlike the scientific. The former tries to progress primarily by thought based on the data available, the latter seeks to advance primarily by collecting additional data. The consequence of this difference is that philosophy is dependent upon the progress of science, but we who pursue the scientific way make no greater mistake than to underestimate philosophy. The warning is needed. Data of observation are a treasure and very precious. They are the foundation of our mental wealth, but that wealth consists of the thought into which the data are transmitted. In pleading therefore for an increased observational study of consciousness we plead, not merely for science, but equally for philosophy. The scientific progress must come first. Hence we urge the advantage of investigating consciousness in its immediate revelations which are accessible now. Let us give up the ineffectual struggle to discover the essential nature

of consciousness until we can renew it with much larger resources of knowledge.

The psychologists ought now to apply the comparative method on a grand scale. They are just beginning to use it. Years of patient labor must pass by, but the reward will be very great. The psychic life of animals must be minutely observed, the conditions of observation carefully regulated and the results recorded item by item. The time has passed by for making generalizations on the basis of our common, vague and often inexact notions concerning the habits of animals. Exact experimental evidence will furnish a rich crop of psychological discovery. Scientific psychology is the most backward in its development of all the great divisions of biology. It needs, however, little courage to prophesy that it will bring forth results of momentous importance to mankind. After data have been gathered, generalization will follow which, it may be hoped, will lead us on to the understanding of even consciousness itself.

The teleological impress is stamped on all life. Vital functions have a purpose. The purpose is always the maintenance of the individual or of the race in its environment. The entire evolution of plants and animals is essentially the evolution of the means of adjustment of the organism to external conditions. According to the views I have laid before you, consciousness is a conspicuous, a commanding, factor of adjustment in animals. Its superiority is so great that it has been, so to speak, eagerly seized upon by natural selection and provided with constantly improved instruments to work with. A concrete illustration will render the conception clearer. In the lowest animals, the cœlenterates, in which we can recognize sense organs, the structure of them is very simple, and they serve as organs of touch and of chemical sensation resembling taste. In certain jelly fishes we find added special organs of orientation and pigmented spots for the perception of light. In worms we have true eyes and vision. In vertebrates we encounter true sense of smell. Fishes cannot hear, but in the higher vertebrates, that is from the amphibians up, there are true auditory organs. In short, both the senses once evolved are improved and also new senses are added. It is perfectly conceivable that there should be yet other senses, radically different from any we know. Another illustration, and equally forcible, of the evolution of aids to consciousness might be drawn from the comparative history of the motor systems, passing from the simple contractile thread to the striated muscle fiber, from the primitive diffuse musculature of a hydroid to the highly specialized and correlated muscles of a mammal.

It is interesting to consider the evolution of adjustment to external reality in its broadest features. In the lowest animals the range of the possible adjustment is very limited. In them not only is the variety

of possible actions small, but they cover also a small period of time. In animals which have acquired a higher organization the adjustments are more complex, both because the reactions are more varied and because they cover a longer period of time. Thus the jelly fish depends upon such food as happens to come within its reach, seizing from moment to moment that which it encounters; but a lobster pursues its food, making complicated movements in order to reach and seize it. One can trap lobsters easily; I doubt if one could trap a jelly fish at all. The next great advance is marked by the establishment of communication between individuals of the same species. About this phenomenon we know exceedingly little; the investigation of it is one of the most important duties of the comparative physiologist. Its bionomic value is obviously great, for it allows an individual to utilize the experience of another as well as its own. We might, indeed, compare it with the addition of a new sense, so greatly does it extend the sources of information. The communication between individuals is especially characteristic of vertebrates, and in the higher members of that subkingdom it plays a very great rôle in aiding the work of consciousness. In man, owing to articulate speech, the factor of communication has acquired a maximum importance. The value of language, our principal medium of communication, lies in its aiding the adjustment of the individual and the race to external reality. Human evolution is the continuation of animal evolution, and in both the dominant factor has been the increase of the resources available for consciousness.

In practical life it is convenient to distinguish the works of nature from the works of man, the 'natural' from the 'artificial.' The biologist, on the contrary, must never allow himself to forget that man is a part of nature and that all his works are natural works. This is specially important for the present discussion, for otherwise we are likely to forget also that man is as completely subject to the necessity of adjustment to external reality as any other organism. From the biological standpoint all the work of agriculture, of manufactures, of commerce and of government is a part of the work of consciousness to secure the needed adjustments. All science belongs in the same category as the teleological efforts of a jelly fish or a lobster. It is work done at the command of consciousness to satisfy the needs of existence. The lesson of all this to us is that we should accustom ourselves to profit by our understanding of the trend of evolution, which, in the progress humanity makes, obeys the same law of adaptation to objective reality which has controlled the history of animals. This view of the conditions of our existence puts science in its right place. As all sensations are symbols of external reality useful to guide organisms to teleological reactions, so is all science symbolic and similarly useful.

Nature never produces what to us seems a perfect organism, but only organisms which are provided with means of adjustment sufficient to accomplish the survival and perpetuation of the species. Man also is imperfect, but in the struggle for existence wins his way because his consciousness has greater resources than that of any other organism. His great power arises from his appreciation of evolution. His highest duty is to advance evolution, and this duty must be most strongly felt by those who accept the religious interpretation of life. The advancement of science is an obligation. To this view of the work of our Association I may safely claim the assent of all present.

The function of science is to extend our acquaintance with the objective world. The purpose of the American Association is not alone to increase the sum total of science, but equally also to preach by word and precept the value of truth, truth being the correct conscious symbol of the objective, by utilizing which our purposeful reactions are improved. The most serious obstacle truth encounters is the prevalence of what I may call 'doll ideas'—by analogy with the material dolls, with which children play. The child makes believe with the doll, knowing all the time its unreality, assigns to it hopes, passions, appetites; the child may feel the intensest sympathy with its doll, weep at its sorrows, laugh over its joys, yet know always that it is a mere inanimate, senseless doll. Adult men and women have ideas, with which they play make-believe; doll ideas, which they know are unreal, and yet they mourn sincerely over the adversities of their mental dolls, rejoice over their successes and fight for them with passion. Such doll ideas become mingled with the real and inextricably woven into the fabric of life. They are treated with the most earnest seriousness. Men will fight for them as a child will fight for its doll, not because it is property, but because it is a sacred personality. So are doll ideas often made sacred and defended with fanaticism. Yet, behind, in consciousness is the sense of unreality, the disregarded admission of 'making believe.' Do not doll ideas, pseudo-opinions, play a great rôle in human life? I think they do, and thinking so, deem it all the more imperative that you and others should teach the people the standard of science, the humble acknowledgment of reality. I wish that an impulse toward this goal from our Association could be imparted to every man and woman in the country, and I hope that the Association may continue to grow in number and power for long years to come, as it has grown in the last few years, so that it shall be a national, all-pervading influence serving the truth.

It seems to me inconceivable that the evolution of animals should have taken place as it actually has taken place, unless consciousness is a real factor and dominant. Accordingly I hold that it actually affects the vital processes. There is, in my opinion, no possibility of avoiding

the conclusion that consciousness stands in immediate causal relations with physiological processes. To say this is to abide by the facts, as at present known to us, and with the facts our conceptions must be made to accord.

The thought which I wish to emphasize is the importance for the future investigation of consciousness of separating the study of what it does from the study of what it is. The latter study is recondite, metaphysical, and carries us far beyond the limits of verifiable human knowledge. The former study is open to us and offers opportunities to science, but it has hitherto been almost completely neglected. Biology has now to redeem itself by effectual researches on consciousness. On the adequate prosecution of such researches we base great hopes.

Before I close permit me a few words concerning the relations of consciousness to the body, to living substances through which it manifests itself. It is intimately linked to protoplasm. Probably no question is so profoundly interesting to all mankind as the old question, what is the relation of the mind to the body? It is a question which has been stated in many forms and from many points of view, but the essential object of the question is always the same, to ask whether consciousness is a function of living matter, or something discrete and not physical or material.

Throughout this address consciousness has been viewed as a device to regulate the actions of the organisms so as to accomplish purposes which on the whole are useful to the organisms, and accordingly we have termed its function teleological. If this view is correct it accounts for the limitations of consciousness, its mechanical mode of work, its precision and definiteness of action, for of course, unless consciousness is orderly and obeys laws, it cannot be of use to the organism, but, on the contrary, it would be harmful, and conscious animals would have ceased long ago to survive. The very fact that consciousness is of such high value in the bionomy of an animal renders it obvious that it must be subject to law. Accordingly it appears to us regulated as do the functions of protoplasm. Hence to certain modern thinkers it presents itself as a function of protoplasm, or, as it may be better stated, as a state or condition of protoplasm.

The internal evidence of consciousness, however, is against this view and presents to us conscious actions as depending upon the consciousness. As before stated I believe that this evidence must be accepted. Now all the sensations of consciousness are derived from physical force, and all the acts of consciousness are manifested through physical force; hence if it has any real power consciousness must be able to change the form of energy. Unless we accept this doctrine, we must give up all belief in free-will and adopt the automaton theory of life. Is not the more reasonable explanation that which is based upon

all the contents of our consciousness rather than that which we can draw by discarding the internal evidence which consciousness brings us? The hypothesis which I offer for your consideration is this:

*Consciousness has the power to change the form of energy, and is neither a form of energy nor a state of protoplasm.*

By this hypothesis there are two fundamentally different things in the universe, force and consciousness. You ask why I do not say three, and add matter? My answer is that we do not have, and never have had, any evidence whatever that matter exists. All our sensations are caused by force and by force only, so that the biologist can say that our senses bring no evidence of matter. The concept 'matter' is an irrational transfer of notions derived from the gross molar world of the senses to the molecular world. Faraday long ago pointed out that nothing was gained and much lost by the hypothesis of material atoms, and his position seems to me impregnable. It would be a great contribution to science to kill off the hypothesis of matter as distinct from force.

To conclude: The universe consists of force and consciousness. As consciousness by our hypothesis can initiate the change of the form of energy, it may be that without consciousness the universe would come to absolute rest. Since I close with a bold speculation let my last words recall to you that my text is: Investigate consciousness by comparative observations. Only from observation can we know. Correct, intelligent, exhaustive observation is our goal. When we reach it human science will be completed.

## THE PANAMA ROUTE FOR A SHIP CANAL. II.

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THE total length of the Panama route from the six-fathom curve at Colon to the same curve in Panama Bay is 49.09 miles. The general direction of the route in passing from Colon to Panama is from northwest to southeast, the latter point being about 22 miles east of the Atlantic terminus. The depression through which the line is laid is one of easy topography except at the continental divide in the Culebra cut. As a consequence there is little heavy work of excavation, as such matters go, except in that cut. A further consequence of such topography is a comparatively easy alignment, that is one in which the amount of curvature is not high. The smallest radius of curvature is 3,281 ft. at the entrance to the inner harbor at the Colon end of the route, and where the width is 800 ft. The radii of the remaining curve range from 6,234 ft. to 19,629 ft.

The following table gives all the elements of curvature on the route and indicates that it is not excessive:

Number of Curves.	Length.	Radius.	Total Curvature.	
	Miles.	Feet.	°	'
1.....	0.88	19,629	14	17
1.....	.48	13,123	11	04
4.....	4.22	11,483	111	32
15.....	11.61	9,842	355	50
4.....	2.44	8,202	90	20
2.....	1.67	6,562	77	00
1.....	.73	6,234	35	45
1.....	.82	3,281	75	51
	22.85		771	39

Throughout the most of the distance between Colon and Bohio on the easterly side of the canal, the French plan contemplated an excavated channel to receive a portion of the waters of the Chagres as well as the flow of two smaller rivers, the Gatuncillo and the Mindi, so as to conduct them into the bay of Manzanillo, immediately to the east of Colon. That so-called diversion channel was nearly completed. Under the plan of the commission it would receive none of the Chagres flow, but it would be available for intercepting the drainage of the high ground easterly of the canal line and the flow of the two small rivers



named, so that those waters would not find their way into the canal. There are a few other small works of similar character in different portions of the line, all of which were recognized and provided for by the commission.

The principal items of the total amount of work to be performed in completing the Panama canal, under the plan of the commission, can be classified as shown in the following table:

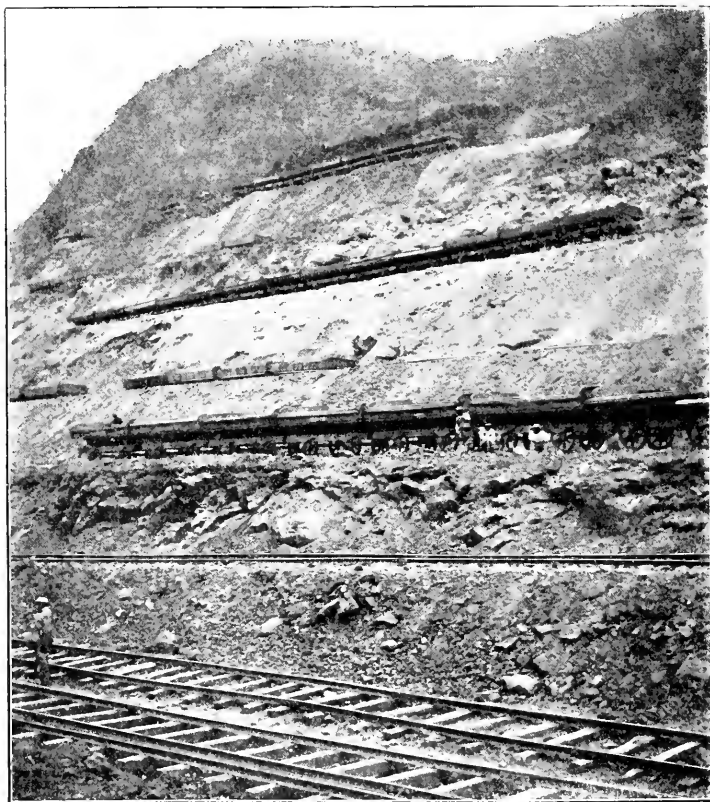
Dredging .....	27,659,540 cu. yds.
Dry earth.....	14,386,954 cu. yds.
Soft rock .....	39,893,235 cu. yds.
Hard rock.....	8,806,340 cu. yds.
Rock under water.....	4,891,667 cu. yds.
Embankment and back filling.....	1,802,753 cu. yds.
Total.....	97,440,489 cu. yds.
Concrete .....	3,762,175 cu. yds.
Granite .....	13,820 cu. yds.
Iron and steel .....	65,248,900 lbs.
Excavation in coffer dam.....	7,260 cu. yds.
Pneumatic work.....	108,410 cu. yds.

The lengths of the various sections of this route and the costs of completing the work upon them are fully set forth in the following table, taken from the commission's report, as were the two preceding:

Total Estimated Cost.	Miles.	Cost.
Colon entrance and harbor.....	2.39	\$ 8,057,707
Harbor to Bohio locks, including levees.....	14.42	11,099,839
Bohio locks, including excavation.....	.35	11,567,275
Lake Bohio .....	13.61	2,952,154
Obispo gates .....		295,434
Culebra section.....	7.91	44,414,460
Pedro Miguel locks, including excavation and dam...	.35	9,081,321
Pedro Miguel level.....	1.33	1,192,286
Miraflores locks, including excavation and spillway..	.20	5,781,401
Pacific level.....	8.53	12,427,971
Bohio dam.....		6,369,640
Gigante spillway.....		1,209,419
Pena Blanca outlet.....		2,448,076
Chagres diversion.....		1,929,982
Gatun diversion .....		100,000
Panama Railroad diversion.....		1,267,500
Total.....	49.09	120,194,465
Engineering, police, sanitation and general contingencies, 20 per cent.....		24,038,893
Aggregate.....		\$144,233,358

The item in this table called Panama railroad diversion affords provision for the reconstruction of the railroad necessitated by the formation of Lake Bohio. That lake would submerge the present location of the railroad for fourteen or fifteen miles.

It will be observed that in the estimates of cost of the canal on both the Nicaragua and the Panama routes 20 per cent. is allowed for 'engineering, police, sanitation and general contingencies.' For the purposes of comparison the same percentage to cover these items was used



THE CULEBRA CUT.

on both routes. As a matter of fact the large amount of work which has already been performed on the Panama route removes many uncertainties as to the character of material and other features of difficulty which would be disclosed only after the beginning of the work in Nicaragua. It has therefore been contended with considerable basis of reason that a less percentage to cover these uncertainties should be employed in connection with the Panama estimates than in connection with those for the Nicaragua route. Indeed it might be maintained

that the exigencies which increase cost should be made proportional to the length of route and the untried features. On the other hand, both Panama and Colon are comparatively large centers of population, and, furthermore, there is a considerable population stretched along the line of the Panama railroad between those points. The climate and the unsanitary condition of practically every center of population in Central America and of the isthmus contribute to the continual presence of tropical fevers, and other diseases contingent upon the existing conditions of life. It is probable among other things that yellow fever is always present on the isthmus. Inasmuch as the Nicaragua route is practically without population the amount of disease existing along it is exceedingly small, there being practically no people to be sick. The initial expenditure for the sanitation of the cities at the extremities of the Panama route, as well as for the country between, would be far greater on the Panama route than on the Nicaragua. This fact compensates, to a substantial extent at least, for the physical uncertainties on the Nicaraguan line. Indeed a careful examination of all the conditions existing on both routes indicates the reasonableness of applying the same 20 per cent. to both total estimates of cost.

The preceding estimated cost of \$144,233,358 for completing the Panama canal must be increased by the amount necessary to be paid for all the property and rights on the isthmus of the new Panama Canal Company. A large amount of excavation has been performed amounting to 77,000,000 cu. yds. of all classes of materials, and nearly all the right of way has been purchased. The new Panama Canal Company furnished the commission with a detailed inventory of its entire properties, which the latter classified as follows:

1. Lands not built on.
2. Buildings, 2,431 in number, divided among 47 subclassifications.
3. Furniture and stable outfit, with 17 subclassifications.
4. Floating plant and spare parts, with 24 subclassifications.
5. Rolling plant and spare parts, with 17 subclassifications.
6. Plant, stationary and semi-stationary, and spare parts, with 25 subclassifications.
7. Small material and spare parts, with 4 subclassifications.
8. Surgical and medical outfit.
9. Medical stores.
10. Office supplies, stationery.
11. Miscellaneous supplies, with 740 subclassifications.

The commission did not estimate any value for the vast amount of plant along the line of the canal as its condition in relation to actual use is uncertain, and the most of it would not be available for efficient and economical execution of the work by modern American methods. Again, a considerable amount of excavated material along some portions of the line has been deposited in spoil banks immediately adjacent to

the excavation from which it was taken, and would have to be rehandled in forming the increased size of prism contemplated in the commission's plan.

In view of all the conditions affecting it, the commission made the following estimate of the value of the property of the new Panama Canal Company, as it is now found on the Panama route:

Canal excavation .....	\$21,020,386
Chagres diversion.....	178,186
Gatun diversion .....	1,396,456
Railroad diversion (four miles) .....	300,000
	\$22,895,028
Contingencies, 20 per cent. ....	4,579,005
Aggregate .....	\$27,474,033
Panama Railroad stock at par.....	6,850,000
Maps, drawings and records.....	2,000,000
Aggregate .....	\$36,324,033

The commission added 10 per cent. to this total 'to cover omissions, making the total valuation of the property and rights as now existing \$40,000,000.' In computing the value of the channel excavation in the above tabulation it was estimated that 'the total quantity of excavation which will be of value in the new plan is 39,586,332 cu. yds.'

In January, 1903, the new Panama Canal Company offered to sell and transfer to the United States Government all its property and rights on the isthmus of every description for the estimate of the commission, viz., \$40,000,000. In order to make a proper comparison between the total costs of constructing the canal on the two routes it is necessary to add this \$40,000,000 to the preceding aggregate of \$144,233,358, making the total cost of the Panama canal \$184,233,358. It will be remembered that the corresponding total cost of the Nicaragua canal would be \$189,864,062.

It is obvious that the cost of operating and maintaining a ship canal across the American isthmus would be an annual charge of large amount. A large organized force would be requisite, and no small amount of material and work of various kinds and grades would be needed to maintain the works in suitable condition. The commission made very careful and thorough studies to ascertain as nearly as practicable what these comparative costs would be. In doing this it gave careful consideration to the annual expenditures made in maintaining the various ship canals of the world, including the Suez, Manchester, Kiehl and St. Mary's Falls Canals. The conclusion reached was that the estimated annual costs of maintenance and operation could reasonably be taken as follows:

For the Nicaragua canal.....	\$3,300,000
For the Panama canal.....	2,000,000
Difference in favor of Panama.....	\$1,300,000

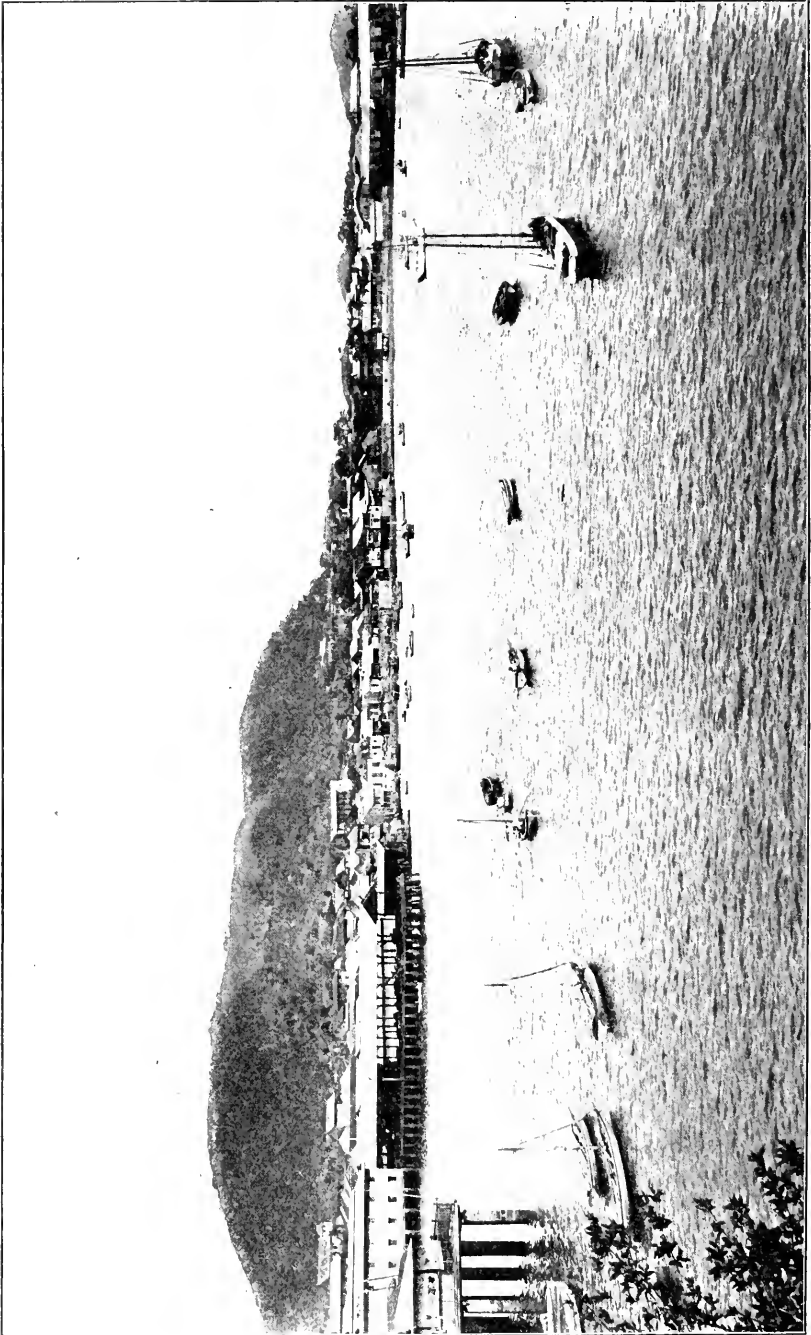
Much has been written regarding the comparative liability to damage of canal works along these two routes by volcanic or seismic agencies. As is well known, the entire Central American Isthmus is a volcanic region, and in the past a considerable number of destructive volcanic eruptions have taken place at a number of points. There is a line of live volcanoes extending southeasterly through Nicaragua and Costa Rica. Many earthquake shocks have occurred throughout Nicaragua, Costa Rica and the State of Panama, some of which have done more or less damage in large portions of those districts. At the same time many buildings, which have been injured, have not been



STREET IN PANAMA.

substantially built. In fact that has generally been the case. Both routes lie in districts that are doubtless subject to earthquake shocks, but there is little probability that the substantial structures of a canal along either line would be essentially injured by them. The conclusions of the commission as to this feature of the matter are concisely stated in three paragraphs at the top of page 170 of its report:

It is possible and even probable that the more accurately fitting portions of the canal, such as the lock gates, may at times be distorted by earthquakes, and some inconvenience may result therefrom. That contingency may be classed with the accidental collision of ships with the gates, and is to be provided for in the same way, by duplicate gates.



BAY AND CITY OF PANAMA.

It is possible also that a fissure might open which would drain the canal, and if it remained open, might destroy it. This possibility should not be erected by the fancy into a threatening danger. If a timorous imagination is to be the guide, no great work can be undertaken anywhere. This risk may be classed with that of a great conflagration in a city like that of Chicago in 1871, or Boston in 1872.

It is the opinion of the commission that such danger as exists from earthquakes is essentially the same for both the Nicaragua and Panama routes, and that in neither case is it sufficient to prevent the construction of the canal.

The relative healthfulness of the two routes has already been touched upon. There is undoubtedly at the present time a vast amount of unhealthfulness on the Panama route, and practically none on the Nicaragua route, but this is accounted for when it is remembered, as has also been stated, that there is practically no population on the Nicaragua route and a comparatively large population along the Panama line. There is a widespread, popular impression that the Central American countries are necessarily intensely unhealthful. This is an error, in spite of the facts that the construction of the Panama Railroad was attended with an appalling amount of sickness and loss of life, and that records of many epidemics at other times and in other places exist in nearly all these countries. There are the best of good reasons to believe that with the enforcement of sanitary regulations, which are now well understood and completely available, the Central American countries would be as healthful as our southern states. A proper recognition of hygienic conditions of life suitable to a tropical climate would work wonders in Central America in reducing the death-rate. At the present time the domestic administration of most of the cities and towns of Nicaragua and Panama, as well as the generality of Central American cities, is characterized by the absence of practically everything which makes for public health, and by the presence of nearly every agency working for the diseases which flourish in tropical climates. When the United States Government reaches the point of actual construction of an isthmian canal the sanitary features of that work should be administered and enforced in every detail with rigor of the most exacting military discipline. Under such conditions, epidemics could either be avoided or reduced to manageable dimensions, but not otherwise. The commission concluded that, 'existing conditions indicate hygienic advantages for the Nicaragua route although it is probable that no less effective sanitary measures must be taken during construction in the one case than in the other.'

The time required for passing through a trans-isthmian canal is affected by the length, by the number of locks, by the number of curves, and by the sharpness of curvature. The speed of a ship and consequently the time of passage is also affected by the depth of water under its keel. It is well known that the same power applied to a ship in deep

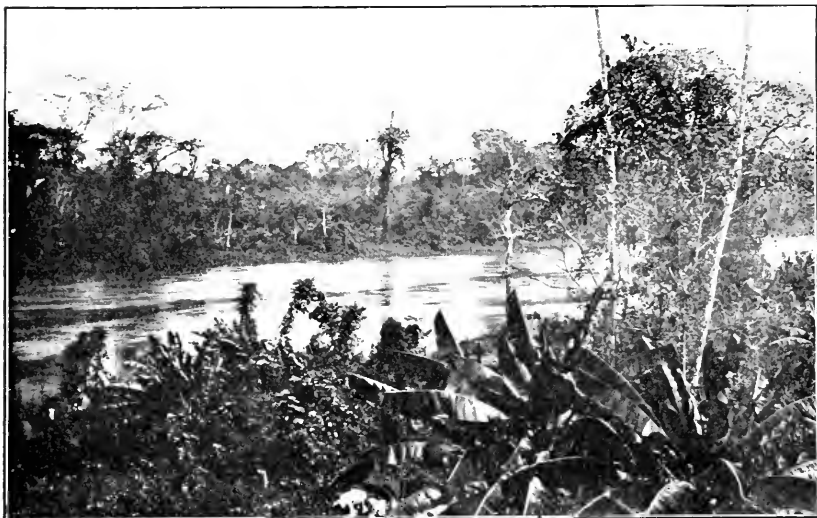
water of unlimited width will produce a much higher rate of movement than the same power applied to the same ship in a restricted waterway, especially when the draft of the ship is but little less than the depth of the water. These considerations have important bearings both upon the dimensions of a ship canal and upon the time required to pass through it. They were most carefully considered by the commission, as were also such other matters as the delay incurred in passing through the locks on each line, the latter including the delay of slowing or approaching the lock and of increasing speed after passing it, the time of opening and closing the gates, and the time of emptying and filling the locks. It is also evident that ships of various sizes will require different times for their passage. After giving due weight to all these considerations it was found that what may be called an average ship would require twelve hours for passing through the Panama canal, and thirty-three hours for passing through the Nicaragua canal. Approximately speaking, therefore, it may be stated that an average passage through the former waterway will require but one third the time needed for the latter.

The time in which an isthmian canal may be completed and ready for traffic is an element of the problem of much importance. There are two features of the work to be done at Panama, each of which is of sufficient magnitude to affect to a controlling extent the time required for the construction of the canal, viz., the Bohio dam and the Culebra cut. Both of these portions of the work may, however, be prosecuted concurrently, and with entire independence of each other. There are no such features on the Nicaragua route, although the cut through the divide west of the lake is probably the largest single work on that route. In considering this feature of the matter it is well to observe that the total amount of excavation and embankment of all grades on the Nicaragua route is practically 228,000,000 cu. yds., while that remaining to be done on the Panama route is but little more than 97,000,000 cu. yds. or 43 per cent. of the former.

The commission has estimated ten years for the completion of the canal on the Panama route and eight years for the Nicaragua route, including in both cases the time required for preparation and that consumed by unforeseen delays. The writer believes that the actual circumstances attending work on the two routes would justify an exchange of these time relations. There is great concentration of work in the Culebra-Emperador cut, on the Panama route, covering about forty-five per cent. of the total excavation of all grades (43,000,000 cu. yds.), which is distributed over a distance of about seven miles with the location of greatest intensity at Culebra. This demands efficient organization and special plant so administered as to reduce the working force to an absolute minimum by the employment of machinery to the



greatest possible extent. A judicious, effective organization and plant would transform the execution of this work into what may be called a manufactory of excavation with all the intensity of direction and efficiency of well-designed and administered machinery which characterizes the concentration of labor and mechanical appliances in great manufacturing establishments. Such a successful installation would involve scarcely more advance in contract operations than was exhibited, in its day, in the execution of the work on the Chicago Drainage Canal. By such means only can the peculiar difficulties attendant upon the execution of great works in the tropics be reduced to controllable dimen-



VIEW ON THE SAN JUAN RIVER IN NICARAGUA.

sions. The same general observations may be applied to the construction of the Bohio dam, even should a no more favorable site be found.

The greatest concentration of excavation on the Nicaragua route is between the lake and the Pacific, but it constitutes only ten per cent. of the total excavation of all grades, and it can be completed in far less time than the great cut on the Panama route. If this were the only great feature of work besides the dam, the time for completion of work on this route would be materially less than that required for the Panama crossing. As a matter of fact there are a succession of features of equivalent magnitude, or very nearly so, from Greytown nearly to Brito, extending over a distance of at least 175 miles, requiring the construction of a substantial service railroad over a considerable portion of the distance prior to the beginning of work. This attenuation of

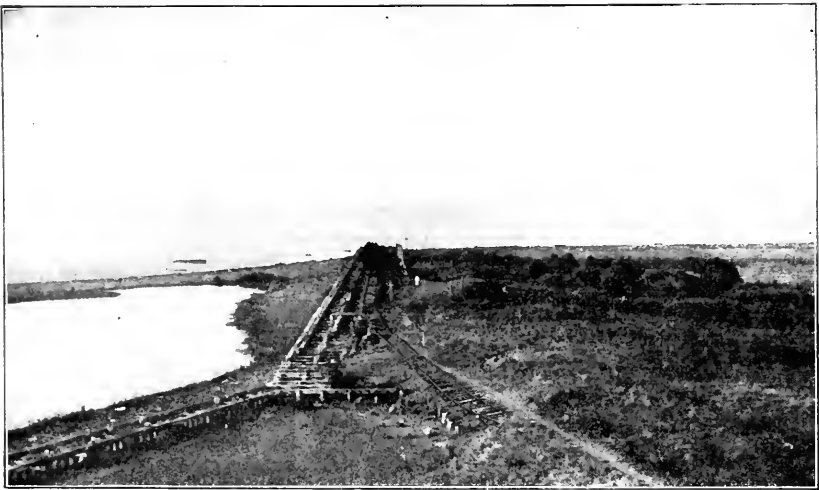
work requires the larger features to be executed in succession to a considerable extent, or much duplication of plant and the employment of a great force of laborers, practically all of whom must be foreigners, housed, organized and maintained in a practically uninhabited tropical country where many serious difficulties reach a maximum. It is not within the experience of civil engineers to execute by any practicable means that kind of a program on schedule time. The weight of this observation is much increased when it is remembered that the total volume of work may be taken as nearly twice as great in Nicaragua as at Panama, and that large portions between Lake Nicaragua and the Caribbean Sea must be executed in a region of continual and enormous rainfall. It would seem more reasonable to the writer to estimate eight years for the completion of the Panama canal and ten years for the completion of the Nicaragua canal.

The prospective industrial and commercial value of the canal also occupied the attention of the commission in a broad and careful study of the elements which enter that part of the problem. It is difficult if not impossible to predict just what the effect of a trans-isthmian canal would be either upon the ocean commerce of the United States, or of other parts of the world, but it seems reasonable to suppose from the result of the commission's examinations that had the canal been in existence in 1899 at least 5,000,000 tons of the actual traffic of that year would have been accommodated by it. The opening of such a waterway, like the opening of all other traffic routes, induces the creation of new traffic to an extent that cannot be estimated, but it would appear to be reasonable to suppose that within ten years from the date of its opening the vessel tonnage using it would not be less than 10,000,000 tons.

The Nicaragua route would favor in distance the traffic between our Atlantic, including Gulf, and Pacific ports. The distances between our Atlantic ports and San Francisco would be about 378 nautical miles less than by Panama. Between New Orleans and San Francisco, this difference in favor of the route by Greytown and Brito would be 580 nautical miles. It must be remembered, however, that the greater time by at least twenty-four hours, required for passage through the Nicaragua canal, practically obliterates this advantage, and in some cases would throw the advantage in favor of the Panama waterway. This last observation would hold with particular force if for any reason a vessel should not continue her passage, or should continue it at a reduced speed during hours of darkness, which could not be escaped on the Nicaragua canal, but might be avoided at Panama. For all traffic between the Atlantic, including gulf ports, and the west coast of South America, the Panama crossing would be the most advantageous. As a matter of fact, while there may be some small advantage in miles

by one route or the other for the traffic between some particular points, on the whole neither route would have any very great advantage over the other in point of distance or time; either would serve efficiently the purposes of all ocean traffic in which the ports of the United States are directly interested.

The effect of this ship waterway upon the well-being of the United States is not altogether of a commercial character. As indicated by the commission, this additional bond between the two portions of the country will have a beneficial effect upon the unity of the political interests, as well as upon the commercial welfare of the country. Indeed, it is the judgment of many well-informed people that the commercial advantages resulting from a closer touch between the Atlantic and Pacific coasts of the country are of less consequence than the unifying of political interests.



THE BREAKWATER OF THE MARITIME CANAL COMPANY AT THE FORMER ENTRANCE (NOW FILLED) TO GREYTOWN HARBOR ON THE COAST OF NICARAGUA.

Concisely stating the situation, its main feature may be expressed somewhat as follows:

Both routes are entirely 'practicable and feasible.'

Neither route has any material commercial advantage over the other as to time, although the distance between our Atlantic (including Gulf) and Pacific ports is less by the Nicaragua route.

The Panama route is about one fourth the length of that in Nicaragua; it has less locks, less elevation of summit-level, and far less curvature, all contributing to correspondingly decreased risks peculiar to the passage through a canal. The estimated annual cost of operation and maintenance of the Panama route is but six tenths that for the Nicaragua route.

The harbor features may be made adequate for all the needs of a canal by either route, with such little preponderance of advantage as may exist in favor of the Panama crossing.

The commission estimated ten years for the completion of the Panama canal and eight years for the Nicaragua waterway, but the writer believes that these relations should be exchanged.

The water-supply is practically unlimited on both routes, but the controlling or regulating works, being automatic, are much simpler and more easily operated and maintained on the Panama route.

The Nicaragua route is practically uninhabited and consequently practically no sickness exists there. On the Panama route, on the contrary, there is a considerable population extending along the entire line, among which yellow fever and other tropical diseases are probably always found. Initial sanitary works of much larger magnitude would be required on the Panama route than on the Nicaragua, although probably as rigorous sanitary measures would be required during the construction of the canal on one route as on the other.

The railroad on the Panama route and other facilities offered by a considerable existing population render the beginning of work and the housing and organization of the requisite labor forces less difficult and more prompt than on the Nicaragua route.

The greater amount of work on the Nicaragua route, and its distribution over a far greater length of line, involve the employment of a correspondingly greater force of laborers with attendant difficulties for an equally prompt completion of the work.

The recent volcanic eruptions on the Island of Martinique indicate a possible danger to the Nicaragua canal, should it be built, from the living volcano of Ometepe in Lake Nicaragua about ten miles from the land line. That there is some danger is beyond question, but it is very remote. There is no evidence to show that a canal or canal structure ten miles distant from Mount Pelee would have been injured by its recent eruptions, although navigation might have been interrupted for a short time. It is an open question, therefore, whether Ometepe in most violent eruption, even, would injure the Nicaragua Canal, although danger would exist.

On the other hand, as there is no volcano within about 175 miles of the Panama route, that route would be free from all danger of volcanic eruption.

Concessions and treaties require to be secured and negotiated for the construction of the canal on either route, and under the conditions created by the \$40,000,000 offer for the new Panama Canal Company this feature of both routes appears to possess about the same characteristics, although the Nicaragua route is perhaps, freer from the complicating shadows of prior rights and concessions.

SOCIAL BACTERIA AND ECONOMIC MICROBES, WHOLE-SOME AND NOXIOUS. A STUDY IN SMALLS.

BY EDWARD ATKINSON, LL.D., PH.D.

The profit of each generation, or in the present era the profit of each decade, consists in the saving of what was wasted in the last one.

I HAVE long sought a method by which the value of the annual product of this country at the prices fixed at final distribution, commonly called retail prices, might be ascertained with approximate accuracy.

In the study of the data of 1880 I was led to the conclusion that the average per capita expenditure (and therefore the annual product in its final stage) of the people of this country for the necessaries, comforts and luxuries of life could not be less than what \$200 per head could buy at the prices of the census year. The proportion of the population occupied for gain varied but a fraction from one in three, leading to the conclusion that the average product of each person occupied for gain could not be less than \$600 worth a year. Assuming this estimate to be approximately correct, this sum must have been the measure in money within which the cost of living, the taxes, additions to capital and all personal expenditures must have been covered. But on multiplying the population of the census year 1880 by \$200 worth per head, I was led to a very much larger estimate of the value of the annual product than the estimates of any other student of social facts.

I revised this computation on the basis of the census of 1890, reaching a conclusion that, while prices had been lessened, the value of the annual product at the lessened prices had reached not less than \$225 worth per head or \$675 per person occupied for gain.

Upon revising the figures of 1900 as far as given—these figures being more adequate than any before compiled—I have again reached the conclusion that the per capita product of the year reported in the census of 1900 was not less than what \$225 per capita would come to, each dollar of that \$225 standing on the average for a considerably larger quantity of products than ever before. At the present time prices have been enhanced, in consequence mainly of a short product of Indian corn, of potatoes and other root crops, and of some other products; but under the present aspect of ample crops and normal production a return to normal conditions may be anticipated within a few months or by the time when the population of this country will

number 80,000,000, say in 1903-4. For convenience in this preliminary study I therefore use 80,000,000 as the factor of population. I have computed the per capita expenditures on many lines from the data of 1900 and 1901, then by multiplying these normal figures of the two normal years before the effect of the short crop of 1901. In this way I compute the per capita and the gross value of each subject treated as it will be on a population numbering 80,000,000. This is only a preliminary study, subject to correction and completion after the final data of the census of 1900 become available; also subject to verification by other methods than the official census, such as I have made use of in this partial analysis.

Within the limited time and space allowed I can not cite authorities. Suffice it that I have, as far as possible, verified figures by reference to the special experts of the census and to various students of specific arts and subjects; notably in iron and steel, liquors, tobacco, cottons, woolens, dairy products, etc.; to all of whom I shall give credit when this preliminary study has been carried to completion.

Item No. 1, *Liquors, Divided into Spirits, Wines and Fermented Liquors*.—The average consumption of liquors has been computed in the Bureau of Statistics of the Treasury Department for many years with outside aid from a special trade expert. It has also been computed year by year by the editor of the *American Grocer*. The two estimates vary. The estimate of the *American Grocer* of the per capita expenditure comes to \$14.20. The official estimate for the same year comes to \$17.90. The latter may be more reasonably accepted than the former conservative estimate. This annual expenditure appears to be very large, but it proves in fact that the people of the United States are temperate as compared with European nations. It is evident that, since quantities are measured by taxation and values can be readily measured at the points of distribution, this computation is subject to a very small margin of error. The editor of the *American Grocer* computes spirits at forty-eight drinks to a gallon, which is the measure of standard liquor per drink in the best clubs. At his estimate of the total quantity, 1.33 gallons per head and amount expended, the average charge per glass of liquor is less than ten cents. Now in view of the custom of watering liquor, making at least sixty drinks to a gallon, and the probably average higher charge than ten cents a drink, his expenditure for spirits is probably too low.\*

\* Quantity of spirits estimated and taxed in the year 1901, 87,086,839 gallons, at 48 drinks per gallon computed at \$4.50 retail, \$391,890.775, if all were consumed as a beverage. In that year there were 26,000,000 males of seventeen years of age and over. The quantity named would give less than half a drink a day to this number. Drinks are at the rate of one or more per day. It follows that less than half the males of seventeen or over ever drink spirits, and by as much as some drink more must others go without.

Again, the consumption of beer at sixteen gallons per head is computed at retail prices in half-pint service. The half-pint drink is seldom of full measure, and the sum of this computation would yield only a fraction over three cents per glass. I think no beer is sold at retail at less than five cents per glass.\*

How the government estimate is computed I know not, but from these figures one may accept the government rather than the *Grocer's* estimate. I think it is safe to adopt an average of not less than \$17 per head for spirits, wines and beer, which, assessed upon 80,000,000 people, would come to \$1,360,000,000.

It may be remarked that the consumption of spirits has been very uniform at 1.33 gallons per head for a long period, slightly diminishing rather than increasing for several years. It is at about the same average as that of the United Kingdom of Great Britain and Ireland. On the other hand, our consumption of beer has rapidly increased, reaching a fraction over sixteen gallons per head of light beer, against an average in England of thirty-five gallons per head of strong beer. The price of beer is lower in Great Britain, but the average expenditure for drink is established at twenty dollars per head. The consumption of liquors in France and Germany is also much greater than in the United States.

Item No. 2, *Tobacco, Cigars, Cigarettes, Chewing Tobacco and Snuff*.—The consumption of tobacco has also been computed year by year by the editor of the *Tobacco World*, by whom a very close analysis has been made, which time will not permit me to quote in full. This estimate clearly proves that the average expenditure comes to \$6.15 per head, say \$6, or on a population of eighty million, \$480,000,000. †

\*The quantity of beer consumed in 1901 was 1,254,653,009 gallons at 16.20 gallons per head, which the editor of the *American Grocer* computes at fifty cents per gallon at retail, \$630,922,886. One gallon yields sixteen half pints. At fifty cents a gallon that comes to a fraction over three cents for a full half pint, which is too low an estimate. This quantity at 16.20 gallons per head would yield only half a pint a day to 29,160,000 people out of over 76,000,000, and as those who drink beer habitually far exceed half a pint a day, it follows that probably not half of the adults drink beer.

† This computation of six dollars per head of population would give each person less than two cents' worth of tobacco a day. But a considerable part of the population goes without tobacco in their early years. It would seem but a small allowance if we estimated that the users of tobacco averaged four cents' worth per day, and at that rate the estimate of the *Tobacco World* would supply only a little over a half of the population. Do half the population use four cents' worth of tobacco per day? If they do, by so much as some use more others must go without. I shall leave it to each smoker to compute the price of his own consumption of tobacco or cigars by his own average. I am afraid I deprive a great many other men of this solace by my own excess—over four cents a day.

I think it is clearly proved that the annual expenditures of the people of the United States for liquors and tobacco must come to at least \$23 per head of the whole population, amounting on eighty million people to \$1,840,000,000 in one year.

But there is an unknown addition which can not be readily computed but which should be added to this expenditure. The editor of the *American Grocer* deducts from the quantity of spirits consumed as a beverage from which the government revenues are derived 16,000,000 gallons, said to be used in the arts. There is reason to believe that more than half the quantity of spirits said to be used in the arts is consumed in making beverages, temperance drinks and quack or proprietary medicines, for which a very high price is paid by ignorant or uninformed persons, many of whom are totally unaware of the fact that they are drinking intoxicating liquor. I will not attempt to add an estimate in money for this waste, resting on the average of \$23 per head on 80,000,000 population, \$1,840,000,000, which, it will be observed, is ten per cent. of my large estimate of the total expenditures of the people of this country for food, clothing and shelter and all other products necessary to life.\*

Omitting the short period of war revenues, 1898 to 1902, now abated, the revenue derived by the Government of the United States from liquors and tobacco, domestic and foreign, for twenty years before the beginning of the Spanish War averaged \$2.50 per head, to which rate we may return after July 1, 1902, which rate on 80,000,000 people will yield \$200,000,000 a year. During the same twenty years prior to the Spanish War this revenue from liquors and tobacco, at \$2.50 per head, covered all the normal expenditures of the government of the United States, except interest and pensions, year by year, at \$2.50 per head, varying but slightly, namely, the cost of the civil, judicial and legislative departments, the support of the army and of the navy (including naval construction during those twenty years), public buildings, deficiency in postal service and all other normal expenditures.

\* PER CENT. ALCOHOL BY VOLUME IN VARIOUS COMPOUNDS.

Ayer's Sarsaparilla, .....	26.2	per cent.
Hood's " .....	18.8	" "
Golden's Liquid Beef Tonic, 'recommended for treatment of the alcohol habit,' .....	26.5	" "
Liebig Company's Cocoa Beef Tonic, .....	23.2	" "
Praker's Tonic, 'purely vegetable, recommended for in- ebriates,' .....	41.6	" "
Boker's Stomach Bitters, .....	42.6	" "
Warner's Safe Tonic Bitters, .....	35.7	" "

For an analysis of a very large number of these nostrums, not only in respect to alcohol, but for the proportion of iodide of potassium and other poisonous drugs and chemicals, see 'Report of Massachusetts Board of Health,' Pub. Doc. No. 34, pp. 614 to 620 inclusive; published in a separate pamphlet.



It will be remarked that when the government again derives a revenue of \$2.50 per head or \$200,000,000 per year from liquors and tobacco after July 1, 1902, that revenue will constitute a little less than eleven per cent. of the total expenditure for liquors and tobacco computed at \$1,840,000,000.

Again, assuming that these expenditures for liquors and tobacco are equal to ten per cent. of the entire cost of living of the whole population, then the government tax upon liquors and tobacco comes to a little more than one per cent., which is assessed upon the total product of the entire country estimated at \$225 per head at retail prices. Yet this tax is a purely voluntary contribution to the support of the government. Those who consume neither liquor nor tobacco pay none of this tax; those who do consume these articles pay the tax in the exact proportion of their consumption.

Item No. 3, *Wheat or White Bread*.—A few years since a well-established estimate of the consumption of wheat flour per head of population was one barrel, say 200 pounds, per year. Since then the increased product of wheat, the lessened price and the greater ability of the masses of the people to consume white bread brings that estimate up from 200 pounds to at least 230 pounds of flour. Assuming that the retail price of flour on the average of all parts of the country is two cents a pound, or four dollars a barrel, or \$4.60 per head of population on a consumption of 230 pounds each, the cost of flour to 80,000,000 persons would be \$368,000,000. Two hundred and thirty pounds of flour will make 325 pounds of bread, yielding a little short of a pound of bread a day per head of population.

I can make and bake six loaves of bread, weighing twelve pounds, in an Aladdin oven with an expenditure of less than two cents for fuel oil burned in a common lamp with some trifling addition for yeast and salt. In other words, a little over eight pounds of flour, costing between seventeen and eighteen cents for the best kinds, can be converted into twelve pounds of bread at a cost of much less than two cents a pound of bread. What then is the cost of bread to the mass of the consumers? What proportion make their own bread? What proportion buy it? This is a problem of difficult solution.

I find that the price of bread in Boston, delivered by grocers and bakers, ranges from a little less than five cents a pound for very poor bread up to ten cents a pound for very good bread. Bread delivered in New York of an average better quality costs less to the consumer. What it is in other cities or in the country I am unable to state. But in view of the large amount of wheat flour which is converted into cake, into fancy biscuits and into pastry, it may not be out of the way to compute 325 pounds of bread per capita at four cents a pound or

\$13 per head expended for wheat flour when converted into bread, cake, biscuit, pastry and cereals equals \$1,040,000,000.

What should be added for bread made of other grain? In the South corn meal is probably used in larger quantity per capita than wheat flour. Large quantities of corn meal, rye meal and oatmeal also serve as bread or as cereal food. There would probably be but a small margin of error if we computed the cost of other grains than wheat in the form of bread or cereal food at \$6 per head, making the total grain bill \$19 per head, or on 80,000,000 people \$1,520,000,000; being considerably less than the expenditure for liquors and tobacco.\*

This brings out the most important question in practical economics. If I can buy the best wheat flour and with twenty minutes a day of light exercise make one pound of bread each for twelve persons—bread-making being one of the simplest arts and one most easily learned; and if this bread costs less than two cents a pound, why should the bread of the masses of the people in the cities cost them more than four cents; or, in other words, what are the relative charges for distribution? The barrel of flour of which my bread is made has been brought to me a thousand miles at a charge of 50 cents or less, of which 30 cents may represent the cost of the service and 20 cents the possible net revenue of the railway to be applied to the payment of interest on bonds or dividends on the stock. That barrel of flour, making 280 pounds of bread, divided into 50 cents, charge for railway transportation, makes the cost of that part of the railway distribution of the loaf less than two tenths of a cent per pound of bread. On the other hand, the cost of distributing the loaves of bread in the city after they have left the mouth of the baker's oven is more than two cents per pound. The misdirected energy of the community has been devoted to denunciation of the railway service and to misdirected efforts to cheapen the cost of food by compelling railway corporations to lessen their rates whether they are profitable or not, while little or no attention has been given to improving the methods of distribution of bread at retail or to getting rid of the exorbitant charge for distributing loaves of bread at the rate of two cents a pound or more as compared to two tenths of a cent a pound or less over the railway. This observation will apply to nearly every article which enters into the cost of subsistence, especially the distribution of fresh vegetables. How to reduce the cost of distributing the necessaries of life in small parcels and how to save the waste of good

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\* An observation in smalls discloses the fact that the one machine shop now making 45 per cent. of the twine-binding grain harvesters of this country now turns out one complete harvester every eighteen seconds during eight working hours of each day for 300 days in the year, and being unable to meet the increasing domestic and foreign demand the company is now extending its works so as to turn out one every ten seconds.

material after it has been distributed are the real problems for practical economists to deal with.

Item No. 4, *Sugar*.—The import and production of sugar are well established in quantity and value; the consumption per capita is known; it is one of the articles on which the cost of refining has been reduced to the smallest fraction, and both the wholesale and retail profits to the lowest point. The latest consumption has been fixed at 68 pounds per head, without counting molasses. If we add the molasses at a very small fraction, we may count the average consumption at 70 pounds per head at an average price of five cents a pound or \$3.50 per head for refined sugar. But a quantity which cannot be measured is converted over into jams, jellies, preserves and condensed milk. In the latter industry one single establishment is reputed to consume more than the entire product of all the beet-root sugar factories in this country, estimated at about 150,000 tons. If sugar were free of duty an immense impulse would be given to agriculture and to fruit growing. A very small number of persons can ever be employed in raising beets for sugar, because the weeding of the beets must be done by hand and there are very few sections of the country where the people are so poor as to find suitable employment in this occupation, but with free sugar an immense impulse will be given to the making of condensed milk for home use and export, and to the saving of fruit now wasted, for conversion into jams, jellies and preserves. We should take the commerce of the world on these lines, and by free sugar provide excellent employment for ten where one can ever be occupied in raising beets.

Another large quantity of sugar is converted into candy. None can measure this factor. The highest rentals at the corners of the most frequented streets in cities are paid for occupation in the distribution of candy. I happen to know of four corners now occupied in Boston on which the rental is more than \$25,000 a year, these shops being devoted exclusively to retail traffic in candy of all sorts with prices of from ten to forty cents a pound. It follows that at least fifty cents per head should be added to the retail price of the refined sugar, making the total expenditure for sugar four dollars per head, or on a population numbering 80,000,000, \$320,000,000 a year.

Item No. 5, *Meats and Vegetables*.—It will be impossible to deal with the average expenditure for meat at the present time. Poultry and eggs at farm values come to \$3.69 per head. The product of slaughtering establishments large enough to be included under the head of 'Manufacturers' in the census comes to \$10.31 per head at the works. Butter, cheese and condensed milk at such works as are big enough to be included in the census come to \$1.72 per head. But more animals are slaughtered outside the large establishments than in them. The figures of poultry and eggs, of butter, cheese and con-

densed milk are probably not half what they are at the farms if farm products are added to census figures. When the agricultural reports are finally published and compared with the census figures it will become possible to reduce these factors to terms very closely approximating the average per capita expenditures for consumption. The only item of necessary expenditure which exceeds liquors and tobacco is the expenditure upon animal food. The expenditure for beer is less than five cents a day per capita; how much is the cost of milk?

Item No. 6, *Pig Iron*.—The people of the United States are not only the largest producers but also the largest consumers of pig iron in the world; yet at 450 pounds per head, which is nearly double the domestic consumption of England, Belgium, France and Germany, who are our chief competitors, the average per capita product of pig iron at the works comes to only \$4.50 per head. Prices are rising and consumption is increasing; by the time we have 80,000,000 people the average consumption will probably be 500 pounds per head if the works can supply it, which may then be computed at about five dollars per head for the average of forge iron, Bessemer metal, and of iron ore converted into open hearth steel, in their crude forms at the works; making on 80,000,000 a consumption of \$400,000,000 worth at the place of production. In order to carry this crude iron and steel into their finished forms through various transformations, it is probable that at the points of final consumption the products of iron and steel may be rated at about \$12.50 per head, or on 80,000,000 population \$1,000,000,000, a little more than half the price paid for liquors and tobacco. So much for some of the chief factors in production and consumption.

In this way I have given a preliminary study of the value of the annual product at its point of ultimate consumption or export. By making the study in smalls I have attempted to call your attention to the relative importance of several elements of subsistence. It will be several months before this study can be completed; suffice it that I have gone far enough to prove conclusively to my own mind that even on the return to normal prices, which may ensue if we have good crops this year before the population of the country reaches 80,000,000, the average of \$225 per head or more will be proved, on which basis the annual product computed at that date and in that manner will be measured by the sum of \$18,000,000,000. It may then be possible to estimate the proportion which this product will bear to the capital of the nation, which will require a separation of the site value of land from the estimate of national wealth by which the public is deluded. What really constitutes national wealth is the use made of land and the improvements placed upon it by human energy.

I may now give you some curious examples of how the income derived from the production, purchase and sale of these commodities

is distributed by way of railway charges, duties, national expenditures, support of schools, fire losses and losses by commercial failures.

Item No. 7, *Tea, Coffee and Cocoa*.—The editor of the *American Grocer* computes the annual expenditure for tea, coffee and cocoa by a method that leaves very little margin for error and which gives \$2.34 per head; which assessed on 80,000,000 comes to \$187,200,000. This sum added to the amount computed for liquor and tobacco gives a fraction over \$25 per head for beverages and tobacco, or over \$2,000,000,000 a year.

Item No. 8, *Textile Fabrics*.—The census data on cotton, woolen and silk fabrics, deducting exports and adding imports, gives approximately \$15 per head for clothing materials and carpets at the works. The extension of these values at mills in clothing and other uses will give approximately \$30 per head as the expenditure of consumers on this class; which assessed on 80,000,000 comes to \$2,400,000,000. After consultation with clothing manufacturers, I put cotton clothing at \$8 per head, woolen, \$12, silks, linens, laces, embroideries, etc., etc., at \$10, subject to further study.

Item No. 9, *Boots and Shoes*.—The value at the factories is \$3.42 per head, approximately \$5 to consumers; which assessed on 80,000,000 comes to \$400,000,000.

Item No. 10, *Wool*.—The average value of the annual wool clip of the United States at the farms and ranches comes to 66 cents per head. The maximum value of the largest product of beet root sugar is 10 cents, making together 76 cents; which sum assessed on 80,000,000 people amounts to \$62,800,000, or a sum not exceeding 1½ per cent. of the total product of agriculture in a normal year. Yet the farmers have been led to believe that their interests demand almost prohibitive duties on these two petty products, leading them to support a policy which costs them in the price of their clothing and sugar twice or thrice the total value of these two products, which duties obstruct the export of their surplus of the principal crops and the development of domestic industry in the most obnoxious way.

We may now deal with a few other problems of distribution which may be of interest.

The freight charges on all the railways of the United States in the year 1900 amounted to a little over \$1,071,000,000, which was at the rate of three quarters of a cent per ton per mile, and at the rate of \$13.79 per capita, which may be compared with \$23 per head for liquors and tobacco.

For this sum of \$13.79, 14 tons of food, fuel, fibers and fabrics were hauled 142 miles for every man, woman and child of the population. The average capital invested per capita amounted to \$151, on which

the railway corporations succeeded in earning \$5.13, or 3½ per cent. on the average per year.

The highways of the country are free, and those who feel themselves oppressed by these great combinations of capital are also free to cart their own 14 tons 142 miles in their own way if they want to. For myself I prefer to hire Morgan, Gould, Harriman and the Vanderbilts to do my carting.

#### *The Support of Schools.*

The annual appropriation for the support of common schools ranges from less than one dollar per head in many States to five dollars per head in Massachusetts. The average is three dollars per head, which sum assessed on 80,000,000 comes to \$240,000,000. Schools are the antidote for liquor—when the money spent on schools exceeds the money spent on whiskey we may boast of our progress.

#### *National Expenditures.*

The amount expended in the year ending June 30, 1901, for civil, judicial, postal service, public buildings, Army and Navy on a peace basis, may be computed at the normal rate of.....	\$2.50 per capita.
Pensions, .....	1.79 " "
Interest, .....	.42 " "
	<hr/>
Normal expenditure free from warfare, ....	\$4.71
Cost of militarism and of the attempt to subjugate the people of the Philippine Islands, .....	1.86
	<hr/>
Total, .....	\$6.57
The cost of militarism, mainly expended in the effort to subjugate the Philippine Islands amounted to.....	\$144,183,239

Our exports to the Philippine Islands in the same year amounted to less than four cents per head of our population. We have wasted nearly two dollars a head for two or three years in the effort to control an export at four cents a head.

I submit this preliminary and partial analysis of consumption for criticism and suggestion. It will require some weeks of close study of the census and other data for its completion. I may hope to finish this work soon after July 1, and expect to prove that my estimate of our annual product at \$225 per head will be more than sustained.

In conclusion I may call attention to what I believe to be the facts. The normal rate per capita of our national expenditures at \$5 per head, tending in time of peace to diminish, bears a ratio of not exceeding 2½ per cent. to my estimate of the national product. Even at the present rate of about \$6.50 per head, imposed upon us by our temporary military aberration, it does not reach three per cent.

Our principal competitors in the great commerce of the world—Great Britain, France, Germany, Belgium and the Netherlands—are subject to an average rate of \$14 to \$15 per capita, mostly imposed to meet the interest on war debts and the cost of militarism. This burden, tending to increase, stands for a rate of from eight to fifteen per cent. on their lesser national product.

On this difference only we save from \$700,000,000 to \$800,000,000 a year, or, in other words, gain that amount which our principal competitors now waste in destructive preparation for war.

People of some prominence in political and clerical life often expose their shallow capacity or their ignorance, by sneering at 'commercialism,' and by trying to discredit those who oppose the brutality of war by speaking of commerce as a mean and selfish pursuit.

Commerce lives and moves and has its being in mutual service rendered by men and nations for mutual benefit. It demands peace, order and industry.

War exists because of the survival of the brute element in man, which has not yet been overcome by education.

As surely as Christianity will displace paganism, as surely as civilization will displace barbarism, as surely as intelligence and education will displace ignorance, so surely will the beneficent force of commerce suppress the barbarity and brutality of war.

## MARRIAGE AMONG EMINENT MEN.

BY PROFESSOR EDWARD L. THORNDIKE,  
TEACHERS COLLEGE, COLUMBIA UNIVERSITY.

THE failure of the human race to reproduce at the top has been the cause of frequent complaints by students of society. The necessity of improving the human species by perpetuating desirable strains and restricting the increase of defectives, delinquents and dependents has impressed every thoughtful observer of human affairs and led him to wonder to what extent various classes of men share in producing the next generation. The reply has commonly been the cheerless dogma that the top strata of society are constantly dying out, that gifted men and women marry much less and later and have fewer children than the thoughtless multitude.

I have tested two of these claims in the case of the eminent men of our own country. The results have more than a curious interest. The well-known 'Who's Who in America' contains the names of about 10,000 men. Some of these are grotesquely out of place and many eminent men are missing from the list. But if we select 1,000 or more, we have a body of men representative surely of the top hundredth if not of the top five hundredth of men of their age. Their attitude toward marriage will give an idea of the attitude of men who have shown superiority over at least 99 per cent. of their fellow men.

The facts cannot be stated with absolute precision since a large percentage of them do not make any report at all concerning their conjugal condition. In an investigation of a number of these cases it was found that three fourths were married. Applying this fact to the whole group we obtain the following figures:

- Of 286 eminent men, between 60 and 70 years old, 88 per cent. are married.
- Of 347 eminent men, between 50 and 60 years old, 88 per cent. are married.
- Of 342 eminent men, between 40 and 50 years old, 88 per cent. are married.
- Of 243 eminent men, between 30 and 40 years old, 85 per cent. are married.

Comparing these percentages with similar ones for the whole male population, we have

Eminent men.	Whole population.
60-70 yrs. 88	93
50-60 yrs. 88	92
40-50 yrs. 88	89
30-40 yrs. 85	79 (about 85 for ages exactly corresponding to those of eminent men)



There is thus little or no avoidance of marriage peculiar to gifted men. The contrary belief seems one of the numerous scientific superstitions.

If we examine their age at marriage, we may justify the claim that gifted men marry not only almost as commonly, but also as early as the rank and file. Of those who have reached the age of forty-four and married before forty-five, 22.2 per cent. married before the age of 25, 43.3 per cent. between 25 and 30, 18.7 per cent. between 30 and 35 and 15.8 per cent. between 35 and 45. The corresponding figures for the general male population of the United States are 22.7, 41.0, 23.1 and 13.1.

Obviously the gifted men marry at almost the same ages as the multitude. Even the slight differences observable might vanish if the statistics were freed from the tendency to report the date of a second rather than a first marriage.

The facts concerning the marriages of gifted men in America seem to disprove another common dogma—that the age at marriage has been rapidly increasing in the case of professional men because of the increasing amount of preparation required for success in professional life under present conditions. If we take all the gifted men born before 1865, who have married before 35, and compute the average age at marriage of those born before 1820, from '20 to '30, from '30 to '40, etc., we find that the age of marriage for gifted men has probably advanced less than six months in a half century. This is a liberal estimate and is surely not alarming. I find no means of ascertaining the change in the marriage age of the general male population during the same period, but there is no evidence that professional men differ from authors, artists or men in business.

These facts witness to the fundamental conservatism of human nature. The casual observer is impressed by the appearance of changes—of revolutions and reformations in human ways; he fancies that some force in the environment is making or marring our customs. But the inborn make-up of men is always a factor and one that remains unaltered through many half centuries.

## UNIVERSITY-BUILDING.

BY PRESIDENT DAVID STARR JORDAN,  
LELAND STANFORD JUNIOR UNIVERSITY.

WITH the end of our republic's first century we had the first clear vision of the greatest of republican institutions, the American university. It was even then only a vision. It is not yet realized, but we know something of what it is to be. Out of the struggles and the prayers, the hopes and the efforts of good men and good women we see it taking form. A university, as fair as those which England has known for a thousand years, as sound and as strong as the deep-rooted schools of Germany, with something of both, yet different from either, is the coming university of America. There will be many of these institutions, for our land is very wide, and they will differ from each other somewhat in kind and as one star differeth from another in glory, still of the same general pattern all must be. They will be schools for training American boys and girls to be American men and women. They will express the loftiest ideals of higher education within our great democracy.

The American college, as it existed thirty years ago and more, and as it still exists in some quarters, is distinctly a school for personal culture. Its strongest agency has been the personal influence of devoted men. It has made no effort to give professional training. It has made no pretense of leading in scientific research. A log with Mark Hopkins at one end of it and himself at the other was Garfield's conception of such a college. Even the log is not essential. The earnest teacher is all in all. Apparatus Mark Hopkins did not need, books he even despised. The medium of a forgotten language and an outworn philosophy served him as well as anything else in impressing on his boys the stamp of his own character. It was said of Dr. Nott of Union College that 'he took the sweepings of other colleges and sent them back to society pure gold.' Such was his personal influence on young men. A notable example of the college spirit was Arnold of Rugby. Another was Jowett, master of Baliol. A teacher of this type in greater or less degree it was the privilege of every college student to know, and this knowledge still reconciles him to his *alma mater*, however many her shortcomings in subject or method. But times have changed since the days of Mark Hopkins. The American college, English born and English in tradition, under the touch of German

influences and in response to actual needs, is changing to the American university. It is no longer a school of culture alone, a school of personal growth through personal example. It is becoming in addition to this a school of research, a school of power. It stands in the advance guard of civilization, responsive not to the truth of tradition alone, but to the new truth daily and hourly revealed in the experience of man.

In the movement of events the American university unites in itself three different functions, that of the college, that of the professional school and that which is distinctive of the university.

The college is now as ever a school of culture. It aims to make wise, sane, well-rounded men who know something of the best that men have thought and done in this world, and whose lives will be the better for this knowledge. It has not discarded the Latin, Greek and mathematics which were so long the chief agents in culture, but it has greatly added to this list. It has found that to some minds at least better results arise from the study of other things. Culture is born from mastery. The mind is strengthened by what it can assimilate. It can use only that which relates itself to life. We find that Greek-mindedness is necessary to receive from the Greek all that this noblest of languages is competent to give. We find for the average man better educational substance in English than in Latin, in the physical or natural sciences than in the calculus. But more important than this, we find that it is safe in the main to trust the choice of studies to the student himself. The very fact of choice is in itself an education. It is better to choose wrong sometimes, as we do a hundred times in life, than to be arbitrarily directed to the best selection. Moreover, so far as culture is concerned, the best teacher is more important than the best study. It is still true, as Emerson once wrote to his daughter, that 'it matters little what your studies are; it all lies in who your teacher is.' A large institution has many students. It has likewise many teachers, and an Arnold or a Hopkins, a Warner or a Thoburn, can come just as close to the students' hearts in a large school as in a small one. But 'the knowing of men by name,' the care for their personal lives and characters, must be the essential element in the new college course, as it was in the old. And the college function of the university must not be despised or belittled. Because Germany has no colleges, because her students go directly from the high school at home to the professional school or the university, some have urged the abandonment by the American university of this primal function of general culture. In their eagerness to develop advanced work, some institutions have relegated the college function almost solely to tutors without experience, and have left it without standards and without serious purpose. It is not right that even the freshmen should be poorly taught. On the soundness of the college training everything

else must depend. In the long run, the greatest university will be the one that devotes the most care to its undergraduates. With the college graduation higher education in England mostly stops. With Germany here the higher education begins. Higher education has been defined as that training which demands that a man should leave home. It means a breaking of the leading strings. It means the entrance to another atmosphere. The high school and the gymnasium cannot have the academic atmosphere, however advanced their studies may be. They must reflect the spirit of the town which supports them and of which they are necessarily a part. They cannot be free in the sense in which the universities are free. A boy who lives at home in a city and goes back and forth on a train cannot be a university student. He may recite in the university classes, but there his work ends. He gets little of the spirit which moves outside of the class room. He cannot enter the university until he breathes the university atmosphere. The 'Spurstudenten' or 'railway students,' those who come and go on the trains, are rightly held by their fellows in Germany to be little more than Philistines. Whatever the other excellencies of the German system, the gymnasium, or advanced high school, is an inadequate substitute for the American college.

The second function of the university is that of professional training. To the man once in the path of culture this school adds effectiveness in his chosen calling. This work the American universities have taken up slowly and grudgingly. The demand for instruction in law and medicine has been met weakly but extensively by private enterprise. The schools thus founded have been dependent on the students' fees, and on the advertising gain their teachers receive through connection with them. Such schools as these stand no comparison with the professional schools of Germany. Their foundation is precarious, they can not demand high standards, nor look beyond present necessities to the future of professional training. Only a few of these schools to-day demand high standards. Those who do not can not share the university spirit. They have no part in university development. Only in the degree that they are part and parcel of the university do they in general deserve to live. The first profession to become thus allied is that of engineering, thanks to the wisdom that directed the Morrill Act. Following this, law, medicine, theology, education in some quarters, have taken a university basis, and the few professional schools in which such a basis exists rank fairly with the best of their class in the world.

The crowning function of a university is that of original research. On this rests the advance of civilization. From the application of scientific knowledge most of the successes of the nineteenth century have arisen. It is the first era of science. Behind the application of

such knowledge rests the acquisition of it. One Helmholtz, the investigator, is the parent of a thousand Edisons, the adapters of the knowledge gained by others. The great function of the German university is that of instruction through investigation. The student begins his work on a narrow space at the outer rim of knowledge. It is his duty to carry the solid ground a little farther, to drive back ever so little it may be the darkness of ignorance and mystery. The real university is a school of research. That we possess the university spirit is our only excuse that we adopt the university name. A true university is not a collection of colleges. It is not a college with an outer fringe of professional schools. It is not a cluster of professional schools. It is the association of scholars. It is the institution from which in every direction blazes the light of original research. Its choicest product is 'that fanaticism for veracity' as Huxley calls it, that love for truth, without which man is but the toy of the elements. Its spirit is the desire 'to know things as they really are' which is the necessary attribute of 'him that overcometh.' No institution can be college, professional school and university all in one and exercise all these functions fully in the four years which form the traditional college course. To attempt it is to fail in one way or another. We do attempt it and we do fail. In the engineering courses of to-day we try to combine in four years professional training with research and culture. This can not be done, for while the professional work is reasonably complete, culture is at a minimum and research crowded to the wall. The subject of law requires three solid years for professional training alone. Three or four culture years go with this and are surely none too many. The same requirement must soon be made in engineering. We can not make an engineer in four years if we do anything else for him, and there are very many things besides engineering which go to the making of a real engineer.

But this we can do in the four years of college culture. We can show the student the line of his professional advancement and can see him well started in its direction before he has taken his first degree. We can give in the college course something of the methods and results of advanced research. In any subject the advanced work has a higher culture value than elementary work. Thorough study of one subject is more helpful than superficial knowledge of half a dozen. To know one thing well is in Agassiz's words 'to have the backbone of culture.' By limiting the range of individual training to a few things done thoroughly it is possible to give even to the undergraduate some touch of real university method, some knowledge of how truth is won. To accomplish this is one vital part of the university's duty. It welds together the three functions of a university, and in so doing it will give the American university its most characteristic feature.

The best education for any man with brains and character should involve these three elements. It should have the final goal in view as soon as possible. It should be broad enough and thorough enough to develop cultured manhood and at the same time to furnish the strength needed to reach this goal. In other words, it should look to success in the profession and to success as a man. Toward both these ends the methods of finding the truth for oneself are vitally essential. The university should disclose the secret of power, and this secret lies in thoroughness. Science is human experience tested and set in order. The advance of science has come through the use of instruments of precision and methods of precision. Opinion, feeling, tradition, plausibility, illusions of whatever sort, disappear when the method of power is once mastered.

The college course should have a little of the professional spirit for its guidance, a little of the university spirit for its inspiration; the best interests of all three will keep them in the closest relation to each other. At the same time they must not starve each other. At the present time the needs of the college in most cases tend to dwarf the more costly functions of the university. The professors have their hands full of lower work. The books and material the university work demand are far more costly than the college can afford. The trustees still too often regard the graduate school as an expensive alien, and its demands in most quarters still receive scant attention. To train fifty investigators costs more than to give a thousand men a college education. The sciences cost more than the humanities, and the applied sciences, with their vast and changing array of machinery, are most expensive of all.

Equally unwise it seems to me, though less common, is the disposition to slight the college course for the sake of advanced research. Poor work, wherever done, leaves its mark of poverty. The great university of the future will be the one which does well whatever it undertakes, be it high or low. Better have few departments, very few, than that any should be weak and paltry. Better few students well taught than many neglected.

It is fair to judge a university by the character of its advanced work. Institutions can not be graded by the number in attendance. This is the most frequent and most vulgar gauge of relative standing. The rank of an institution is determined no more by the number of its students than by the number of rocks on its campus. What sort of men does it have and what are they doing? These are the living questions. Buildings are convenient; beautiful buildings have a great culture value. We should be the last to underrate the effect of the charm of cloisters and towers, of circles of palms and sweet-toned bells. But these do not make a university. Books are useful, they are vital to

research, but wiser men than we have ever known have grown up without books. Shakespere had few of them, Lincoln had but few of them, Homer and Jesus, none at all. Books serve no purpose if they are not used. The man who reads it gives the book its life. Specimens are inevitable in natural history. Apparatus is necessary in physical science. Collections and equipment are really the outgrowth of the men that use them. You can not order them in advance. Professor Haeckel once said bitterly that the results of research in the great laboratories were in inverse proportion to the perfection of their appliances. An investigation may be lost in multiplicity of details or in elaboration of preparation. Some men will spend years in getting a microscope or a microtome just right and then never use it. It is said that the entire outfit of Joseph Leidy, one of the greatest of our microscopists, cost just seventy-five dollars. It was the man and not the equipment that made his investigations luminous.

Publication is necessary, but it would be the greatest of mistakes to measure a university by the number of pages printed by its members. Much of the so-called research even in Germany is unworthy of the name of science. Its subject matter is not extension of human experience, but an addition to human pedantry. To count the twists and turns of literary eccentricity may have no more intellectual significance than to count the dead leaves in the forest. Statistical work is justified not by the labor it requires, but by the laws it unveils. Elaboration of method may conceal the dearth of purpose. Moreover, it is easier to string the web of plausibility than to recover the lost clue of truth. Of a thousand doctor's theses each year scarcely a dozen contain a real addition to knowledge. In too many cases a piece of research is simply a bid for notice. American universities are always on the watch for men who can do something as it should be done. Work is often done solely to arrest the attention of the university authorities. A professorship once gained, nothing more is heard of research. The love of novelty with the itch for writing often passes for the power of original research. The fanaticism for veracity has nothing in common with versatile writing or paradoxical cleverness. It took Darwin twenty-five years of the severest work before he could get his own leave to print his own conclusions. Other writers put forth sweeping generalizations as rapidly as their typewriters can take them from dictation. In certain works which have arrested popular attention, the investigations must have gone on at the highest speed attainable by the pen of the gifted author. Such work justifies Fechner's sarcastic phrase, 'cuckoo's eggs laid in the nest of science.'

The work of science is addressed to science, no matter if half a dozen generations pass before another investigator takes up the thread. The science of the newspapers is of quite another type, and so is much of the

science of famous men from whom newspaper science derives its inspiration.

While the university on its human side is interested in all that touches the life of to-day, on the scientific side it deals with the eternal verities and cares nothing for those things which are merely local or timely.

The university must conduct research to ends of power. This it has hardly begun to do in America. Half our graduate students are not ready for anything to be called investigation. They are not real students of a real university. The graduate departments of our universities are now engaged almost exclusively in training teachers. That profession may be the noblest—where noble men make it so—but it is only one of many in which success must rest on original investigation. We are proud of our crop of Doctors of Philosophy, dozens or hundreds turned out every year. But most of them are trained only to teach, and we know that half of them are predestined to failure as college teachers. We must broaden our work and widen our sympathies. We must train men in the higher effectiveness in every walk in life, men of business as well as college instructors, statesmen as well as linguists, shipbuilders as well as mathematicians, men of action as well as men of thought. This means a great deal more than annual crops of Doctors of Philosophy to scramble for the few dozen vacant instructorships open year by year.

But with all these discouragements original research is the loftiest function of the university. In its consummate excellence is found the motive for its imitation. There is but one way in which a university can discharge this function. It can not give prizes for research. It can not stimulate it by means of publication, still less by hiring men to come to its walls to pursue it. The whole system of fellowships for advanced students is on trial with most of the evidence against it. The students paid to study are not the ones who do the work. When they are such they would have done the work unpaid. The fellowship system tends to turn science into almsgiving, to make the promising youth feel that the world owes him a living.

All these plans and others have been fairly tried in America. There is but one that succeeds. Only those who do original work will train others to do it. Where the teachers are themselves original investigators devoted to truth and skilful in the search for it,—men that can not be frightened, fatigued or discouraged,—they will have students like themselves. To work under such men, students like-minded will come from the ends of the earth. It is the part of the investigators to make the university as the teachers make the college. There never was a genuine university on any other terms. It is not conceivable that there should ever be one. It is not necessary that all depart-



ments should be equal to make the university real. It was enough at Harvard to have Agassiz and Gray, Lowell, Goodwin and Holmes to justify the name of the university. Silliman and Dana made a university of Yale. Such men are as rare as they are choice, and no university faculty was ever yet composed of them alone, and none ever yet had too many of them. President Gilman has wisely said:

In the conduct of a university secure the ablest men as professors regardless of all other qualifications excepting those of personal merit and adaptation to the chairs that are to be filled. Borrow if you cannot enlist. Give them freedom. Give them auxiliaries. Give them liberal support. Encourage them to come before the world of science and of letters with their publications. Bright students soon to be men of distinction will be their loyal followers and the world will say amen.

The merit of a university depends on the men who are called to conduct it, upon them absolutely if not exclusively, for although the teacher must have such auxiliaries as books and instruments, books are nothing but paper and ink until they are read, and instruments but brass and glass until craft and skill are applied to their handling.

But it is in its men that the real university has its real being. Through the work of such men it stands in the vanguard of civilization. By such men it counts the milestones in its course, and no trick of organization, no urging of the printing press, no subsidy of students can be made to take their place.

A final word as to the practical side of advanced research. Mr. Carnegie once ascribed the foundation of his great fortune to the fact that he first employed trained chemists where other manufacturers chose workmen skilled in making steel by rule of thumb. His chemists were able to suggest improvements. They devised ways of making better steel, cheaper still, and at the same time of utilizing the refuse or slag.

In the future the success of each great enterprise must depend on the improvements it makes. The nation successful in manufacture and commerce will be the one richest in labor-aiding devices. All these must depend on the advancement of knowledge. Pure science must precede applied science.

Once the manufacturer or the nation could employ its chemists as it needed them. Now it must make them. The advancement of any branch of science depends on the mastery of what is known before. Everything easy and everything inexpensive has been found out. To train the chemist of the future, we need constantly finer instruments of precision for his advanced work; access to greater and greater libraries that he may know what is already done, for each generation of scientific workers must stand on the shoulders of those gone before, else it can make no progress beyond them. The scholars of to-day would be helpless were it not that they can save time by drawing freely on the accumulated knowledge of the past.

To learn the elements of any science costs little. It can be learned at one end of a log with a great teacher on the other. It can be even learned without a teacher. But to master a science so as to extend its boundaries—this is quite another thing. More than a man can earn in a lifetime it costs to make a start—for this reason a university which provides means for such work is a very costly establishment; for this reason the investigator of the future must depend on the university. The nation with the best equipped universities will furnish the best trained men. On the universities the progress in manufactures and commerce must depend. Through the superiority of training Germany is passing England in the commercial world in spite of her handicaps of position and history. Through the excellence of her universities, without most of these handicaps, America is likely to excel both Germany and England.

As men of science are needed, they can not make themselves. Those with power can help them. This fact has given the impulse to the far reaching gifts of Stanford, Rockefeller, Carnegie and Rhodes. These are not gifts but investments, put to the credit of the country's future. The people too have power. The same feeling of investment has led them to build their state universities and to entrust to them not only the work of personal culture, but of advancement in literature, science and arts. With general culture and professional training must go the advancement of knowledge, the progress of society, through the advancement of the wisdom and the power of man.

SOME OBSERVATIONS ON THE BEHAVIOR OF THE  
SOCIAL WASPS.

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LITTLE has been published concerning the social wasps since de Saussure wrote so interestingly of them nearly half a century ago. His work is justly regarded as a classic, but unfortunately it has become so rare that, nowadays, it is inaccessible to the average student, and accurate knowledge of the group, save that derived from an occasional disagreeable encounter with one of its members, is meager indeed. Moreover, the wonderful ingenuity displayed here, and among the highest Hymenoptera, the care for the young, and provisioning against the rainy day have served, not only to point a moral, but to credit these forms with an intelligence second only to the human. Even those who adopt a purely mechanical explanation of animal activities are inclined to except the bees and wasps. Mr. E. L. Thorndike, in his general conclusions concerning the nature of animal intelligence, makes reservations in favor of this group, while Mr. and Mrs. G. W. Peckham, in their admirable study of the solitary wasps, contrast them with the social wasps in the following terms:

The social Hymenoptera are born into a community and their mental processes may be modified and assisted by education and imitation, but the solitary wasp (with rare exceptions), comes into the world absolutely alone. . . . It must then depend entirely upon its inherited instincts to determine the form of its activities and, although these instincts are much more flexible than has generally been supposed and are often modified by individual judgment and experience, they are still so complex and remarkable as to offer a wide field for study and speculation.

The conclusions noted here, derived from the study of a group which is among the more primitive social Hymenoptera, may then be of interest as contributing somewhat to problems which are receiving anew the attention of both the naturalist and the comparative psychologist.

*General Account.*

In the tropics of the Old and New World, the family of social wasps or Vespidae comprises seven genera, but only three of these, *Polistes*, *Polybia* and *Vespa* are represented in the United States. Of these, *Polybia* is the smallest and rarest, being restricted to California and Florida; *Vespa* is widely known as our common hornet or yellow-jacket,

while *Polistes* is smaller and more timid and its colonies never reach such formidable dimensions as those of *Vespa*.

Here, as in the other genera, the colony consists of three kinds of individuals—males, females and workers or neuters, and is founded usually\* by a single female somewhat improperly called the queen. She, with perhaps several other females, is the sole survivor of a colony of the previous season, and has passed the winter in some warm crevice or sheltered corner. During the first warm days of spring, she may be seen seeking a suitable nesting-place and, this found, she begins the construction of the nest, which has the appearance represented in the accompanying figure. Each cell contains an egg suspended near its apex by the aboral end, and in the course of a few days this egg develops into a worm-like feeding larva. The queen works incessantly when the weather permits, increasing the number of cells, lengthening the cells already there and strengthening the stalk which supports the whole, so that when, at the end of six weeks—the first workers emerge, the nest may comprise as many as forty or fifty cells. From this time the workers gradually assume all the duties of the colony except the egg laying,† though, as far as I have observed, in a spirit‡ far different from that of the queen. Thus, one nest, which at the beginning of July was made up of forty-three cells, and represented the work of a single queen or mother, contained at the end of the season only one hundred and twenty-seven cells, the eighty-four additional cells being presumably the product of at least fifty workers which had emerged during the summer months. Toward the latter part of August and early September the males and females appear, and the nests are more and more deserted for the flowers and fruits of autumn. Here the males and females mate, the workers and males linger through the warmer days, while the fertilized females alone survive the winter and lay the foundation of the new colony in the spring.

#### *The Site of the Nest.*

This varies for different localities and to a certain extent in different species. In Wisconsin, where most of these studies were made, the

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\* The queens usually work singly, but in three cases two wasps were observed associating in the construction of the same nest. These may have represented a queen and a worker that had accidentally survived the winter. It is difficult to see how a partnership of queens could be formed, since the owner of a nest strongly resents the intrusion of another wasp, expelling her from the scene with the utmost ferocity.

† The careful researches of Siebold and Marehal show that even this function is assumed by the workers in case of the death of the queen.

‡ In writing a paper of this nature it is somewhat difficult to avoid misleading 'anthropomorphisms,' and it may be well to state once for all that the occasional use of expressions similar to the above is purely figurative and for the purpose of avoiding awkward circumlocutions.

preference seems to be for the sloping under side of old roofs, eaves and the protected casements of windows. Indeed, so strong has been the attachment to certain sites, that I have several times seen the wasps suspending one comb from another in the style of architecture characteristic of the hornet. In New England *P. pallipes* builds in the open on wild rose bushes and other low shrubs, in protected recesses of stone walls, while a tin can, a water pipe perforated by rust and a sheep's skull are other nesting places which have come to my notice. At Willow Grove, Pa., great numbers have made use of the space enclosed by the sheet-iron water-table of a new car barn, thus securing a maximum of warmth and immunity from the zealous wasp hunter. In Texas, I am told, certain species build on the cacti, while others prefer stone ledges; and doubtless further observation will disclose many other interesting variations in the nesting habits.

#### *The Nest and its Construction.*

The nest, as is well known, consists of a single layer of hexagonal paper cells. It is modeled from a soft gray pulp which is a mixture of fibers of weather-worn wood and a secretion from the wasp's mouth. The little ball of semi-fluid pulp is applied roughly by means of the fore legs, all along the edge of the cell to be extended, making an irregular addition about four times as thick as the cell wall. The wasp then walks back and forth for two or three minutes continually touching the material with her antennæ, and with her mandibles pats and smooths it into shape. This operation extends the wall each time from one eighth to one fourth of an inch, depending of course on the size of the ball of material at the beginning. In addition to this, the wasp applies a glutinous secretion which renders the paper tough and waterproof, the nests built in the open being more thickly coated than those sheltered from the rain and dew.

The geometrical sense of the bees and wasps has long been a matter of controversy. In *Polistes*, so far as I have observed, the first cells always approach a circle in cross-section, and the six-sided form is the result of the flexibility and the consequent compressing of the walls. Once pressed into shape, the material added may take the same form, and the artificer appears to possess a superior mathematical sense; but that the cells are not intentionally fashioned thus may be seen by examining those first formed, or those comprising the margin of the nest at any later stage of construction. These are always circular in outline.

#### *The Care of the Young.*

The larvæ, which develop in a few days from the eggs, are fed from this time until the beginning of the pupal stage both with nectar and proteid matter. The nectar is obtained from flowers, is stored for a

time in the crop of the mother or the nurse, and then regurgitated into the mouth of the larvæ. This process may be easily watched in the case of captive wasps. They nearly always make the round of the cells containing feeding larvæ some minutes after partaking of the sugar solution provided as their store of food. The animal food consists of caterpillars which have been worked by the mandibles into a mass about the consistency of marmalade.

This wasp does not sting her prey. Her habit is to seize the squirming caterpillar in her fore legs, pass it back and forth several times between her mandibles until it is quite limp and dead, and then to roll it deftly into a ball and hold it between the fore legs while she flies to the nest. There, the operation is continued three or four minutes longer, until the malaxation is complete. In distributing the food, the mass is held firmly against the ventral side of the thorax, by means of the femora of the first pair of legs and a bit partly pinched off with the mandibles. Next, the wasp inserts her head into a cell, lightly touches the larva with her antennæ, causing it to stir and open its mouth, and then pushes the bit of food into the mouth with the tarsal joints of the fore legs. With the remainder, the wasp now passes to another cell and the process is repeated until the ball of food is used up. Observations on the social Hymenoptera indicate that the polymorphism occurring here is in large measure dependent on the kind of food given to the larvæ. So far I have no evidence that *Polistes* exercises any selection in the quality or amount of food furnished the larvæ which are to develop into the various members of the wasp community.

The foregoing constitute the chief activities of *Polistes*, but several other minor performances may be briefly noted. Among these are the stroking and rubbing movements which serve to keep the body clean. They are chiefly six in number: (1) Hanging by the four posterior legs, while doubling the first pair backward over the head and repeatedly passing them forward over the face and antennæ. The latter are thus drawn between the tibiæ and the spurs which these bear on their distal ends. (2) Drawing the first pair of legs alternately between the mandibles, and thereby removing any foreign substances accumulated by them during the first step of the process. (3) Doubling the first pair of legs as above mentioned and passing them backward over the dorsal surface of the thorax and the bases of the wings. (4) Hanging by the two anterior pairs of legs and passing the hindmost pair backward over the abdomen and the folded wings. (5) Suspending the body by the first pair of legs and drawing each of the others in turn between the tibial spurs of one of the remaining legs. (6) Drawing the wings alternately on each side between the abdomen and the hindmost leg of that side. These are sometimes gone through in the order given, but not necessarily so; some of the steps may be altogether

omitted, although the movements of the anterior usually precede those of the posterior appendages.

Then the wasp makes frequent careful inspection of the cells of her nest. She may return every few minutes in the interval of her other activities apparently for the sole purpose of satisfying herself that all is well. To test the wasp's power of observation I have several times cut away a bit of the cell wall. In one case, the mutilation was immediately detected and an attempt made to repair the breach. Once, one of the eggs was replaced by one from another nest. When, in the course of the customary examination, this cell was reached, the wasp paused, gazed long and fixedly, as if unable to believe the evidence of her senses, and then with signs of great agitation, cleaned the cell out and deposited a new egg of her own. To ascertain whether the mucilage by which the egg was attached was the exciting cause, several eggs were smeared with it and left in their original positions. In this case the mucilage was carefully removed, but the eggs were left untouched.

*Polistes* is said also to store honey in the cells from which the perfect imagines have emerged. In the height of the season these cells are used a second time for the development of the young. They are then carefully renovated before the egg is deposited. I have never yet found honey stored in the nests taken, but in two nests which were kept indoors for the purpose of experimentation, many of the cells were found to contain a few grains of perfectly transparent sweetish substance which undoubtedly had been elaborated from the sugar solution forming the food store of the little colony.

#### *The Larval and Pupal Periods.*

The sole activity of the young during the three weeks' larval period appears to be the feeding on the elaborated nectar and proteid matter furnished by the mothers or the workers. At the end of this time the larva spins a silken lining and a covering for its cell. This is done by passing the head from point to point of the cell wall while a glairy fluid issues from its mouth and hardens into a delicate silken thread. I have noticed a considerable difference in the form of the cell covering. Under normal conditions, the cell is lengthened by the workers or queen to suit the increasing size of the larva, but in captivity the wasps cease the work of construction though they may still continue to feed the larvæ. The cell is therefore too short for the full-grown larva. In such cases it not only lines the cell but extends the wall with the same silken substance, finally capping it with a dome-shaped cover. This apparent forethought on the part of the larva is entirely accounted for, when we see that in spinning its cocoon the larva begins near the bottom of the cell, gradually approaches its mouth and finally stretches as far as possible beyond it. If the cell wall is already sufficiently

extended, this serves solely as a lining, if not, as, in part, extension to the original cell, providing the space necessary for the metamorphosis.

During the three weeks of the pupal period the pupa is quiescent, except for occasional twitchings of the abdomen. About two days before emergence the muscles of the appendages begin to undergo periodic contractions, which carry the pupa to the end of the cell, and rotate it to some degree. At the same time the jaws become functional, and the continued action results in the removal of the lid of the cell and the emergence of the wasp to assume its share in the duties of the wasp community.

*Behavior of the Newly Excluded Worker.*

The study of the newly excluded wasp is extremely interesting and throws some light, I think, on the character of its mental activities. There is at the outset considerable variation observable in its actions. Sometimes the little worker does not take the trouble to cut the lid of its cell entirely away, occasionally it not only cuts away the lid, but neatly trims the edges of the cell, and very rarely it pushes its head into the cell, as if to satisfy a curiosity concerning the place whence it has come, even making comparisons from the contents of neighboring cells. But I question whether this performance is rewarded by any intelligence.

Emergence accomplished, there ensues a period of quiescence, which for the most part is passed on the back of the nest, and which is probably necessary to the proper hardening of the tissues. Meanwhile the queen does not cease her labors, but makes it her first duty to clean out the cell left vacant by the newly excluded imago and lay an egg in it. Returning, perhaps, a little later with a ball of food, she thrusts it into the face of the worker, but no notice is taken of it, and she proceeds alone with the work of malaxation and distribution. This may be repeated several times before the young worker finally accepts the urgent invitation to take up its family responsibilities. There is no doubt that the worker sees what the queen is doing, and when, after apparently watching her go through the process of malaxing and dispensing the food several times, it comes up to take part of it and do the same, the inference is perfectly natural that the worker is imitating its mother. This idea is strengthened when we observe that it takes the young one about three times as long as its mother, to accomplish the task of feeding, and that there is great uncertainty displayed in offering the food to the larvæ. The young worker is apt to waste much time in poking its head into the wrong cells, and running unnecessarily about over the face of the nest.

To test whether the worker learns to do its work by imitation, I removed one nest, whose founder was missing, to a place half a mile distant from any known nest before any of the workers had emerged.



After the appearance of four workers, fresh caterpillars were repeatedly offered them. Two weeks passed before this met with any response, whereupon one day they all surprised me by coming up and very eagerly preparing and distributing the food. I have since made sure that the nursing habit is entirely independent of the example of the mother and, further, that its appearance is to some extent variable for different individuals.

In the experiments conducted the past summer, bits of the larvæ of the Ribbed Rhagium, a beetle whose eggs develop under the bark of decaying trees, were offered at intervals to the newly excluded neuters before they had had any association with others of their kind. With slight exception, great trepidation, or rather movements which I interpret as indicating fear, was shown at the first appearance of the morsel. The wasp retreated precipitately from the proffered morsel, sometimes turning and running away in the wildest manner imaginable. But usually when the bit had been presented for the fourth or fifth time (at intervals of one half to one minute), the wasp would no longer back or run away, but stop and look at it. The next action was to touch it with the antennæ and finally it was seized and disposed of in the customary manner. Usually the experiment met with success in the way described if performed any time after the first half day of imaginal life. But I have seen a worker not four hours old spontaneously go through the same reaction while others waited several days before manifesting the instinct.

The whole process seems to be a reflex called forth by the presence of the food, and an important factor in calling it forth is hunger on the part of the wasp. It is highly probable that in the crushing process liquids are extracted from the mass, which are swallowed by the wasp. I have frequently seen them *chew at* morsels without molding or mixing them, and even dropping the mass to lap up the liquid which had exuded from it. Once started, however, the reflex unfolds in the natural order, first the crushing and molding, then a slow marching round the nest with frequent pauses, and, if larvæ are present, the pinching off of the food bit by bit until all has been disposed of. If no larvæ are present, if, for instance, the young worker is living in an inverted tumbler and has never seen a larva the various stages in the process are the same. It will run searchingly over the glass and pause every few seconds to thrust the ball against it. This naturally meets with no success and the food is again worked over and the process repeated, perhaps several times, before the bit is dropped and not again noticed. Very rarely the wasp will attempt to fly with its burden, although naturally, since it has had no association with a nest or larvæ, it flies nowhere in particular. These observations remind one strongly of Faber's experience with the mason-bees which, when their half-built

nest was replaced by one that was finished, went on building until it was half again as high as it should have been. In *Polistes* it seems that the very success with which these first unfoldings of the feeding instinct meet, serves to stamp it into a useful habit. If the worker is at home, with the feeding larvæ at hand to seize the proffered bit, all goes well, and it becomes henceforth an efficient member of its community. But remove it, and so interfere with the normal unfolding of the reaction, and the wasp soon disregards the food altogether or contents itself with a few perfunctory turns and squeezes.

Not that the wasp has any idea of performing a service for the benefit of its kind. I have seen a young neuter gnaw a piece out of the side of a dead wasp larva fallen from its cell, and turning, offer it as food to the mouth of the self same larva. More than this, I once observed a neuter attack a live larva and, after she had cut out and crushed a fair-sized piece of its body, come back eight times in the course of her examination of the cells of the nest to this larva, which had naturally died in the operation, and offer it this part of its own body with the evident expectation that it would be seized and eaten. The eighth time she dropped the piece on the face of the dead larva and went away with an air of 'duty well done' which was comical to behold. There can be little doubt that the normal repetition of the reflex perfects it, so that finally the process is quicker and easier than at first; and in this sense the little worker learns, but thus far I have had no evidence that it gains anything by the example of its elders.

One other note on the feeding habit may be of interest. Throughout the social Hymenoptera the male is the drone of the colony and usually among the solitary wasps the work of excavating or otherwise constructing and storing the nest devolves entirely on the female. Mr. and Mrs. Peckham recount cases of cooperation of the male with the female of *Trypoxylon* to the extent of guarding the nest and even taking the spiders as they were brought by the female and packing them properly away. In one colony under observation this fall, the males eagerly took portions of dead larvæ from one another, and crushed and turned them in their mandibles; and, in one instance, when the malaxation was complete, one of them carried it over the nest in the same searching manner as the female, and finally fed it to a larva. This is the only recorded instance among the Vespidæ known to me, but it is likely further careful observations would show similar aberrations of instinct.

#### *The Locality Study.*

Several days usually elapse before the young *Polistes* makes its first essay into the world. When it does appear, the impulse to fly is strong, though in most cases it soon spends itself. That is, if in captivity, the wasp will repeatedly beat itself against its prison walls and steadfastly

refuse to perform any of the reflexes it may have shown prior to this time. If at liberty, the impulse usually carries it a short distance, perhaps two or three feet from the nest, where it spends a considerable amount of time running about in an inquiring way. This alternation of short flights and strolls may last for an hour or more, and the wasp extends its examination of surrounding objects to some distance, before it returns leisurely and as if by accident to the nest. There is no such apparent purposefulness in the procedure as has been described for the solitary wasps.

The social wasps seem to fly because they feel like it, and the flight is not long because at first it is exhausting. Then follows rest and a stroll, because strolling is easier than flying; then, after another period of repose, perhaps another flight, until a period of this aimless wandering brings it back within reach of the distinctive odor of the nest, whereupon it returns to the accustomed place. Occasionally, the little wasp gets lost in these first casual ventures, and it is not improbable that some wasps become wanderers from the very beginning.

Unquestionably, being on the nest brings about a state of satisfaction analogous to that evinced by Mr. Thorndike's chicks when they had rejoined their mates. I have several times put a nest in a glass jar where wasps were confined, and when, after fifteen or twenty minutes' wild buzzing and running about, they accidentally came in contact with it, their behavior was, at once, entirely changed. They became quiet and observant, and soon showed a disposition to go on with their usual activities.

It is somewhat difficult to suggest to what this may be due. The nest has a faint characteristic aroma resembling that of wild honey, which becomes very perceptible when it is confined in a small space. Both the manner of using the antennæ and the behavior of wasps in which one or both of these organs have been excised indicate that sense perception by means of them is an important factor in orientation. Within certain limits, the odor of the nest may then serve to guide the wasp and modify its activities when it reaches home.

It may be profitable here to reflect on the factors of the extremely useful feeding habit. The whole appears to be a complex of reactions which are at first quite separate and distinct. The first step is the perfection of the process of malaxation and distribution of the food, and is taken before the wasp feels the impulse to leave the nest, or has had any opportunity of finding food for itself. Next comes the familiarizing with surroundings. This at first has apparently no relation to food-seeking, yet in course of time, and aided probably by the olfactory sense, the wasp naturally comes upon something edible, and, after extracting the juices, it may well be that it tries to distribute the food on the spot. This being impossible, there is a second alternative,

that is, to fly, and, if flight takes it back to the nest, the rest of the procedure is probably carried out. Repetitions of this chain of actions causes it to occur oftener and with greater constancy, until the habit in all its complexity is well established.

It is well known that usually the wasp flies straight out from the nest, and does not return by the path it took in leaving. And while it appears that the first 'locality studies' are the desultory wanderings just described, there are nevertheless circumstances where *Polistes* makes the swift survey of the objects surrounding her nest, which has been described by Mr. and Mrs. Peckham for many of the solitary wasps. I observed this in numbers of instances where the wasps were set free after having been left in captivity long enough to habituate themselves to their new surroundings.

One nest with four workers was brought into the laboratory and established in a large glass cylinder, with a supply of food and weather-worn wood, so that they might go on with their activities if so inclined. They soon ceased their attempts to escape, and by the end of a week were attending to the wants of the larvæ in the usual manner. The glass plate from which the nest was suspended, was then moved to one side so as to leave an opening of several inches, but the wasps not perceiving this after several trials, the whole was carefully lifted out and rested on two supports, so that the wasp would find itself free if it flew six inches in any direction. Following is an account of a typical locality study transcribed from my notebook:

11:10. Freed nest (way already indicated). One of the wasps has flown out from the nest, hovers above it at a distance of twelve inches, and rising to the ceiling hovers there for some seconds. During the next six minutes descends to hover and circle within six inches of the nest, and, a second time, comes within two inches, without, however, alighting on it. First, flies round with its head directed toward nest, then turning, circles with its head away from the nest. This performance is repeated, and at 11:10 it alights on the glass, from the under side of which the nest is suspended, and for twenty seconds it beats its head against the glass. Rising, it explores first the upper, then the middle section of the room. Rising to the ceiling once more, hovers there and then descends to rest on glass as before. Spends several minutes exploring the room, and, returning, hovers for a few seconds before dropping upon the nest.

This is a fairly representative procedure, though there is great individual variation in the number and character of the circlings and the amount of search necessary in finding the nest after the more distant parts of the room have been visited.

Although no lengthy series of experiments was carried out with the same individual, those that were made show a decrease in the number and minuteness of the circlings proportional to the number of times the wasp so left the nest. The wasp never returned to the nest along

the path by which she had left it. Experiments were also made by moving the nest as soon as the locality-study had been made, and seeing whether the wasp returned to the place where the nest had been. Invariably the wasp did return to the exact former site of the nest, but considerable variation was shown in the ability to find the nest in its new location. One wasp had no difficulty, when the nest had been moved a distance of eighteen inches; others were unable to do so if moved more than eight inches. In one instance, the site of the nest was changed while the wasp was sipping honey from a dish about fourteen inches away. Returning, and not finding its nest in the usual place, the wasp, in circling, reached the honey dish once more, and again started for the nest along essentially the same path. This was repeated eight times before the wasp in its explorations finally reached its nest and rested there. The whole performance looked as though the wasp were consciously using the honey dish as a landmark. It started out from this point each time, the same way as a person might, when he became aware that he was making some mistake in finding his way to a desired destination.

It would be interesting to speculate on the meaning of the various actions described above. What sense best serves *Polistes* in finding its way about? Does it actually see and make a mental note of the various factors of its environment? Or does a mere blind following in response to other sense impressions, namely, the olfactory, serve its purpose? Theory is fascinating, but with the slight data at command, it is hardly profitable. Observation shows that the wasp instinctively flies toward the light; its course is also materially affected by currents of air, such as draughts in a room where it is held captive. Mechanical response to these two influences will, in this case, usually serve to liberate it without the use of any other sense or faculty. Again, the antennæ seem to play an important rôle in orienting the insect. Accidental loss of one antenna in one case retarded the finding of the nest. Further, the flight in circles, when leaving or approaching the nest, might be interpreted as due to the difference in stimulation of the antennæ of the two sides—the side toward, and the side away, from the nest; and the flight straight to the nest, when the wasp has poised for a moment with both antennæ directed toward the nest, seems to add evidence in favor of this view. However, further experimentation is necessary before it is possible to attempt a satisfactory explanation.

During the cold days of autumn, when there are no more larvæ to rear, about the only activity observed on the nest is that occasioned by the home-coming of a member of the wasp family. This one is tumultuously set upon by the half dozen wasps nearest him, each of which is favored with an embrace which is amusingly like the affectionate demonstrations shown on the return of a human being to his family

fireside. Here, however, the attentions are lavished, not only on the newcomer, but on those who were the first to meet him, and plainly the meaning of the whole performance is simply the distribution of nectar by one of the wasps which has just returned from a foraging expedition. Earlier in the season, this nectar is regurgitated into the mouths of the feeding larvæ, but in their absence it is stored in the cells or serves directly as food for the adults.

Finally, I think the habits *Polistes* acquires may bear a decided relation to its rhythm of activity and repose. If we watch any wasp community, we see that periods of general sluggishness alternate with furies of activity and, in the case of the individual, any marked exertion is always promptly followed by great quiescence. Of course, what actually happens to the nervous system when impressions are fixed and habits formed is largely a matter of conjecture. But in the establishment of any reaction, it is generally thought that the repair of the nervous element is quite as important as the change which it undergoes while the reaction is taking place. And it would seem that the delicate nervous organization here implied would lend itself readily to the 'stamping in' of reactions or trains of reactions. That is, a particular performance, once called forth, would the more readily occur had a period of repose prevented the reception of any intervening impression and brought about the restitution of the nervous mechanism affecting the reaction in question.

The period of repose on the nest is usually terminated by one of the wasps starting up and commencing an examination of the cells of the nest. Others immediately follow suit, until the whole colony is in a tumult. But it is not the example of the first wasp that is responsible for this, only the external stimulus furnished the sleeping colony by the movements of the first wasp on the nest. Simple tests prove this. Godart relates how the colonies of *Bombus* have a trumpeter-bee, whose duty it is to rouse the colony to work in the morning. If this bee is removed, another takes its place the following day. An observer of a wasp colony might easily believe that similar duties had been delegated to particular wasps. But here, and probably in the case of *Bombus*, it is the fact that any external stimulus, such as a loud noise or jarring the nest, produces the same effect. The wasp examines the cells not because it is aroused to a sense of duty by seeing what the others are doing, but because this is the habitual response whenever it is gently stimulated while on the nest, by any means whatever.

In summarizing these observations, it may be said that, although they are perhaps hardly extensive enough to warrant definite conclusions concerning wasp intellection, they nevertheless indicate several things:

1. All wasps possess the instinct of fear. This is especially strong the first few days after emergence, but is readily overcome by the frequent appearance of the awe-inspiring object.

2. The feeding instinct is evidently called forth in response to olfactory impressions. These responses become more precise as they are repeated.

3. Once established, under favoring conditions separate reactions combine to form complex habits.

4. In a sense, the wasp remembers. This is indicated by the manner in which it accustoms itself to the sight of strange objects, and by its behavior when a change is made in its nest or surroundings.

5. It shows considerable individual variability, both as to time and manner of its response to stimuli.

6. Wasps do not imitate one another. Instinct and individual experience account sufficiently for their powers, and their apparent cooperation is due entirely to the accident of their being born on the same nest.

## FIELD NOTES OF A GEOLOGIST IN MARTINIQUE AND ST. VINCENT.

BY DR. THOMAS AUGUSTUS JAGGAR,

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“So late as 1851, Mont Pelée burst forth furiously with flames and smoke, which naturally threw the people into a serious panic, many persons taking refuge temporarily on board the shipping in the harbor. The eruption on this occasion did not amount to anything very serious, only covering some hundreds of acres with sulphurous débris, yet serving to show that the volcano was not dead, but sleeping. Once or twice since that date ominous mutterings have been heard from Mont Pelée, *which it is confidently predicted will one day deluge St. Pierre with ashes and lava, repeating the story of Pompeii.*” M. M. Ballou in ‘Equatorial America,’ Houghton, Mifflin, 1892.

THE extraordinary accuracy of the above prediction, printed ten years ago, has been forced upon the world’s attention recently by the sad story that the newspapers have told of the volcanic disasters in the Caribbee Islands. The following notes and the accompanying illustrations were collected hastily in the field after a month spent in incomplete study of the two volcanoes and their effects. Such notes necessarily contain inaccuracies; they may be more accurate, however, than many of the fairy stories that have gained currency in the dailies, and if I succeed in correcting some false impressions that have gone abroad about the meaning of these eruptions from the scientist’s standpoint, I shall accomplish all that is necessary prior to more complete and accurate publication as the product of laboratory research at home. When the first news of the explosions reached America the newspaper accounts proved marvelously accurate; when half a hundred correspondents reached the field the degree of accuracy waned—probably directly as the public interest, which needs fiction to keep it alive. It is to be hoped that when the magazine stage of recording the Caribbean eruptions is reached, the truth curve will rise once more and the facts assert themselves. Even here—I write from Barbados—the most remarkable statements are solemnly believed; victims were found with their intestines charred and the outer skin untouched; a man was found seated on the box seat of a carriage in a lifelike position, twirling his moustache; scientists assert that the whole island of Martinique is likely to blow up at any minute, and great rents traverse the island from end to end; St. Vincent is in flames, a hundred minor craters have broken out, not a living green plant persists on the island and vessels cannot land; Ameri-



can scientists say that these eruptions have no parallel in history, and the electrical and gaseous phenomena make them unique—these and a hundred other similar statements have absolutely no foundation in fact, while other most interesting details have passed unnoticed. The fault,

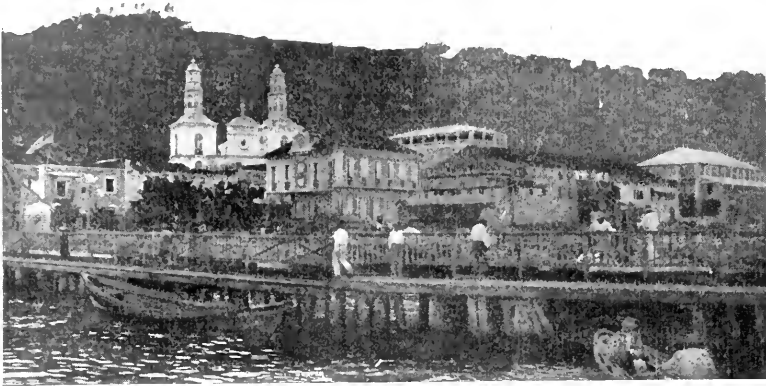


FIG. 1. ST. PIERRE. SHOWING THE AMERICAN CONSULATE AND THE CATHEDRAL AS THEY WERE BEFORE THE ERUPTION.

however, does not rest with the correspondent; it rests with those at home who 'cook up' cable despatches, and with those living in the islands whose nerves are gone and who are thereby in an overimaginative frame of mind. Thus while I was occupying a beautiful little villa under the leeward slopes of Soufrière, a small thunderstorm broke about



FIG. 2. ST. PIERRE: THE SAME GENERAL VIEW AFTER THE ERUPTION OF MAY 8, 1902.

midnight over the mountain—thunderstorms occurred nearly every day. It was described next day as follows in the local paper:

At about three o'clock in the morning, May 30th, whilst the moon shone in dazzling splendour, an enormous silvery cloud rose from the Soufrière, and immediately afterwards roars, which in all probability issued from the crater,

once again awed the inhabitants. The cloud ascended majestically to a great height and was lit at close intervals by flashes and streaks of red lightning. It is reported from Cumberland that ashes fell from the eruption this morning.

With such an account ten miles from the scene of action, it is not remarkable that the story has lost all semblance of truth when it reaches New York.

When the scientists were embarking on the *Dixie*, they were constantly asked 'Well, doctor, just what do you expect to do when you get to Martinique?' It was at that time a difficult question to answer, but may now be answered by telling briefly what we have done. The

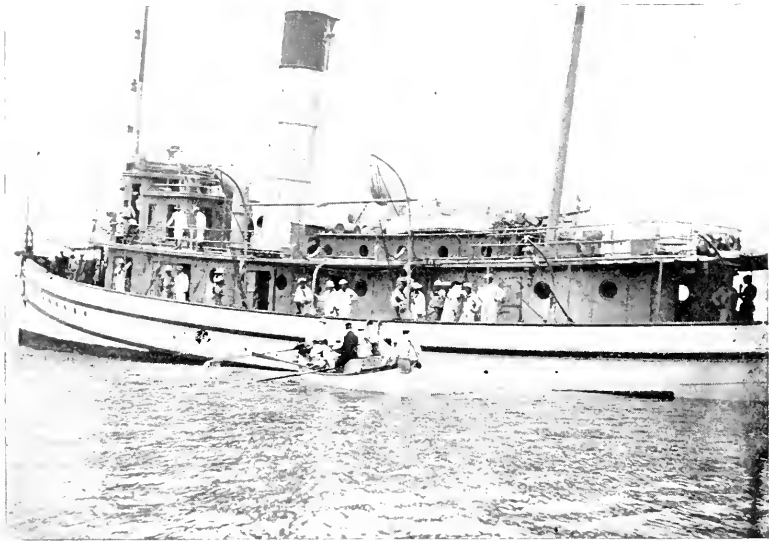


FIG. 3. ST. PIERRE: U. S. TUG POTOMAC IN THE HARBOR, MAY 19, 1902, starting to search for the remains of Consul Prentiss.

*Dixie* arrived at Fort de France at daylight, May 21. At 10:30 that morning a party of officers, scientists and correspondents were taken on the *Potomac* to St. Pierre and landed. The second great eruption of Pelée had taken place the day before, so that every one was on the alert, and we were warned by Lieutenant McCormick, commanding the *Potomac*, that if the tug's whistle blew we were to make for the boats at once. We wandered through the dreary ruin, which has been described. I was impressed by the completeness of the destruction of the masonry and the absence of visible large volcanic fragments. The streets were filled with masonry rubble, mostly rounded sea-worn boulders, and everything was coated with green-gray powder or sand. The roofs were gone, an occasional timber was burning, bodies were still numerous if

one went into the houses and looked for them. There was a baby in an iron cradle, a man face downward in a tank, and a man lying on his



FIG. 4. ST. PIERRE: RUE VICTOR HUGO, the main thoroughfare of the city, before the eruption.



FIG. 5. ST. PIERRE: RUE VICTOR HUGO NOW.

back in a deep baker's oven. One of the party found eight or ten bodies crowded together at the foot of the cliff. The end of the town toward

the volcano is deeply buried under fallen sand or gravel—the southern end has a covering of only a foot or two. There is a great change in the aspect of the city now, since the later eruptions, from the condition shown by photographs immediately after the destructive blast of the eighth of May. It seems agreed by those who witnessed the eruptions that the explosion of the twentieth was greater than the first one. In any case, the second blast demolished third stories and leveled the second belfry of the cathedral—the heap of beautiful bells, the chimes ‘whose soft, liquid notes used to ring across the water of the bay with touching cadence at the Angelus hour’—they lie tumbled in rubbish, splinters and steaming vapors, their ancient engraved inscriptions half buried in dust. The bodies found were mostly shriveled to a crisp—this too was in part the effect of the second hot blast of the twentieth, for many of the bodies found earlier were described as being not much altered, and some such are shown in the accompanying photographs. The odor was not especially bad, but it is a haunting smell that one dreams about afterward; it is a combination of foundry and steam and sulphur matches and burnt things, with every now and then a whiff of roast or decayed flesh that is horrible.

I had returned over the heaps of rubble along the Rue Victor Hugo, the main street parallel to the water front, to a point not far from the landing, and looked about me. It was impossible to realize that this ruin had been a thriving French city just one fortnight previous; literally not a roof was left the whole length of the city for two miles, and scarcely a timber; nothing but twisted iron and masonry and corpses. Here and there steam rose through little holes in the wet brown sand over a pile of cobbles, and a sickening whiff of it showed whence it came. I found a dead cow in a back stable-yard, and a lot of children’s toys, and the dishes set on a dinner table; but one must needs search for these things. Almost everything is buried under fallen walls. The tropical architecture, almost wholly cobblestone masonry and pink plaster, with open courts, alleyways and inner gardens, strongly suggests Pompeii; a wooden New England town could not have persisted three hours in the presence of the giant blowpipe that destroyed St. Pierre; it would have been simply burned up and blown away as ashes. The timbers of St. Pierre are practically gone. I looked toward the gray old volcano, whose summit was shrouded, but the lower slopes were sunlit and silent and powdery; the whole landscape is powdery, like old statuary with a dust coating that makes stronger the modeling of the city; mountain slope and cliff are bare, the verdure of the Carbet hillside ends abruptly along a sharp line, and there begins the new volcanic landscape, clean chiselled, rocky, weird, gray, uniform, without any color, without any motion except steam-

jets on Pelée's slopes. But look! What are those steam-jets doing? There were one or two along the sea-front when we landed, but now there are eight, ten, twenty, and they are spurting higher all over the slope. Dr. Church was standing near me and saw me watching them. We did not either of us like the look of it. Now there were about forty, like so many ghostly locomotives that had run out from their tunnels in the volcano roundhouse and were all getting up steam at once. White-coated officers and men of science were to be seen in groups here



FIGS. 6, 7. ST. PIERRE: VIEWS OF THE CITY, showing the dust-covered ruins.

and there far away among the ruins and on the higher walls and slopes, but they were under the cliffs out of sight of Mont Pelée. We looked towards the *Potomac*; yes, she had seen it too, and a white steam-jet from her preceded the sharp blast of her fog-horn as she sent out a quick-repeated summons for all to return at once. Pell-mell they came tumbling to the water front and there was always someone else who had not turned up yet; the white-coated jackies were in place and the boats started from the shore. No sooner were they clear of the



FIG. 8. ST. PIERRE: INTERIOR OF A HOME. Woman, girl and boy. The living figure is Dr Haven, U. S. Consul at St. Kitts. Photograph taken May 19, the day before the second great eruption.



FIG. 9. ST. PIERRE: A VICTIM.



FIG. 10. ST. VINCENT: ONE OF THE INJURED.

landing than two more figures appeared and we had to put back for them. Meantime the mountain was sending up clouds of steam from all over its slopes as though it were rifting in a hundred places preparatory to a titanic outburst. But it did not do anything, and I now strongly suspect that what we saw was the product of a smart shower over the mountain from the clouds lowering on its summit. The cool water rills running down the slopes come into contact with beds of hot dry gravel previously thrown out. Wherever such a contact is made a jet of steam at once is formed; we had opportunity to see much of this action later on at St. Vincent, and it is this process that has given rise to many stories of small craters forming.

We spent another day among the ruins, exploring St. Pierre to the mountain slope at its northern end and to the steep roadways that climb the southern cliff. The city was in a *cul de sac*, hemmed in by a cliff south, a higher cliff east and the ocean west; its northern end was on the actual foot slope of the volcano. The present crater was blown clear of clouds as we steamed past and we saw a cup on the summit open to the west, walled in on the east, with a huge pile of sealy looking hot bowlders in its midst steaming violently. At the distance from which we saw it, it was estimated roughly that the cup would measure perhaps 2,000 feet across by 800 feet deep. This crater ends in a deep gulch west that extends down to the sea; old photographs show that this gulch was there before the present eruptions. Apparently it was down this gulch that the mud flood came which overwhelmed the Guerin factory. All along the foot of the mountain are steaming fan-shaped deltas of débris, and far up the slopes these are matched by leaf-shaped arroyos or deep trenches hollowed out of the old earthy volcanic beds of which much of the island is composed. This trenching has been accomplished by the cloud-burst torrents of water laden with grinding sand that fell during and after the eruptions—in part condensed steam and in part heavy rains that recently have been exceptionally abundant. Much of the material which fell in the first outbursts of probably both Pelée and Soufrière was dry and red hot; it was relatively fine, the largest fragments falling near the vent. The grades of the hillsides were already steep and it is probable that this material flowed somewhat like dry sand. This, if seen at night, would account for the reports current of glowing molten lava on Pelée. When I was in Martinique there was no sign of molten rock, nor have I seen any in St. Vincent, and the greater part of the evidence at present makes these eruptions purely steam explosions which have blasted out and comminuted large quantities of the old country rock, or bedrock of the islands, itself an ancient volcanic product.



FIG. 11. ST. VINCENT: THE SOFFIERE VOLCANO AND THE STEAMING GRAVEL BEDS OF THE WALLIABOU RIVER, LOOKING N. E. The steep sea-cliff's shown are the product of submarine landslips. Under the 15 feet of sand, gravel and boulders heaped in the foreground, Richmond Village is buried. This corner is the St. Pierre of St. Vincent in location and effect of the explosion. Note the coating of wet sand above the fiery gravels up the Walliabout and at its mouth. Photograph taken by C. Taylor of St. Thomas, May 31, 1902, the day of the ascent of the leeward slope; the climbing party were on the crater's edge when this picture was taken.



On the 23d of May the *Dixie* landed us and a goodly store of supplies for the sufferers, at Kingstown, St. Vincent. There I left her, in company with Dr. Hovey and Mr. Curtis. It was with deep regret that we parted from Captain Berry, whose splendid hospitality had made the entire voyage a pleasure that all the guests on the ship will never forget. It was really the first parting from American territory, for on a man-of-war one feels rather safer than on land. Good friends sprang up, however, among the hospitable English colonists, and supplies, houses, servants and horses were furnished us before we could ask for them. The government supply steamer *Wear* was on several occasions placed at our disposal, so that we coasted around three fourths of the shores of St. Vincent before going into the interior at all. We saw the Soufrière in partial eruption in clouds and rain; we landed at Georgetown on the fatal windward coast and visited the hospitals, where opportunity was given for interviews with the scorched victims of the explosive blast of hot cinders that had burned faces and ears and hands and feet, but curiously failed to burn clothing or houses. The hot sands, when they fell on these people, seem to have been at a temperature hot enough to inflict scalding wounds, but not hot enough to ignite anything or burn through coverings. On May 29 we proceeded in a long dug-out canoe rowed by five stalwart blacks to Chateau Belair, and from that point explored the west coast of the volcano proper and made a successful ascent to the edge of the great crater on a brilliantly clear day. The following week we made a similar ascent from the eastern or windward side, but reached the crater's rim in a most unpleasant black fog after a rather perilous climb along precipitous wastes. After two weeks of most instructive work at St. Vincent, I came to Barbados, ninety miles to windward, to learn something of the dust which fell here in showers on the evening of the Soufrière eruption. This completes the itinerary of the writer to this date.

The devastation at St. Vincent does not appear especially different from that at Martinique. The human conditions were different and the destruction of property wrought by the first eruption was much more widespread. In this respect, and from the size of the crater and greater diffusion of the dust, it seems certain that the Soufrière eruption was phenomenally much more violent than the eruption of Mont Pelée. The crater is more than twice as large as that crater of Pelée which I saw on May 21; the dust-fall has been reported from Trinidad, from Barbados, and from vessels at sea to the east and southeast at distances from one hundred to nine hundred miles from St. Vincent. At Walliabou sugar works southwest of the volcano, and in Richmond next to it, exactly the same fiery blast swept the cliff face as at St.



FIG. 12. ST. VINCENT: AVENUE IN CHATEAU BELAIR, showing the Soufrière in the distance. Just outside of the destruction belt, on the west side of the island.



FIG. 13. ST. VINCENT: AVENUE FROM RICHMOND HOUSE TO THE SUGARWORKS, one mile from Chateau Belair. Just within the destruction belt showing the ruin of Richmond House. In location Richmond was the St. Pierre of St. Vincent.

Pierre. In the same fashion Richmond is buried, 45 feet deep at its northern end, 3 feet at the southern. In the same way the one masonry building in Richmond village was thrown down, and five-foot blocks of masonry blown forty feet away from the mountain. The very odor over the ruin is the same. Just south of the Soufrière there is a group of high mountains. These blocked the passage to leeward southwest, and the heavier material thrown out of the crater's throat accumulated in the basin between these mountains and the volcano. Great drifts of fiery hot sand and gravel fell here and remained hot for weeks. The local torrential streams at the beginning of the rainy season, working on these beds, are converted into steam and make spectacular explosions, which alarm the natives, but are really quite harmless. At the sea-front west of the Soufrière there have been submarine landslips on a considerable scale, leaving in some instances vertical earthen walls 50 feet high where before there was a peaceful little village of thatched huts. The sea laps the foot of these unbalanced precipices, and a twelve-foot oar three feet from the strand-line finds no bottom. To a geologist one of the most remarkable effects of such an eruption is the rapid wearing away of the land that succeeds it. The protecting matter of tropical jungle has been burned and buried under two to ten feet of angular sand-grains; heavy rains cut torrent trenches in this material and all the old slopes are suddenly steepened by the falling away of the seashore and the piling of volcanic débris on all the crests of the land. The mountain is soaked in steam and water, local showers are at work all the time, and the result is like playing the hose on a steep mud pie; trenched and rill-marked in every direction, landslides are the rule in such topography and no slopes are safe. I landed for only a few moments to collect a specimen in one of the deep canyons northwest of Soufrière; a few blows of the hammer started a twenty-foot block of solid rock out of the gulch-slope a hundred yards away, and immediately afterwards a great bank of earth some twenty-five feet high came crashing down only a few feet from me. Needless to say I beat a hasty retreat to the boat from such an unstable land. We learned from this experience that the only safe place on new volcanoes is on the crest—unless one includes the Irishman's position, on 'leave of absence.'

There are a number of questions constantly asked of a geologist in this field, and some of these I must try to answer briefly here, without going further into a description of geological details. Was there any forewarning of the eruptions? Clearly there was; the prediction quoted at the head of this article was based on well-authenticated data. At Pelée, the lake in the crater was warm, and the smell of sulphuretted hydrogen perceived as far back as January. In April



FIGS. 14, 15. ST. VINCENT: THE U. S. S. DIXIE AT KINGSTOWN unloading supplies for refugees; one of the *Dixie's* lighters unloading on the beach at Kingstown; a camp of refugees, using the U. S. tents sent by the *Dixie*, and a hungry family waiting for 'government rations.'

there were noisy rumblings and steam was emitted; actual eruption is reported from April the twenty-sixth on, and yet the city was not evacuated. In St. Vincent local earthquakes have been on the increase for a year in the neighborhood of the volcano; people were actually frightened away from Windsor Forest on the northwest slope of Soufrière, as far back as May, 1901, by rumblings and quakings. The water of the lake has been seen to bubble and sulphurous coatings are described as being deposited on the rocks. So violent were the signals early in May, especially when the news of the Guerin disaster came from Martinique, that the leeward slopes of the Soufrière, at all times sparsely inhabited, were abandoned. Hence the small loss of life on that slope. On both islands, if the respective governments had maintained vulcanological stations with instruments, doubtless, there would have been perceived a gradually increasing series of signals of different sorts, tremors, sounds, sights, smells and temperatures. This record, if we had it now, would be invaluable. It cannot be reconstructed.

The question 'What actually happened in the eruptions?' involves no very great difficulty. The eruptions were small manifestations of a common type. Probably the Plinian eruption of Vesuvius was similar; the Central American volcanoes have quite the same history; Krakatoa in 1883, Tarawera (New Zealand) in 1886, and Bandai San in Japan in 1888, all present phenomena identical in the main, with local variations. A slip of some sort liberated a steam column; the cause of the fracture or the source of the steam is one step too far back into theory to venture to treat it here. Release once started followed old vents, water-holes, and these vents were Soufrière and Pelée. The explosion that followed release of pressure tore away the walls of the fissure and its violence ground the material to powder. The material came from a depth where the rocks were hot, and it was heated further by friction. Those who saw the eruption of Pelée on the twentieth of May describe a black column of dust and rocks that looked like smoke with wonderful purling, interbillowing nodes that overrode each other like cauliflowers or 'brains'; this column shot up silently at first, followed by heavy detonations that finally became a continuous roar. The column was estimated by Lieutenant McCormick of the *Potomac* to be at least five miles high; he witnessed the spectacle from Fort de France. Lightning shot through the great billows in all directions in a network. When it reached its maximum height the column spread out like a flower on its stalk and the upper edges of the hard smoke-steam masses were lighted white by the rising sun. A perceptible cold wave was felt. A shower of gravel took place followed by fine dust which continued falling for an hour. This was the day of the funeral of Consul Prentis. A visit to St. Pierre later the same day showed that a terrific blast had

razed much that before had been upright, 'hot ashes were steaming at the water's edge, and there were immense bowlders lying in a bed of ashes.' These horizontal blasts are not hard to account for and do not



FIG. 16. ST. VINCENT: THE FATAL WINDWARD SLOPE OF THE SOUFRIÈRE. Leaving the horses preparatory to the ascent. The mountains in the background in clouds. June 1, 1902.

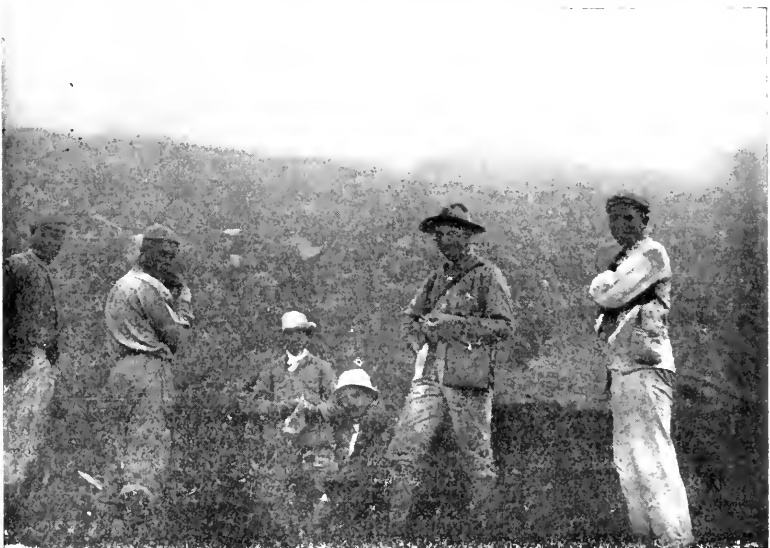


FIG. 17. ST. VINCENT: ASCENT OF THE WINDWARD SLOPE OF THE SOUFRIÈRE, showing the author and party, in a black fog, 2,700 feet up, the height of the western rim of the crater. An anxious moment. The high rim was shortly after reached, 3,200 feet up (on the right).

require a horizontal nozzle to project them. They are simply the result of the downblast after the heavy gravel has begun to fall, acting against the upblast from the throat of the volcano, and both together

deflected and thrown into terrific whirls or tornadoes by the prevailing wind, which on Mont Pelée is northeast. St. Pierre is southwest of the mountain and the crater is somewhat overturned to the westward.



FIG. 18. ST. VINCENT: ON THE MARCH, JUST BELOW THE CLOUDS. Three of the porters have already turned back. June 4, 1902.



FIG. 19. ST. VINCENT: ASCENT OF THE WINDWARD SLOPE, JUNE 4, 1902. In the clouds 2,000 feet up. Luncheon preparatory to the last effort. Note the increasing darkness of the four photographs: they were taken by Mr. Clare Taylor of St. Thomas, who accompanied the expedition.

The death-dealing billows of falling hot sand and gravel, *themselves a mighty downward wind*, deflecting with them the rising hot steam and

gases, finally rush down the mountain slopes in whatever directions they are guided by vale and ridge and wind. They were guided into the cliff-hollow of St. Pierre at Martinique and Walliabou at St. Vincent, both to leeward of the craters. In St. Vincent there was also an outrush symmetrical to the great crater in all directions, windward as well as leeward; hence the destruction of the windward estates. That there was tornado action is proved by the frightful demolition of masonry and the bending of trees; in St. Pierre this is away from the mountain and curving from south-southwest to southwest as we go southward from the volcano, these directions being shown by the downbent trees.

A common question is 'How were the people killed? Was it some strange gas? Were many killed by lightning?' There is no need for calling in any unusual gas; no doubt there were several gases present and the combustion of tropical vegetation made others that were highly explosive if mixed with air. This may account for some flame explosions reported as coming in from the sea-front at St. Vincent. The people of St. Pierre were killed by steam, hot dust, falling stones, falling buildings, drowning, burial alive and burning. The heat of a burning city fanned into a 'whirlwind of fire,' killed all who were left over from the other sources of death. The little city was as an ant-hill to a forest fire, in the presence of the terrible earth forces at work.

In conclusion let me say a word about the place of these eruptions in the geological history of the islands. They are not at all different from what the old cliffs, carved by the sea along the shores, show to have been the source of the heaping up of all the rocks that make the foundation stones the hills of these islands are carved upon. For these old sections are what geologists call agglomerates—masses of volcanic fragments, large and small, bedded in gravel and mud. Just such agglomerates are made anew by the great banks of dirt the volcano has vomited into the Walliabou at St. Vincent or Pelée into the gulch of the Factory Guerin. There are also old lavas interbedded with the agglomerates, showing that frequently the eruptions have been concluded in the past by the flowing out of molten incandescent rock. Perhaps this may come now, in the near future; even as I write there are cable despatches describing glowing lavas at Mont Pelée. The bared slopes of the Soufrière, devoid of vegetation, reveal a topography and geological structure so exactly like many things in our own Rocky Mountains that it is difficult to believe that one is in the tropics. There, too, in the tuff beds of the Yellowstone Park, is a fossilized tropical verdure which gives evidence that when those volcanoes of Wyoming were active, their slopes were covered by the vegetation of a warm climate near the level of the sea.



MENTAL AND MORAL HEREDITY IN ROYALTY.

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THIS inquiry into the characteristics of royalty, of which the following pages are a summary, is an attempt to solve several interesting and important questions. First, by including all modern royal families, it tries to give a fair estimate of the mental and moral status of these privileged personages as compared to the world in general. Second, it seeks to find the influences on the individual and on the breed of that environment of rank and power in which these specially elect have lived and moved. Third, by taking a great group of inter-related human beings with known pedigrees and characteristics, it seeks to throw a little light, in the nature of facts, on the old enigma—Which is the more important, environment or heredity, or do both together somewhat fail to explain all the phenomena, and must we postulate a third ultra-natural cause, working aside from biological laws, in order to account for all the varying facts of personal history and character?

It is evident that each human being has certain definite mental, moral and physical characteristics and that these are due to not more than three causes, heredity, environment and free-will. The first two are generally considered to play an important part, and the third is far from being ignored by some. It is also very evident that there is but a hundred per cent. of cause for human character, and whatever in our natures is due to one of these causes takes that much from the others. It is the chief aim of these pages, by the use of a scientific method, to get an insight, rough though it may be, into the proportionate influence played by these three factors in the make-up of mental and moral life.

The other questions touched upon are the effects of inbreeding, the relation of genius to insanity and sterility, and also the relationship between the rise of a country and the character of the blood of its kings. This last has been strikingly evident in several instances, notably Spain, Portugal and Prussia, where the prosperity of the lands have been a reflection of the ability of the rulers. Here one can trace a hidden but important cause for the condition of the country in the different combinations of ingredients of blood which have led to the individual peculiarities in the men and women who ruled over these realms and stamped their impress upon them.

The vexing question of determining in any way the proportionate average influence taken by the three possible causes in the determination of human faculties and character can probably only be solved when we possess, on the one hand, a knowledge of the circumstances in which the individuals lived, and, on the other, a complete knowledge of the characteristics of their ancestors and family to a reasonable degree of remoteness.

In many instances psychologists, historians and philosophers have observed the evident relationship between the lives and actions of men and the environment in which they lived. Even as early as Aristotle the characteristics of the Greeks were noted as midway between the Chinese and the Egyptians, and their different relations to the climate, geography, etc., were observed and reasoned upon. One of the most famous of recent names in this connection is that of Buckle, who attempted to reduce history to a science, and explain the actions of men according to natural laws. To his mind, food, climate, volcanoes and other external causes played an important part. Against Buckle stood Carlyle and many others who considered it degrading to attempt to reduce human action to mechanics; for them the great soul or 'hero' was the all-important element, and history was to be considered largely as a set of biographies of great men. Mohammed, Luther and the great kings could not be explained as a product of the times. With Carlyle must always stand the theologians who dwell upon the greatness of the human will and the divinity of the spiritual side of man, which is supposed to raise him above his trials and make him the true lord of creation.

In more recent years an attempt has been made to show that heredity is very important in producing those geniuses whose influence is so paramount in molding the lives of others. Galton and de Candolle have met with much success in this line. Thus the three factors have all had their supporters—heredity, environment and free-will—some would give preponderance to one and some to another, and no one knows which is the most important or influential.

Now, thanks to the researches of Galton, Pearson and others, the proportionate amount of hereditary influence from each parent, and from each more remote ancestor is known with considerable approximation, except as regards certain peculiar types; as when for instance the maternal and paternal stocks differ very much from each other, or for some other reason we have prepotency, as in the case of albino animals, or perhaps when new varieties make their appearance we seem to have errors from the expected.

Still the law may be considered virtually true when we deal with large averages, and thus by knowing what we ought to expect from heredity alone, we may take a large number of verified individuals

with known pedigrees, and see how closely the characters of persons correspond with what we should expect were heredity the sole cause of mental and moral peculiarities—in other words, see if the results are as certain when applied to mental traits as to the more physical and tangible qualities like eye and hair, color, stature, etc. If it should be found that the human mind and moral character are subject to the law of Galton, and with an accuracy as constant as the coloration of animals, then we may conclude that the mind and character are very strongly inherited, since coloration in animals is due to what we at present at any rate consider heredity. Of course we do not expect to find the same accuracy in dealing with psychic aspects, since every one knows that moral traits, for instance, are much the result of environment—education, example, etc. Let us, by studying human characters and comparing them with their close blood relations, see how strong inheritance appears to be.

It is often impossible to say in any individual, how much is due to one and how much to another cause, but by taking a large number we may estimate in a rough way the proportionate reliance that is to be placed on each factor on the average. Galton's law, based on stature and color in animals, in human hair and eyes, etc., is this: Each child inherits one half of his make-up from his parents, one half of the remaining half from his grandparents, one half of the remaining one fourth from his great grandparents, and so on to infinity. Thus each parent contributes one fourth of the entire influence, each grandparent one fourth of one fourth, each great grandparent one eighth of one eighth, or one sixty-fourth, and so on. So we see how little is the influence to be expected from heredity from one distinguished great grandfather.

In order to get material for such a study, one might take individuals at random and then their brothers and sisters and all their ancestors to a reasonable degree of remoteness, say all the great grandparents, which would give  $87\frac{1}{2}$  per cent. of the entire influence. This would be extremely difficult, as it is almost impossible to verify even the names of all the great grandparents of most people, let alone their mental and moral traits. Or one might use a large number of uncles and aunts to determine the latent inheritance of the ancestry, not known in the parents. Unless one had some proper way of selecting the material he might take instances that illustrate some theory and neglect others that do not.

The method I have employed has been to take individuals merely by blood relationship, and include every person about whom anything could be found. By doing this, I have escaped any selection of cases which illustrate a theory and at the same time know the exact blood relationship of every person to every other person. Of all families

applicable to this method the royal ones offer the most favorable field, owing to the maintenance of family trees and the great interest that has always been taken in their lives and characters as found in histories, biographies and memoirs. Besides, although all have the highest social rank, they have lived in different countries, in different centuries and under varying circumstances, with different educations and opportunities. Their peculiar positions make it unwise to compare them with men at large, but, having a great number, we can properly compare them with each other and judge them according to a standard of their own.

Galton in his 'Hereditary Genius' purposely avoided royalty, because, as he says, the qualities that make a great king are not the same as apply to genius in general. In this work it is no drawback, since here I have gone with more pains into the question of intellect and actual achievements, and a man is not given the same rank for being a wise and successful ruler that he is for great and brilliant creative achievements. The adjectives that are used by biographers and historians are the basis of the estimate, and by this standard William I. of Germany would not rank with Frederick the Great, since one does not find the same admiration expressed for his intellect.

By taking down every individual met in every degree of blood relationship and also everything in the nature of a characterization or adjective applied to him, I have been able to verify or check the estimates, and avoid the difficulty which one might expect to arise from a lack of uniformity of opinion. It is really very easy to get a sufficiently clear idea, in a rough way, of the mental and moral status of any historical character. The accounts may vary on some points but not much on essentials. Thus in the case of Frederick the Great none would question his high intellectual standing, though considerable difference of opinion would be found relative to his moral qualities, most putting him rather low. The same would apply to Napoleon, but in both these instances the interesting and important thing to be explained is the intellect, and of this we can form a sufficiently just estimate. In the same way the important fact regarding Prince Albert, consort of Queen Victoria, is his high moral tone and studious tendencies, and about these we can have no question. So that in the main, two sufficiently accurate scales can be formed in which to place them all, one for the intellectual side and one for the moral side.

Grades from 1 to 10 have been used for each class of traits, intellectual and moral; and attention has also been paid to the law of 'Deviation from an average,' by which most people are made to range close to mediocrity, the geniuses and imbeciles being relatively few. This law is set forth in Galton's 'Hereditary Genius,' page 22, and

is probably as true of mental stature as of physical, where it has been proved by actual measurements. This consideration is of great importance in proving the inherited nature of genius and stupidity, because if after placing most of our individuals in grades four, five, six and seven, and admitting only a very few to grades nine and ten, or to one and two, we still find them to be closely related to others, it is all the more a proof of heredity.

Besides this number I have been able (thanks to the 'Genealogy' of Lehr, which contains the full pedigree, male and female, to the twelfth generation, of all the northern ruling families) to extend the number to about 3,500 related persons as a field for study of genius alone.

This book contains the names of 3,312 distinct persons, but by intermarriages and repetition the actual number is raised to 32,768. It would of course be a very long undertaking to look up the characters of 3,312 persons, but by using the index and 'Lippincott's Biographical Dictionary' it was not hard to tell how many of the number are not mentioned at all, and consequently were not geniuses or worthy of grades nine or ten. It seems fair to assume that if a person was of noble rank (and there are practically none others in Lehr's 'Genealogy') and did not distinguish himself sufficiently to gain a place in a biographical dictionary as large as Lippincott's, he could not have been very great, at least as regards outward achievements, which is the standard here employed.

The standard for grades nine and ten is very high indeed. It is made up of really great names and includes few below the standard of William the Silent, Gustavus Adolphus, Peter the Great and the Great Condé, Turenne, Maurice of Nassau, and, among the women, Isabella of Castile, Maria Theresa, Elizabeth of Palatine and the Duchess de Longueville.

Of course being in Lippincott's is no criterion of mental calibre in a king, so that many who are there must be at once thrown out, as for instance Louis XIII., XV. and XVI. of France. No one is placed in grade nine or ten for intellect, unless his or her name appears in Lippincott's and also appears there in virtue of mental endowments or distinguished achievements. There are only a few, and those are actual kings, who appear in this biographical dictionary merely on account of their birth. They are easily detected and would be excluded by any one.

Occasionally I have met with a character in the histories or large biographies who seemed to me to be worthy of rank nine or ten, whose name is not to be found in Lippincott's. Such a person was Sophia 'The Philosophical Queen,' of Prussia, and grandmother of Frederick

the Great, but these have been rigorously kept out, in order to make the standard as impersonal as possible.

By starting with the present king of England and including all his ancestors to four generations, and then all the other descendants of these ancestors, all their wives and their ancestors, and stretching out in every direction by this endless chain method, taking every one about whom enough could be found to be satisfactory, I have at present obtained mental and moral descriptions of 633 interrelated individuals, including pretty completely the following countries of Europe: England (House of Hanover), France, Prussia, Brunswick, Hesse-Cassel, Holstein, Saxe-Coburg, Russia, Sweden, Denmark, Spain, Portugal, Savoy, Italy, Austria and the Netherlands. The period covered extends in general back to about the sixteenth century, but in the case of Spain and Portugal to the eleventh century.

Let us take up the countries separately and study the quality of the blood introduced into the royal families and its relation to the character of the subsequent breed and to the history of the land itself.

#### I. *Evidence from House of Hanover in England.*

George I. was a rather weak, dull and indifferent scion of a gifted stock. He was descended from the brilliant House of Orange, which we shall afterwards see was able to form the greatness of the Hohenzollerns in Prussia, but he himself was nothing. From his time to the present the following unions have been made with the results of introducing the following stocks:

Brunswick, stock pretty good, no genius.

George II.=Brandenburg, stock good, no genius.\*

Frederick Prince of Wales=Augusta of Saxe-Coburg, stock good, no genius.

George III.=Charlotte of Mecklenburg, stock 'obscure,' good, no genius.

Edward Duke of Kent=Victoria Maria Louisa, of Saxe-Coburg, stock excellent, no genius, strong literary bent.

Queen Victoria=Albert of Saxe-Coburg, stock excellent, no genius, strong literary bent.

Edward VII.=Alexandria of Denmark, stock excellent, no genius.

Thus from George the First's time on, there has never been any genius introduced into the pedigree of the House of Hanover, and, as we all know, none has appeared in any of the descendants bearing the name. So as regards high mental attainments, we have what we might expect, dullness the characteristic, with here and there fairly good

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\* No genius means that no individuals worthy of grade 9 or 10 for intellect are to be found.

minds. There is certainly nothing higher than grade eight (that of Queen Caroline, Consort of George II.)

There have never been a large percentage deficient on the moral side, and we find the pedigree upholding this, for compared with the Bourbon-Hapsburgs and Romanofs, the families that have allied themselves to the ruling house of England have been remarkably good. Quiet, domestic and religious traits have been the characteristics of the various female lines and since the direct progenitors, George III. and Edward of Kent, have had the same, such have been the later characteristics of most of the members of the English house. These moral qualities are perfectly in line with heredity but might be also explained by environment, either home influence or public opinion changing with the centuries.

But if we adopt the environment view, we can not rightly explain the bad characters as they appear, nor the contrasts that often mark the children. There have not been any very depraved since George IV. He and his brother, the Duke of York, were silly, dissipated men without ambition or serious purpose; William IV., another brother, was not much better. Their father and mother, George III. and Charlotte, were as unlike them as could be, painfully punctilious in their daily lives, so domestic and quiet as to be a subject of satire on this account.

But George III. had eleven children who have left records. Of these, three were the only black sheep. Why was this? Because all the others represent the majority of hereditary influence and turn out well. George IV. and the Duke of York revert to their grandfather, Frederick Prince of Wales, and are just like him. William IV., in his eccentricity, subbornness, simple ways and feeble mind, resembled his father, George III. His vices, if due to heredity, came from further back. In the generation before this (brothers and sisters of George III.), there were two in six who were very immoral. These were Edward, Duke of York,\* and Henry, Duke of Cumberland.†

This percentage of one third is not as high as called for by heredity, since both Frederick, Prince of Wales, and his consort, Augusta, were rather immoral, which should call for fifty per cent., and to this should be added the slight amount of influence from such characters further back.

The generation before this contains seven children of George II. and Queen Caroline: × Frederick, 3, 3; ‡ × William, 6, 3; Anne, 4, 4;

\* Doran, 'Queens of Hanover,' p. 406.

† Jesse, 'George III.,' Vol. II., p. 2.

‡ 3, 3 means grade 3 for intellect, 3 for the moral side.

6, 3 means grade 6 for intellect, 3 for the moral side.

The mark × is placed before those who may be considered 'bad' and is applied to those below grade 4.

Louisa, 4, 9; Amelia, 5, 6; Mary, 4, 8, and Caroline Elizabeth, 4, 9. Both sons were below the average morally, the others range pretty close to the average, except Caroline Elizabeth, who was an exceptionally lovely character.\* These are not out of line with heredity. The generation before this contains only George II. and his sister, who became queen of Prussia. She was a mediocrity, and George II. represented the bad side of the family inheritance.

George I. was a poor representative of an illustrious stock as his mother was the intellectual Sophia, Duchess of Brunswick, a descendant of the great House of Orange on both sides. It was left for the sister of George, who was the 'Philosophical Queen' of Frederick I., of Prussia, to transmit the genius of Orange into Prussia to the generation of Frederick the Great. It can easily be seen that after the two first Georges, each the poorest among his kind, that the ancient greatness must necessarily die out, as it was never rejuvenated in this house.

To summarize the House of Hanover: It contains 28 persons whose pedigrees have been studied. The total number brought together on a chart containing in addition the full pedigree for George IV. to five generations is 87. Of these 87 only two show high intellectual variation; these are Sophia, Duchess of Brunswick (10) and Caroline of Brandenburg (8). It was shown that these higher streaks were lost by selection. There are only five as low as grade 3 and one in grade 2. Thus the house of Hanover has never deviated much from the average, either in itself or in the nature of the blood introduced, and the characters are much as one would expect from heredity alone. It is a great mistake to consider that Queen Victoria had a bad ancestry. On the other hand, it was in general very good. The ancestry of King Edward VII. is even better and most of Victoria's children have upheld the standard.

#### *Saxe-Coburg the Reigning House of England.*

As I started with the present King of England, and since his father was a prince of Saxe-Coburg, I was at once led into that family, which will now be considered.

Albert, the lamented consort of Queen Victoria, was, as every one knows, a highly cultivated, earnest and noble man, a devoted husband and an enthusiastic reformer in all affairs related to the public good. Well versed in science and literature, he was also an accomplished musician. Did he come by this character through inheritance? It will be seen that characters of this sort are written all over his family pedigree. As the group, just considered, Hanover was remarkable for its dullness, so this group is remarkable for its virtue and bent towards literature, science and art. It is not that the dukes in the male line

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\* Wharton, 'Wits and Beaux,' p. 177.



have shown such tendency in a marked degree, but it is that at each step going back, the pedigree is what we should expect.

There are 118 individuals in this group, which may be considered as a region of the entire chart. It will be seen, by referring to a chart of this house, that the main tap roots of this stock have been from Ernst, the Pious, Brunswick Wölfenbruttel, Saxe-Coburg, Saxe-Salfeld, and other branches of the Saxe houses. Ernst 'The Pious,' himself, who appears many times in the pedigree, was a man of wisdom, virtue and marked religious bent; the Brunswick family was noted for its strong literary taste, as will be shown more in detail later, and all marriages with the Saxe houses can be seen to have kept alive those same qualities as the salient characteristics of the breed.

We see that after two hundred and fifty years, the same traits exist because there has never been a time when blood of another sort was introduced to contaminate or dilute it. Everywhere we notice that love of ideas and refinement of taste have been the object sought after, rather than the sway of power or the obtainance of military fame. There has not been one soldier of sufficient renown to appear in any of the smaller biographical dictionaries like Lippincott's or Rose's. One only was what may be called a successful general, but his career is described solely in the larger German dictionary.

From Ernst, the Pious (1601-1675), to Frederick IV. (1774-1793) the branch of Gotha contains 64 names. The branch of Coburg from John Ernst (sixteenth century) to Albert, consort of Queen Victoria (1819-1861) contains 118 names. There is considerable intermarriage, so that we find some persons repeated several times. Thus the actual number of individuals is less than this, still the value scientifically is  $64 + 118$  or 182. Although in the furthest degree of remoteness we deal with sixty-four different tap roots, owing to intermarriages there are only twenty-one family names. Among these sixty-four, we find the following families composing the stock:

Saxe (different branches) twenty-one times. That is, the breed was perpetuated to the extent of about a third from itself. We find the name of Brunswick seven times, Mecklenburg six, Anhalt five, Holstein four, Hesse three, Reuss two, Solms two, Schwartzburg two, Baden, Bentheim, Castell, Erbach, Hohenlohe, Logwenstein, Cettinger, Sayn, Stolberg, Waldeck and Zinzendorf each one. Among all these 182 related persons, there is not a single genius or individual worthy of grade 9 or 10 for intellect. The only two in 8 are Ernst II., of Gotha (died in 1801), who was a distinguished astronomer, and Louis Dorothea of Saxe-Meiningen (8) who corresponded with Voltaire, and was called the 'German Minerva.' She was the mother of Ernst II., the astronomer. Also there is not a fool, imbecile or moral degenerate among them all as far as is known.

From Ernst, the Pious, on, selection was constantly made of men and women of his own type, so that sound judgment, high moral qualities and strong literary taste are continually reappearing and were never lost even after nine generations. There were among this group of 182 (counting a person every time he occurs) no less than eighteen who were authors or had strong literary tastes. In the most remote generation we find five in thirty-two, in the next three in sixteen, in the next one in eight, in the next two in four, in the next two in two and in the next two in two; the remaining three occur in the more recent part of the chart, and are even more closely related. Thus we see Ernst, 'The Pious,' and Augustus of Brunswick, who were both literary, perpetuated down the line in this family by the force of intermarriage and selection.

The intellectual average is everywhere near the mean or slightly above, and the moral average is everywhere near the mean or very much above it. There being not a single bad character introduced into the blood directly, the children apparently could not turn out badly. It is the cleanest and best pedigree to be found in any royalty, and its influence on European history has come to be very great, since its very merits have entitled it to several thrones. In fact it can be shown that no royal family has been able to maintain itself without degenerations, unless it has taken a good share of Saxe-Coburg blood. The good qualities, if due to heredity at all, in Austria, England, Germany, Belgium and Greece are largely due to it. It probably saved the Bourbons in Portugal.

Thus in tracing the pedigree and accounting for the virtues of Albert, Consort of Queen Victoria, we find the theory of mental and moral heredity sufficiently sustained in *his* case, as well as in the others. At least five of the close relations of the Consort may be considered as almost exact repetitions of his character. These are his grandfather, Franz Frederick Anthony, his two uncles, Ferdinand and Leopold I., King of Belgium, his brother, Ernst, and cousin, Ferdinand of Portugal.

The family of Saxe-Coburg and Gotha shows by its 118 members here represented that the assumption of high rank and power and the consequent opportunities for ease and luxury do not in the least tend to degeneracy of the race when the good qualities are kept up by marriages with stocks of equal value and no vicious elements are introduced into the breed. A parallel to this is found among the kings of Portugal during its days of supremacy, where for twelve generations nearly every sovereign had all the wisdom and strength required of a ruler.

(To be continued.)

## SCIENTIFIC LITERATURE.

*PHYSIOLOGICAL CHEMISTRY.*

THE publication, by an American author, of another new work devoted exclusively to physiological chemistry gives evidence of the increasing recognition which this branch of science is receiving in this country. The 'Text-book of Physiological Chemistry,' by Dr. Charles E. Simon,\* of Baltimore, is a satisfactory addition to the few really valuable books on this subject in English. Resembling in many details of treatment the widely known volume by Hammarsten, Simon's new treatise shows the same features of presentation which have made the author's work on Clinical Diagnosis so favorably received. In somewhat over 400 pages the chief facts and important methods of physiological chemistry are offered in the light of the recent advances, the purely chemical aspects being emphasized.—A new English translation (470 pp.) of Bunge's 'Text-book of Physiological and Pathological Chemistry'† is announced by American publishers. The new edition of this work which has lately appeared in German as the second volume of Bunge's new 'Lehrbuch der Physiologie'‡ shows the same unique peculiarities of style which make his publications so readable. Bunge's views on many topics seem, however, somewhat extreme; they frequently attract attention from the unusual standpoints assumed, rather than from any indication of broad and pro-

gressive familiarity with the literature of the subject.—The 'Lectures on Chemical Pathology' by Dr. C. A. Herter,\* of New York, forms one of the most suggestive and interesting publications of the year. They point out the importance of chemical considerations in the study of both physiological and pathological processes, and abound in illustrations drawn from an extensive acquaintance with clinical and experimental data. The medical practitioner who has lately been hearing about physical factors in therapeutics will find in Dr. Herter's chemical treatment much that is new and stimulating. The distinctive scientific attitude of the author is everywhere apparent.—Oppenheimer's 'Die Fermente und ihre Wirkungen,'† which appeared two years ago, is now available in English form under the title 'Ferments and their Actions.'‡ The extensive references to the literature make it helpful to the physiological chemist. Dr. Effront's work on enzymes has also been translated (in part) from the French by Dr. Prescott, of the Massachusetts Institute of Technology.§—In the book of 290 pages on 'Les fonctions hépatiques,'|| Gilbert and Carnot have reviewed the physiology of the liver in its various aspects. Like Hédon's publication on the pancreas, it indicates a return to the monograph form of presenting the details of physiological research.

\* Lea Brothers and Co., Philadelphia and New York.

† P. Blakiston's Son and Co., Philadelphia.

‡ F. C. W. Vogel, Leipzig.

\* Lea Brothers and Co., Philadelphia and New York.

† F. C. W. Vogel, Leipzig.

‡ Griffin, London.

§ John Wiley and Son, New York.

|| C. Naud, Paris.

## THE PROGRESS OF SCIENCE.

*THE PITTSBURGH MEETING OF THE AMERICAN ASSOCIATION.*

THE American Association for the Advancement of Science held its fifty-first annual meeting at Pittsburgh on the last day of June and the first three days of July. There was a registration of 435 members, and some 350 addresses and papers were presented before the several sections and affiliated societies. As the number of papers so nearly equaled the number of members, it is evident that those present were chiefly working men of science. It must also be remembered that some members of the affiliated societies are not members of the Association, so that the gathering of scientific men numbered about 600. They were almost entirely different from the 300 students of the natural sciences who met in Chicago last winter. At the next meeting of the Association to be held in Washington during convocation week, the two groups will come together, and the meeting will probably exceed in size and importance any similar congress of scientific men held outside of Germany.

The address of the retiring president of the Association, Dr. Minot, of the Harvard Medical School, is printed above. Though admirably expressed and on a topic that should be of general interest, it must be confessed that the relations of consciousness to organic evolution and the material world is a subject outside the range of the consciousness of the ordinary man. The addresses of the vice-presidents maintained a high scientific standard, but were in most cases addressed to specialists, whereas it seems that there should be at the meetings of the Association some addresses and discussions

that appeal to all scientific men and to those who take an intelligent interest in science. Of this character were the interesting evening addresses by Professor D. S. Kellicott and Dr. Robert T. Hill, but otherwise the programs were addressed to specialists. Indeed the sectional meetings tend to be too special even for the specialists. Some method should be adopted for the presentation of scientific papers that will make attendance more interesting and profitable. A distinction should be made between small groups of men interested in a common topic and larger numbers who even within the limits of their own science should not be expected to listen to papers that they would not read. Several amendments to the constitution were adopted tending to strengthen the organization of the sections and the permanence of administration. The council will hereafter elect each year three members at large who will doubtless add to the efficiency of that body, and the sectional committees will become more nearly sub-councils, while the term of office of the secretaries is extended from one to five years. The membership of the Association has considerably increased during the year, being now about 3,500, and the finances are in excellent condition, the permanent secretary, Dr. Howard, having handed over \$2,000 from current income to the permanent fund.

Professor Asaph Hall is succeeded in the presidency by Dr. Ira Remsen, the eminent chemist, president of the Johns Hopkins University. The vice-presidents are, for mathematics and astronomy, Professor George Bruce Halsted, of the University of Texas; for physics, Professor E. F. Nichols, of

Dartmouth College; for chemistry, Professor Charles Baskerville, of the University of North Carolina; for mechanical science and engineering, Professor C. A. Waldo, of Purdue University; for geology and geography, Professor W. M. Davis, of Harvard University; for zoology, Professor Charles W. Hargitt, of Syracuse University; for botany, Dr. F. V. Coville, of the U. S. Department of Agriculture; for anthropology, Dr. G. M. Dorsey, of the Field Columbian Museum, Chicago; for social and economic science, H. T. Newcomb, of Philadelphia, and for physiology and experimental medicine, Professor W. H. Welch, of the Johns Hopkins University.

#### FUNDS FOR THE PROMOTION OF RESEARCH.

THE appropriations for research made by the American Association are very small compared with those of the British and French Associations. The British Association has a large income from local members, who pay fees for the meeting, and the French Association has a large endowment which is continually increased by bequests; each of these associations appropriates about \$5,000 annually for research. The permanent funds of the American Association are slowly increasing, chiefly by savings from income, and now amount to about \$12,500. The income from this fund, however, only permitted making at Pittsburgh five small grants, \$75 each to committees on blind vertebrates, on the relation of plants to climate and on the velocity of light, and \$50 each to committees on anthropometry and on the atomic weight of thorium.

It was announced at a general meeting of the Association that the Botanical Society of America has set aside the sum of \$500 from its yearly income, this year and every succeeding year, to be used in making grants in aid of investigations. The funds of the Botanical Society consist of the

accumulated dues and interest paid in by the members, and the grants in question probably constitute the only series ever offered in America, the money for which has been contributed wholly by a body of scientific workers. Should the members of the American Association be equally self-sacrificing there would be available an annual income of \$35,000 for research. It must, however, be said that the more important demands for funds for research are pretty well met. The National Academy administers funds large enough to meet all pressing needs, the Elizabeth Thompson Science Fund has a fair income at its disposal, and all other funds are of course overshadowed by the great endowment of the Carnegie Institution. Some disappointment was expressed at Pittsburgh that no officers of the Carnegie Institution were present, and that the plans of the institution have not been more freely made public. But it is certainly the part of wisdom for those responsible for the conduct of the institution to take ample time before coming to any final decision. Ample opportunity for public discussion will doubtless be afforded before the institution commits itself to any definite policy.

#### NATIONAL LEGISLATION.

THE government of a nation is becoming increasingly a problem of applied science. Opinion and the rule of thumb are gradually being superseded by knowledge and the direction of the trained expert. This is clearly shown by the more important measures passed by the recent congress. The destructive activities of warfare are becoming less important than the commissariat and the medical department; but they rest equally on the applications of science. This is indicated by the usual superiority of the navy over the army, and by the place in the army taken by West Point graduates as compared with the amateur volunteer. Fortunately war is no longer the chief busi-

ness of a nation; our present duty in the Philippines is pacification rather than warfare, and in arranging a civil government, Congress has been largely concerned with questions of applied science. The matter next in general interest before Congress was the isthmian canal, where legislation has been definitely based on the report of a committee of experts. Nearly of equal importance was the subject of irrigation, where the law enacted and its execution depend entirely on scientific advance. So other important measures, such as the establishment of a permanent census bureau, and a large part of the routine conduct of the business of the nation, may be regarded as direct applications of science. It is interesting to note that questions which belong to the more backward political and social sciences did not fare as well as those resting on the natural and exact sciences. There was less agreement as to tariff, subsidies, franchise, currency, etc., and legislation concerning these questions was mostly dropped as postponed. It seems curious that when legislative and executive work depend so largely on science so few men of scientific training should be found in Congress or in the Cabinet. The retiring prime minister of the British Empire has been president of the British Association for the Advancement of Science, and it is said that he retires to engage in scientific work; his successor is the author of books in which the fundamental problems of science are treated. In France men of science have taken an active part in government. Here, where the government is more dependent on science than in any other nation, there can scarcely be found a single scientific man in any elective position. Perhaps it is just as well under existing conditions that men of science should not be politicians. We have, however, in fact four main branches of the government—the executive, the legislative, the judiciary and the scientific; and there is reason to

suppose that the expert or scientific department may at some time be recognized as coordinate with the others.

#### AN UNFORTUNATE TRANSLATION.

A TRANSLATION of Laplace's 'Philosophical Essay on Probabilities'\* has been issued by Messrs. Wiley and Sons, this being its first appearance, as far as we know, in English. No algebra is used in this essay, its aim being to present the fundamental principles and the general results of the theory of probability in a simple and popular manner. This aim is attained in some portions, especially in those relating to judicial decisions, elections, insurance statistics and annuities. Other discussions, particularly those treating of the adjustment of observations and Laplace's method of generating functions, are not clear. In fact the last-mentioned subject is so obscurely presented that Todhunter in his 'History of Probability' characterizes it as a waste of space, while Langsdorf's German translation devotes eight pages of notes to its elucidation. The present translation, however, has no notes, and the obscurities of the original are often rendered darker yet by renderings into imperfect English.

The work of translation has been done by F. W. Truscott and F. L. Emory, of the West Virginia University, the former being professor of Germanic languages and the latter professor of mechanics and applied mathematics. A combination of this kind should produce the best results, for the competent linguist will see that idiomatic English is used, while

\* 'A Philosophical Essay on Probabilities,' by Pierre Simon, Marquis de Laplace. Translated from the Sixth French Edition by Frederick Wilson Truscott, Ph.D. (Harv.), and Frederick Lincoln Emory, M.E. (Wor. Poly. Inst.). New York, John Wiley & Sons, 1902. Duodecimo, cloth, 196 pages. Price, \$2.00.

the competent specialist will see that the correct technical terms are employed and that explanatory foot-notes are given in all doubtful cases. Here, however, the French word that means addition is sometimes rendered as 'unite' and the word that means subtraction is rendered 'draw from.' What is the meaning of such expressions as 'manner of relating past events with the probability of causes,' 'to conclude the order of preference,' 'diminution of subsistences,' etc.? We are told that stars are 'called double, on account of their conjunction' and that 'laws are the ratios which connect particular phenomena together.' The strange expression 'salubrity of the sun' only ceases to be puzzling upon reference to the original, where we learn that *sol* is the word which the translators suppose to mean 'sun.' On one page 'primary number' is used six times where prime number should have been employed. Expectation is a common term in the theory of probability, but the translators prefer the word 'hope.' DeMoivre is a name well known to American mathematicians but the translators call him 'Moivre,' as Laplace properly did. For the same reason, no doubt, Pliny appears as 'Pline,' but it is hard to understand what reason or fact justifies the statement that 'the duration of the rotation of Saturn is 0.427 minutes.'

In the concluding paragraph of the essay occurs the well-known statement of Laplace that the theory of probability is really only common sense reduced to calculation. The translators, however, calmly tell us that 'the theory of probabilities is at bottom only common sense reduced to calculus.' Alas, that American scholarship and American science should have fallen upon them the blot of such poor work. No doubt, the translators put forth this book, really believing it to be a creditable production; they honestly think that they are good linguists and

that they have a good knowledge of the subject matter of Laplace's essay. Such a state of mind can only be due, we think, to grave defects in the methods of instruction in the schools and colleges where these men were educated, methods not worse probably than those in many others. Lastly, what shall be said of publishers who issue such crude material and thereby bring disgrace upon American scientific literature! Here was an opportunity where both translators and publishers might have won credit and advanced mathematical learning, for a good translation of this essay, well annotated, would furnish excellent collateral reading to many students of probability and least squares. Nathaniel Bowditch honored himself and American science by his magnificent translation of Laplace's '*Mécanique céleste*,' and thereby astronomical learning was advanced in all lands. The translation of this essay on probabilities, however, brings no credit to any one, but much disgrace to many, and the only possible reparation that the publishers can make is to immediately withdraw the book from the market.

#### SCIENTIFIC ITEMS.

WE note with regret the deaths of Dr. John Daniel Runkle, professor of mathematics at the Massachusetts Institute of Technology since its foundation and president from 1870 to 1878; of Professor J. B. Johnson, dean of the College of Engineering of the University of Wisconsin; and of M. Hervé Faye, the eminent French astronomer.

THE coronation honors in Great Britain have been announced, in spite of the postponement of the coronation. A new order of merit has been established which includes in its list of twelve original members the names of four distinguished men of science, namely, Lord Rayleigh, Lord Kelvin, Lord Lister and Sir William Huggins. Among those who have been knighted

are the physicists, Principal Rücker, of the University of London, and Principal Lodge, of the University of Liverpool; the chemist, Professor Ramsay; the engineer, Dr. Thornycroft, and a number of prominent physicians.

THE Albert medal of the London Society of Arts has for the present year been awarded to Professor Alexander Graham Bell, for his invention of the telephone.—The eminent astronomer, Professor Giovanni Schiaparelli, has been elected an associate of the French Academy of Sciences, and M. Amagat a member of the section of physics.—The Academy of Sciences of Vienna has elected Lord Rayleigh a corresponding member.

PRESIDENT ELIOT, of Harvard University, was elected president of the National Educational Association at the recent Minneapolis meeting.—Dr. William H. Forwood has succeeded Dr. George M. Sternberg as surgeon-general of the army.—Professor Edward S. Holden has accepted the appointment of librarian of the Military Academy at West Point.

MR. F. H. NEWELL, chief hydrographer of the U. S. Geological Survey, has gone to the West to supervise surveys in connection with the work in irrigation authorized by Congress. Surveying parties are in the field in California, Oregon, Washington, Montana, Utah, Nevada, Idaho, Arizona and Colorado.—The American Museum

of Natural History, New York city, has sent an expedition to eastern Colorado to examine the unexplored portions of the Prototippus Beds in the hope of securing a complete skeleton of this animal. At the same time search will be made in western Nebraska for the same fossil species of horse, in the locality where Professor Leidy first discovered it. The expenses of these expeditions are defrayed by the gift of Mr. William C. Whitney.—The *Windward* is being fitted for its fifth and last trip and will soon sail via Etah for Cape Sabine on Smith Sound, where it is expected that Lieutenant Peary will be found.

IN honor of the late Alpheus Hyatt a memorial fund is being collected for field lessons in natural history. Professor Hyatt was greatly interested in extending the teaching of natural history to the schools, and this memorial appears to be especially appropriate. While the fund will be administered by a board of trustees at Boston, contributions from Professor Hyatt's former pupils or friends, wherever living, will be welcome. The treasurer, to whom subscriptions may be sent, is Mr. Stephen H. Williams, 2 Tremont Street, Boston.—Dr. Joseph Leidy, Jr., 1319 Locust Street, Philadelphia, is collecting the correspondence of the late Professor Joseph Leidy for publication. He would be glad to possess copies or the originals of any letters of interest that may be in the possession of readers of the POPULAR SCIENCE MONTHLY.



# THE POPULAR SCIENCE MONTHLY.

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SEPTEMBER, 1902.

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## AREOGRAPHY.

BY PERCIVAL LOWELL.

Vidi ego, quod fuerat quondam solidissima tellus  
Esse fretum: vidi factas ex acquore terras;  
Ovid, *Metam.*, xv., 262.

“What once was solid ground I’ve seen to be a strait:  
Lands I’ve seen made from out the sea.”

HAD Ovid not let Pythagoras say this intentionally of the Earth he might be credited with having meant it for Mars. So startlingly apposite is its application to the history of Martian discovery. For the verse expresses to a presentment the course of man’s acquaintance with that planet. A surface supposed at first partly land and sea: the land next seen to be seamed with straits; and lastly the sea made out to be land. Such is the history of the subject, and words could hardly have put the facts more neatly. ‘Vidi ego, quod fuerat quondam solidissima tellus esse fretum’ sounds like Schiaparelli’s own announcement of the discovery of the canals. Indeed I venture to believe he would have made it had he chanced to remember the verse. ‘Vidi factas ex acquore terras’ certainly sums up what has since been found for the seas.

Three stages mark the course of Martian map-making from its beginning sixty-odd years ago to the present day. They constitute three epochs in the subject, which may be recognized distinctly in the chain of successive charts made of the surface of the planet from then till now. Such a series, however, is not for most people obtainable. Only to specialists is the evidence for or against any scientific belief present at any time in its entirety. Not only has the new evidence not had time to filter through the usual channels into general absorption, but

the old too has often remained either unknown or ignored, buried in the books which nobody reads. Thus the whole chain of argument is rarely available to those not engaged in the investigation, and the conclusions reached appear to hang on slenderer threads than is really the case. It has seemed to me, therefore, not without profit to collect into one the various views of the cartography of Mars, so much, that is, as is essentially original and not mainly confirmative of the work of previous observers. To this intent, I have produced the new maps, reproduced the old and set them opposite one another. Thus brought face to face they make a rather impressive self-confessed avowal of relationship.

Twelve maps constitute the series. Each marks the point areography had reached at the time. No map has been left out which added anything new except when a contemporary added more. The twelve maps arranged in chronological order are these:

I.	Beer and Mädler,	1840.
II.	Kaiser,	1864.
III.	Dawes by Proctor,	1867.
IV.	Résumé by Flammarion of all to date,	1876.
V.	Schiaparelli,	1877.
VI.	“	1879.
VII.	“	1882.
VIII.	“	1884.
IX.	Lowell,	1894.
X.	“	1897.
XI.	“	1899.
XII.	“	1901.

As is commonly the case when things are summed up, much more results than one anticipates. It always turns out that one has spent more than he imagines; and fortunately with accumulations it is sometimes the same. Much emerges thus from the present assemblage and three points in particular stand out to command attention. The three points will be found to be:

1. The fundamental agreement of the whole series.
2. Evidence that the peculiarity of the markings seen by Schiaparelli was not the fathering of fancy, but a recognition forced upon him by the markings themselves.
3. A visible evolution in discovery which has steadily progressed from the beginning to the present day marked by three stages—pre-Schiaparellian, Schiaparellian and what we have learned since.

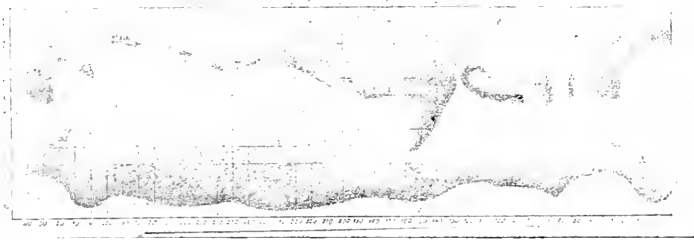
To be struck by these three deductions it is only necessary to compare the several maps with one another when one shall have learnt so much of the circumstances of each as to make their relations understandable.

The first map ever constructed of Mars was drawn by Beer and Mädler in the fortieth year of the last century, and is here numbered I. The observations upon which it was based were made with a four-inch telescope and extended in all over eight years. In this map all the main features which we note to-day are unmistakably depicted. The 'Eye of Mars' (the Lake of the Sun) is well seen, as well as the



MAP 1. BEER AND MADLER, 1810

dark marking that makes eyebrow to it on the south. Next come the Mare Sirenum and the Mare Cimmerium as one long leech-like patch, duly inclined to the parallels. Then follows the Syrtis Major, the first discerned of all the markings on the planet. It was drawn by Huyghens in 1659. Out of it is delineated the Icarium Mare, ending unmistakably in the Sabæus Sinus seen as a scroll. Dark patches to the south

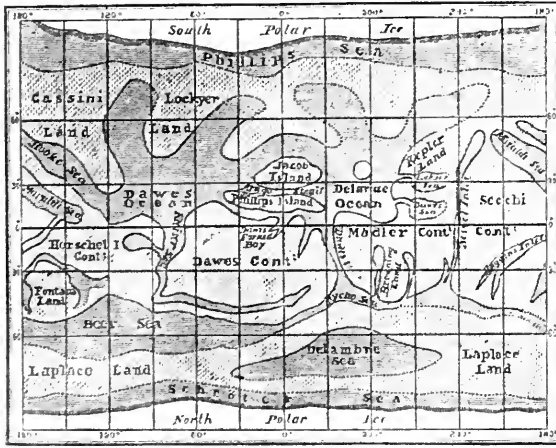


MAP 2. KAISER, 1864.

stand for the Mare Erythraeum and sporadic ones in the midst of the great continental areas north give adumbration of the canals and oases later to be discovered there.

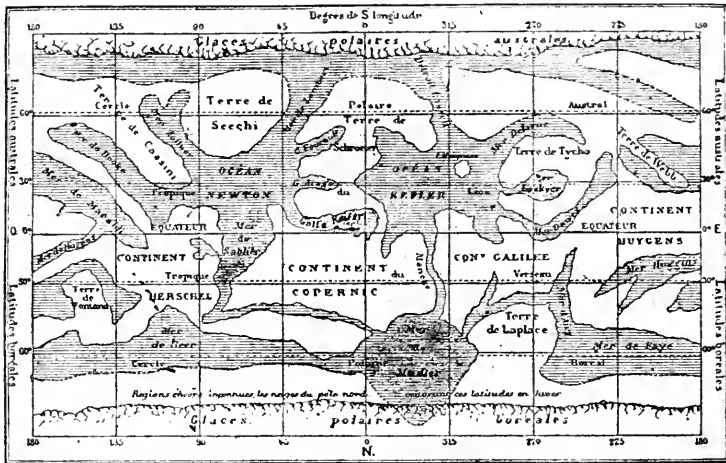
The next map, No. II., is Kaiser's, made in 1864. In it it is easy to trace all the fundamental features we have noted in the chart of

Beer and Mädler: the Eye, the Maria, the Syrtis Major, the Sabæus Sinus. In general they perfectly reproduce their prototypes, while in detail they present a little more closely the appearance of the same



MAP 3. DAWES BY PROCTOR, 1867.

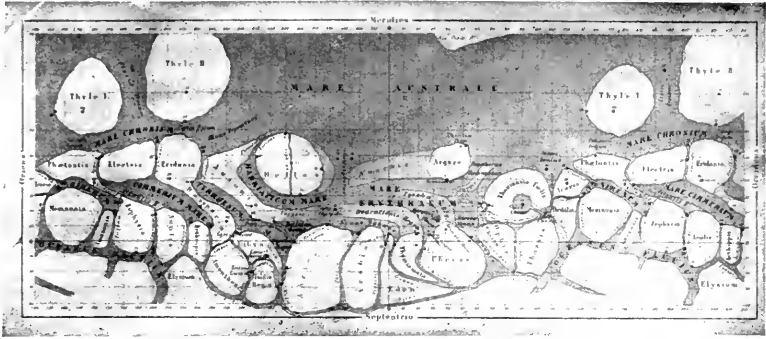
markings to-day. The map is a slight advance upon its predecessor, and a complete corroboration of it. In these portraitures Kaiser stood not alone. About the same date Lockyer, although he constructed



MAP 4. RÉSUMÉ BY FLAMMARION OF ALL TO DATE, 1876.

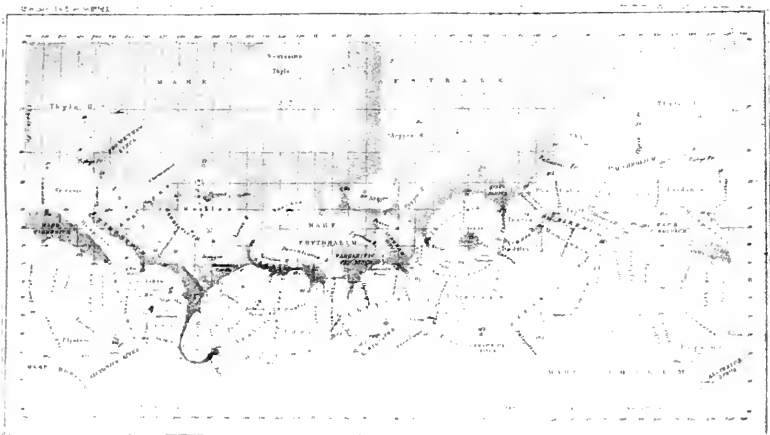
no map, made some excellent drawings quite confirmative of Kaiser's and rather better. So also did Dawes (Map III.), nicknamed the eagle-eyed for his ability to detect difficult phenomena.

Schiaparelli opened a new era in 1877 (Map V.). Unsuspecting of what he was to stumble on, he seized the then favorable opposition to make, as he put it, a geodetic survey of the planet's surface. He hoped to find this undertaking feasible to the accuracy of micrometric measurement. His hopes did not belie him. He found that it was



MAP 5. SCHIAPARELLI, 1877.

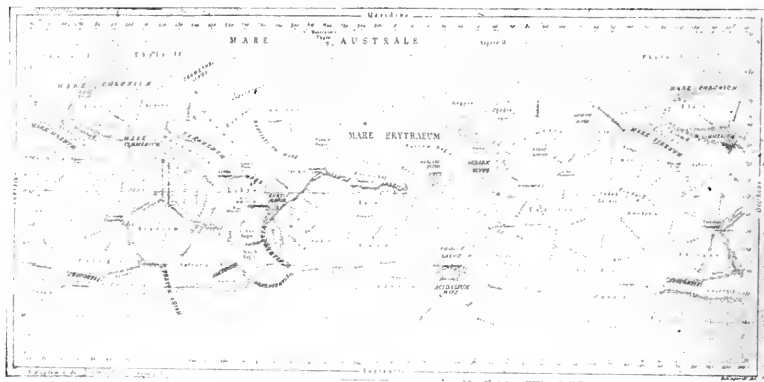
possible to measure his positions with sufficient exactness to make a skeleton map on which to embody the markings in detail—and thus to give his map vertebrate support. But in the course of his work he became aware of hitherto unrecognized traits of the so-called continents.



MAP 5. SCHIAPARELLI, 1879.

Instead of displaying a broad unity of face the bright areas appeared to be but groundwork for streaks. The streaks traversed them in all directions, tessellating the continents into a tilework of islands. Such mosaic was not only new, but the fashion of the thing was of a new order or kind. The old markings were patches which might well

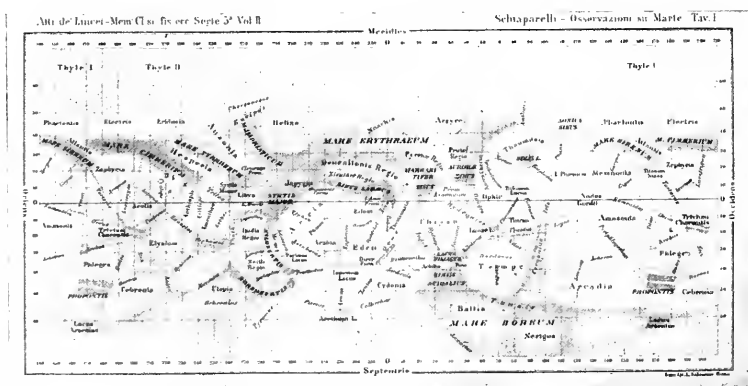
enough be seas and oceans, but here were narrow bands which could hardly pass muster as straits, so long and narrow were the arms thus thrust out into the continents by the seas. Straits, however, Schiaparelli considered them and gave them the name canali, or channels.



MAP 7. SCHIAPARELLI, 1882.

How unfamiliar and seemingly impossible the new detail was is best evidenced by the prompt and unanimous disbelief with which it was met.

I have spoken of Dawes as draughting some of these lines; but it must not be supposed that he did more than adumbrate them. It is



MAP 8. SCHIAPARELLI, 1884.

possible now to recognize in what Dawes saw, glimpses of something which later Schiaparelli observed, but it would be quite erroneous to imagine such suggestions as in any sense forestalling a view of the things themselves. Perhaps the best proof of such insufficiency is that

Schiaparelli himself was the only person who perceived any relationship between the two, and that after the fact.

Unmoved by the universal scepticism which rewarded his epoch-making discovery, Schiaparelli went on, in the judgment of his critics, from bad to worse—for in 1879 (Map VI.) he took up again his scrutiny of the planet to the detecting of yet further peculiarity. He re-observed most of his old canals and discovered half as many more. But the striking part of the affair is something which does not seem to have attracted attention—the increased unnatural look of his lines. Lost in the general incredulity a little bizarreness more or less escaped significant criticism. It was all so strange that any change in strangeness simply went to confirm the universal skepticism.

In 1881–2 (Map VII.) he attacked the planet again and with results yet farther out of the common. His lines were still there with more beside, but the startling thing about them was their appearance. If they had looked strange before, they now appeared positively unnatural. The things were simply fine, narrow, uniform, straight lines sometimes alone, sometimes astoundingly paired, but, however associated, geometrical to a degree. As he himself expressed it, they seemed as if drawn by rule and compass, these absolutely regular lines connecting one dark marking with another.

In 1883–4 (Map VIII.) the same thing occurred. An unnatural precision distinguished all his 'canali.' To add to the difficulty of acceptance, as in 1882, they followed arcs of great circles, and were in every respect markings of a highly suspicious cast of character. Nor did his exclusive perception of them conduce in astronomic estimation to the assurance of their objective existence.

The map compiled from the observations of 1883–4 was the last made by Schiaparelli of the whole planet. In subsequent oppositions the south pole was so tilted away from the earth that only the regions of the northern hemisphere were well seen and in consequence charted. But the omissions are not material to the present purpose, for the character of the charting remains substantially the same.

As will have been gathered from the above description, the factitious appearance of the 'canals' was the chief bar to their acceptance. That they looked inconceivable argued their conception in the brain of the observer alone. An inference, this, not without a certain justification in the inability of others to follow in his steps. But one point contained in the charts failed of making its impression. If we compare with special reference to the unnaturalness of the lines the several maps of the series with one another we shall be aware of a progressive increase in regularity in the physiognomy of the canals with the time. Schiaparelli's map of 1877 viewed in the light of his subsequent productions seems but a tame bit of innovation after all. His canals as he saw them

then were narrow winding streaks, hardly even roughly regular and by no means such departures from plausibility as to be without the scientific expurgatorial pale. Indeed to a modern reader prepared beforehand for geometric construction they will probably appear no 'canals' at all.

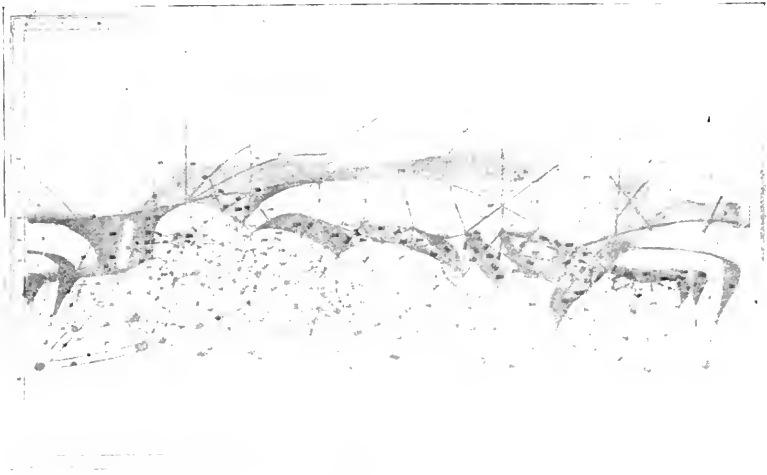
Certainly the price of acceptance was not a large one to pay. But like that of the Sybilline books it increased with putting off. What he offered the public in 1879 was much more dearly to be bought. The lines were straighter, narrower and in every way less natural than they had seemed two years before. They were again refused belief and on seemingly better grounds. In 1881-2 they progressed still more in unaccountability. They had now become regular rule and compass lines as straight, as even and as precise as any draughtsman could wish and quite what astronomie faith did not desire. Having thus donned the character, they nevermore put it off. Their precision grew persistent until finally other men began to admit what on much easier terms they had earlier rejected.

Now this curious evolution in design points to one interesting deduction. It shows that Schiaparelli started with no preconceived idea on the subject. On the contrary it is clear that he shared to begin with the prevailing hesitancy to accept anything out of the ordinary. Nor did he overcome his reluctance except as by degrees he was compelled, for the canals did not change their characteristics nor could the glimpse he got of them have altered as time went on, except in frequency, so far as the eye itself was concerned. But the brain made different account of the reports as it grew familiar with the messages sent it, and gradually by acquaintance learned to distinguish more particularly what it saw. In other words, the geometrical character of the 'canals' was forced upon him by the things themselves instead of being, as his critics took for granted, foisted on them by him. We have since seen the regularity of the canals so undeniably that we are not now in need of such inferential support to help us to the truth, but too late, as it is, to be of controversial moment the deduction is none the less of some historic force.

The year 1890 brought Schiaparelli's labors to a close: and 1892 ushered in at once a new cycle of the planet's seasons and a fresh set of observers on earth. In 1892 the planet was again favorably placed for observation, much as it had been in 1877, and the chief observers of it were W. H. Pickering at Arequipa, Peru, and Schaeberle and Barnard at the Lick Observatory, California. Just as Dawes had made in some sort a transition between the first period and the second, so these observers furnished the stepping stone from the second period to the third. W. H. Pickering detected in the planet's dark regions certain yet darker ramifications which he denominated river-systems. Nearly simul-



taneously the Lick observers noted what they called streaks in the same regions. These markings were as their names imply irregular or indeterminate. Nor were they credited by their discoverers with



MAP 9. LOWELL, 1894

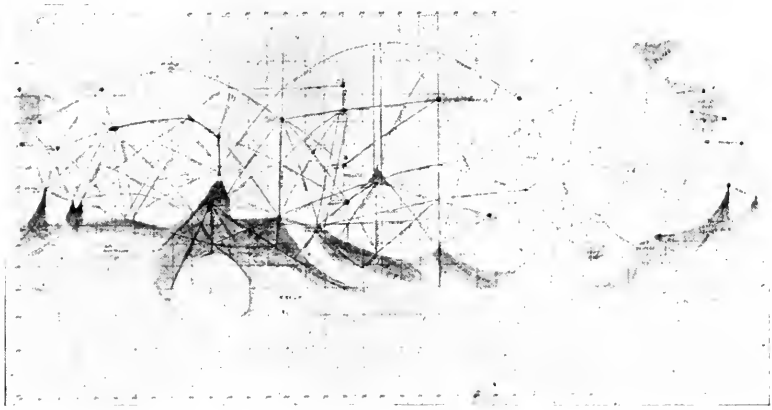
significance beyond what the names import. They were thus of the same transition character as Dawes' delineations. But Pickering drew some important inferences from what he saw. From what he detected



MAP 10. LOWELL, 1897.

he concluded that the greater part of these dark areas could not be seas as they had been supposed to be even by Schiaparelli. Schaeberle and Barnard on this and on other grounds advanced something of the same theory.

In 1894 (Map IX.) Douglass at Flagstaff discovered a fact which did for the dark regions what Schiaparelli's canals had done for the light ones. He found on scrutinizing the southern dark areas that Pickering's river-systems, which he too had seen in 1892, came out



MAP 11. LOWELL, 1899.

again and proved to be but part and parcel of a systematic set of lines networking those areas. He noted that these lines were not only simple streaks, but that they had nothing irregular about them, and could not possibly, therefore, be the river-systems supposed by Pickering. The lines were straight, equable in width and connected with one another at



MAP 12. LOWELL, 1901.

certain determinate points. They followed apparently arcs of great circles and covered all the dark regions which could be well seen with a singularly symmetric mesh. In other words, they presented all those strange, peculiar and enigmatic characteristics which distinguished the

so-called canals, and rendered them unlike anything else in heaven and earth. Here was a fact of the utmost significance. The curious canal system was not confined to the bright regions of the planet. The dark regions, too, had a canal constitution as intricate and as complete as theirs and its perfect parallel.

It is interesting to note that the dawning recognition of these canals followed the same course that it had with the others. Both sets were perceived as streaks and sinuousities before their strangely regular character flashed upon the observer.

As time went on it became evident that the two sets of canals formed part of one whole. The mesh in the bright regions ended at points on the so-called coast-line where the mesh in the dark regions began. The system was thus knit together and made of a piece over the whole surface of the planet. On the belt of narrow 'seas' lying between the continent and the chain of islands to the south, it was as of a lacing run through eyelets in the coast-lines giving an effect of slashed trunk-hose, so singularly did the canals criss-cross them working up in a zigzag progression from one end of a sea to the other.

In 1896-7 (Map X.) the dark region canals came out still more distinctly and especially the oases or spots at their junctions.

At the succeeding oppositions they continued visible and the few dark areas in the northern hemisphere were found in 1899 (Map XI.) and still more so in 1901 (Map. XII.) to be similarly but groundwork for a superposed mesh of knots and netting. No part of the somber portions any more than of the light ones remained free of the systematic triangulation.

Furthermore each period contains within itself a progressive development in particularity. Each successive opposition has made the foundation it found more secure and added a superstructure of its own. And what has been true of each period by itself has been equally so of the three taken together. As the maps show, each has been at once a review and an advance. This has been due not only to increased optical facilities and improved atmospheric conditions, but still more to systematic, persistent and extended work on the part of the observers.

It will thus be seen that three stages mark the advance in areography from the time of Beer and Mädler to the present day and that these stages are distinguished by the detection of essentially new and fundamental phenomena:

- I. Stage of supposed continents and seas.
- II. Stage of 'canals' found intersecting the lands.
- III. Stage of 'canals' found traversing the 'seas.'

Each of the stages is here represented by four maps, and each is an advance upon its predecessor.

## UNIVERSITY CONTROL.

BY PROFESSOR J. J. STEVENSON,  
NEW YORK UNIVERSITY.

THE pessimism with which some recent writers regard the university outlook in our country is, unfortunately, not wholly unreasonable. Yet the conditions, far though they be from the ideal, are not such as to make one despondent. The rapid development of our country has brought difficulties to colleges and universities as it did to business enterprises. The business world recognized the difficulties and overcame them at the cost of complete change in methods. Let the business common sense, which has made the United States preeminent in commerce, be applied to university matters and it will give us equal pre-eminence in education. It is necessary to recognize the conditions frankly, to cast aside injurious makeshifts and to adjust the methods to the new surroundings and the new demands. For the surroundings and the demands are new. Within the last thirty years, the relations between the teaching and the corporate boards have undergone a serious transformation; the relations of college professors to the community, as well as to their students, have been revolutionized; the manner and the matter of the professor's work in many departments bear no resemblance to those of thirty years ago. The extent and nature of these changes are known in but slight degree to those in the corporate boards of colleges and universities; the community is wholly ignorant of them. Let us understand them.

At the close of the Civil War, American colleges were comparatively small. Their trustees, for the most part, were alumni or professional men familiar with college work, as it then existed, and personally acquainted with the professors with whom they were in sympathy and for whose benefit they held their place. But, within a generation, the small colleges have become large, many of them have expanded into true universities with numerous departments, hundreds of instructors and thousands of students; while the financial interests, expanding more rapidly than the institutions, have attained a magnitude in some cases as great as that of New York's finances fifty years ago. No trustee in a large college to-day can know much of college work as such, can be acquainted with the faculties, can do much more than bear his share of the business responsibility. Vast sums of money needed for expansion, even for continued existence, are sought from men, who, having

accumulated wealth, desire to leave the world better than they found it. Such men, in many cases, hesitate to entrust the disposition of their gifts wholly to others and each year finds them in increasing numbers upon corporate boards of colleges and universities—sometimes because they have contributed, sometimes because it is hoped that they will contribute.

These patrons, if not college graduates, labor under a disadvantage in that they are unacquainted with the nature of the work for which colleges have been founded; even if they be college graduates they are at an almost equal disadvantage, as absorption in business or professional pursuits has prevented them from keeping track of the changes which have come about since their graduation. As a rule, their new responsibility does not tend to create or to renew acquaintance with college work; the trustees' duties usually begin and end with labors on committees, so that naturally enough the business affairs with which they have to do become for them the all-important work of the institution. And this conception is strengthened by thoughtless assertions of men who ought to know better. Only recently this community was informed that the millionaires make the universities. With such flattery ringing in their ears, one is not surprised that some trustees forget the object for which the university exists and think of professors, when they think of them at all, as merely employees of the corporation, whose personality and opinions are as unimportant as those of a bank clerk.

Unacquainted with the faculty, unfamiliar with the extent and even character of the work done by individual professors, the trustees depend for knowledge of the educational affairs upon reports by the college or university president, for in rare instances only have faculties, as such, representatives in the board. Unfortunately, very few of our college presidents have taken a preliminary course to qualify them for the position. Indeed, it must be confessed that ability to superintend educational work has not been regarded in all cases as the essential prerequisite: in some cases that appears to have been thought less important than a supposed ability to collect money. But at the best no one man is able now to understand all the phases of university or even college work, as many college presidents already recognize; but were he able and willing, he has little opportunity to make his trustees comprehend them. Discussion of purely business matters occupies so much attention during board meetings that discussion of other matters must be deferred and the president's report is printed that it may be read at leisure. The best of presidents becomes weakened by the overwhelming importance of the financial side and comes to look upon increasing numbers as the sure proof of success. He soon finds himself between the upper millstone of the trustees and the nether millstone of the faculty, the former insisting upon numbers, the latter upon a high

standard, so that in an honest effort to perform his duty, he is in danger of receiving censure from both.

The change in relations of the educational and corporate boards is due to a drifting apart of the two boards, leading to the loss of that sympathy, which was the bond, and to a reversal of the relative importance of the boards. Formerly trustees existed to care for the faculties; now many trustees evidently feel that the faculties are appendages to the board of trustees.

But while the conditions in respect to the relations between educational and corporate boards have undergone a change, on the whole, decidedly for the worse, the conditions in respect to the professor's relations to the community and to his work have undergone a change no less radical, not indeed for the worse, but at a cost to himself so serious as to impair his usefulness and to threaten that of the institutions themselves. Here lies, in the opinion of many thoughtful men, the secret of deterioration observable in the output.

The common belief is that the college professor's teaching work is purely incidental, an easy method of obtaining a good living, that he may pursue his studies without anxiety respecting worldly matters. Whatever may have been the case in some prehistoric period, it is certain that in our day there is no calling in which the pecuniary compensation is so low, while the intellectual requirement is so high as in that of college professor. The average salary of college men in New York city is much less than the average salary of clergymen. The expansion, one may almost say the very existence, of American colleges is due to the consecrated devotion of those who give the instruction. Of the immense gifts made to American colleges, comparatively little goes toward increasing salaries of professors already at work; almost the whole goes to meet the insatiable demand for expansion.

Nor is the college instructor a man of 'abundant literary leisure, as many still suppose. College professors of a generation and a half ago were, for the most part, recluses—made so by the nature of the studies then included in the college curriculum. The hours of teaching were short, and beyond those the institution demanded little. There was abundant leisure and it was used well in study. But now, in many departments the hours are long, often covering in one way or another the whole day, while other requirements are severe. The college demands that the professors be encyclopedic in knowledge of the subjects covered by their chairs, no matter how broad these may be, that they contribute frequently to the journals, that they be prominent in social, scientific, political or religious affairs. How much of the literary leisure remains in some departments one may imagine—and the increasing requirements, all involving pecuniary expenditure, have come with decreasing salaries. For the most part, professors are no longer doctri-

naires; the character of their work compels close contact with the world. Museums of applied chemistry, physics, biology and geology are notable features in all the larger universities and are not unknown in the smaller institutions. Social science and psychology no longer deal in merely *à priori* discussions; they deal with facts for which search is made everywhere.

But far more important is the change in the professor's relation to his work. And here reference may be made parenthetically to a matter of some importance. The college curriculum of forty years ago was, to say the least, elementary. A reasonably good graduate was fit to be tutor in any branch and a professional man, who had kept up his literary tastes was not thought to be presumptuous when he applied for any one of the chairs. The college president was usually professor of mental and moral science, because a clergyman of rather more than average ability was, of course, fitted for that chair. But in this day, special, prolonged preparation is required for any chair, be it philosophy, history or chemistry. The progress which this condition indicates has led to an unforeseen difficulty which is becoming a subject of anxiety. For a long period the college curriculum, framed on narrow lines, remained practically unchanged and the secondary schools, with small equipment, prepared pupils in a leisurely way. As a rule the preparation was good and the boys entered college practically on a level. Within twenty years our colleges have not only increased the entrance requirements for some parts of the old course, but they have introduced new courses, even new departments, each with special entrance requirements, often very high. In great part, the secondary schools, with their limited resources, have been unable to increase their staff so as to keep pace with increasing demands from the colleges, and the students from different schools, though nominally alike in sum of preparatory work, are no longer approximately on the same plane. The college instructor, who has to do with the earlier years, finds himself burdened not merely with the work legitimately belonging to him, but also with much of the preliminary training. This combination of preparatory drill and advanced work is perplexing.

It is very true that the burden of changed conditions in respect to college work is not felt equally in all departments. Professors in charge of some of the older chairs have an increased burden, in that the method of teaching differs, yet, taken as a whole, matters in so far as undergraduate work is concerned, remain with them pretty much as they were thirty years ago. But the teaching of concrete subjects is so completely changed both in matter and manner that one must dwell somewhat in detail upon the conditions; the more so because they have come about so rapidly that even professors in other departments are unaware of their extent.

Science, for a long time, was an insignificant feature of the college curriculum; its treatment was more elementary than that of history. The professor had an immense field to cover—the whole of nature aside from man's achievements in a few directions—but, while he taught many subjects after a fashion, he studied only one. The stock of knowledge was very small and anything new to one observer was likely to be new to all others. Investigation was a simple matter; ingenuity, industry and keen discrimination made up most of the necessary equipment; so that there were few earnest teachers who failed to contribute frequently to the common stock. But, by their earnestness, these men worked their destruction as investigators; for while each had his chosen field of study, he still covered the whole area as teacher. Many of the discoveries made by these men were startling and were discussed in a more or less inaccurate way by the newspapers. Students sought explanation from the professor who was supposed to know everything. The botanist was puzzled by questions respecting chemical physics or psychology; the physicist was worried by questions respecting alleged discoveries in biology or geology. Practical application of newly discovered principles followed quickly to add to the teacher's trials. There was no longer time for special investigations and all one's energies had to be devoted to a vain effort to keep pace with investigations in the several directions.

The danger of this condition was recognized early in some of the older and wealthier institutions, so that in them, as in some of the newly organized and well-endowed universities, the fact was accepted that the several sciences were soon to be independent professions, and the departments of chemistry, physics, biology, psychology, geology, paleontology and mineralogy became practically schools, each with its own staff of professors and assistants.

But in too many of our colleges the danger was not recognized at an early period and in too many it is still unrecognized. Only a few of our institutions have more than four chairs in natural science, many have only two, and far too many are still in the sub-high school stage of only one. Yet the catalogues of such institutions offer a long series of courses, graduate as well as undergraduate, in several departments. A rather prominent college trustee not long ago informed the writer that a professorship of psychology or physics or geology is hardly equal in extent to one of Latin or pure mathematics. Yet any one of the chairs first named covers a group of subjects as unrelated as those embraced by the old-time chair of 'mental and moral science, history and belles lettres.' It is broader in scope than that other chair of 'ancient and modern languages' which existed in many colleges thirty-three years ago. A professor who teaches three branches of chemistry, physics or geology in three successive hours deals with three wholly



different matters, three distinctly unrelated lines of investigation, requiring independent methods of preparation and each demanding as much knowledge as does the whole work of a professor holding a chair of languages. But, aside from this class-room labor, the teacher of science in the average institution must prepare demonstrative lectures, must keep apparatus in proper condition, must procure and care for museum material, must spend time with classes in field demonstration, while, in addition, he has the never-ending grind required to keep him in touch with the growth of knowledge respecting subjects embraced in his department. These are burdens from which professors in the older courses are happily free.

It is true that the science teacher in most of our colleges has only himself to blame for the severity of his burden. Determination to give to his students what he believes due to them has led him to make exertions which were not required but which, once begun, came to be regarded as part of his duties. Had he not manufactured apparatus and begged money with which to procure more, he would have had little for which to care; had he not expended ingenuity in preparing elaborate experiments with limited advantages, he would have had no occasion for greater expenditure; had he not expended his money and his vacations in procuring museum material and his energy in pestering acquaintances for generous donations of such material, he would have had little labor in connection with a museum; had he not insisted upon the introduction of laboratory teaching no one else would have insisted upon it. But having a clear conception of duty, he has sacrificed himself deliberately. The great expansion of the scientific departments of American colleges is due to the exertions of the teachers of science; and they in many instances have received neither gratitude nor any other acknowledgment.

And yet not without reward, for the influence of the science teacher has gone out far beyond the college limits. The great discoveries, up to within a few years, were made by college professors, and these, applied by inventors, have changed the face of the civilized globe, while those to whom the world is indebted for its comforts are unknown even by name. Their work has spread intelligence and revolutionized educational methods. Children in the upper classes of grammar schools know more respecting the earth and the relations of nations than did the college graduate of forty years ago. The high school teaching of science is far in advance of ordinary college teaching as it was twenty-five years ago, and in some respects fully equal if not superior to that in a large proportion of American colleges to-day. One is guilty of no exaggeration in saying that high school graduates know as much of chemistry, physics, biology and geology, when they enter the freshman class, as is offered in many colleges, for in those schools the subjects are not taught

superficially. This fact cannot be stated too emphatically and it should be forced upon the attention of those in control of college affairs. With the broadening in science teaching there has come a similar broadening in other studies. Full of the self-sufficiency encouraged by the older system of education, the college graduate who has reached middle life does not recognize that the ordinary man and woman are intelligent, well-informed and, in some respects, as well drilled intellectually as he. The proof is at hand. The lightest of our monthly magazines finds a demand for articles upon mining, sociology, electrical inventions, applied chemistry, bridge building, of a type which would have been about as intelligible as Choctaw to the community forty years ago; newspapers publish detailed descriptions of apparatus for wireless telegraphy, discuss problems in psychology, the mechanics of flying machines and pay generously for elaborate articles upon earthquakes and volcanoes; even the children talk glibly about ohms, volts and ampères as they play with electric toys. The high school is, so to speak, 'abroad in the land'; its bell tolls the knell for colleges which persist in the old method of specializing to the last degree in subjects which concern chiefly the intellectual side of man—an intellect regarded by most defenders of that method as debased by sin—while compressing within narrow limits those studies which concern the direct work of the Creator himself.

This advance adds to the burden of the science teacher. The 'elements' of a science in college often covers, or should cover, an area almost as extensive as that of the whole science thirty-five years ago. It has become difficult for science teachers to be investigators. The hours devoted by others to relaxation are required by them for study; their summer vacations are employed largely in the effort to catch up with the progress in their branch or branches. It is remarkable that so much work and so much good work is done by them in the way of original research, largely, it is true, in hours which should be given to rest. But, in too many instances, the opportunity for thorough work is lacking even where there may be time. Instead of scores, there are now hundreds of investigators in every branch of research, many belonging to government organizations, many employed by great corporations that their discoveries may be utilized, and some connected with universities which do not overwork them; publications are scattered through hundreds of journals and the literature on any subject has become appalling, so that the task of consulting it is of itself almost enough to deter any but a man of means and leisure from undertaking systematic investigation. Libraries, museums and costly apparatus are essential now, where, half a century ago, little was required aside from will and mental ability.

Especial emphasis has been laid upon the burden of the scientific

side, because the writer is more familiar with its changes during the last thirty-five years; but the condition is serious enough for incumbents of many chairs not scientific. Men in most of the American colleges and universities are badly handicapped by routine work; not that too many hours are spent in actual teaching, but as a rule the teaching covers too many things, while too much is expected or required outside of purely college duties. The condition is unfortunate for the world, which no longer reaps the fruit of college men's work as investigators; but it is many times more unfortunate for the student. To be a thorough educator, the college instructor must possess the instinct and the experience of an investigator, otherwise he cannot train men to think. The present method of utilizing professors tends to convert them into superficial purveyors of second-hand knowledge; it must lead to decay in our educational system which has owed its virility to professors who were independent thinkers because they were thorough investigators.

The condition is serious, so serious as to inspire hope for the future. Many suggestions have been presented, most of them good but almost all of them premature. Changes more radical than any yet proposed must be made before those suggestions can be considered.

American colleges have still to contend with two fundamental difficulties—poverty and an ancient method of control.

A college professor can hardly administer the remedy for poverty, but he may suggest what is on the surface. There are too many colleges which ought to be merely academies, too many which should be high schools, too many so-called universities which ought to be modest colleges, and there are enough of true universities to supply the country's need for a long time. Unquestionably, coalition in some cases and consolidation in others would go far toward relieving the stress; but consideration of even this matter is premature, for a radical change in the method of control must be brought about before either coalition or consolidation can become possible.

Originally, in most of our institutions, the college was the only school under control of the degree-granting corporation and the professional schools which grew up around it had but a nominal connection, managing their own affairs, both educational and financial. But the college is no longer the all-important portion of our universities: professional, technical and scientific schools, some of them in part replacing the college, predominate and all are actually, as well as nominally, under one corporate control. The college itself is not the school of thirty-five years ago; the whole system of training has been changed, and there is offered not a narrow but a broad education. Yet one finds in control of the vast institution the same president as in the olden time, with powers like those of an academy principal and often with

the same sense of personal ownership; the same board of trustees, with authority and privileges as in the days when the college was the whole and itself little better than an academy. In other words, we are controlling the great university with its thousands of students in many schools, with its many groups offering hundreds of courses, after the fashion which prevailed when there was but one group of courses, arranged expressly with reference to the needs of those looking forward to the clerical profession. The method is not adapted to the conditions; as well try to manage the New York Central of to-day by the railroad methods of forty years ago.

The time has come for a complete reorganization of the system; the educational work and the business management must be under separate boards, and the boundaries of the provinces should be definite.

The faculties, each for itself, should control appointments of professors and instructors; should determine all matters concerning curricula; should decide questions as to expansion or contraction of work; should have the final word respecting internal arrangement of buildings—in short should be the supreme authority in all matters directly affecting the educational work. Matters affecting the work of the university as a whole should be referred to a council composed of representatives from all of the faculties whose determination should be final. In very many institutions most of these powers are still vested in the board of trustees, which means simply that in these matters the whole control is in the hands of one or two members; since no board of trustees can possibly be competent to decide respecting qualifications of candidates for professorships or upon changes in curricula, decisions respecting these matters are most likely to be rendered in deference to the opinion of some trustee or officer who is supposed by the rest to know something about them. In other words, the individual trustees have transferred their powers while nominally retaining them.

The presiding officer of the council, the educational head of the university, should be one who has studied the educational problem from all sides; not necessarily a great scholar in any one department, but a broad scholar, possessing tact and executive force. Such men are not rare, though one may be pardoned for regretting that so many have chosen other professions in preference to that of college president. The faculties should select this officer.

The trustees should have charge of the financial interests of the institution. In some of our universities, those interests exceed those of some western states; even in less pretentious institutions they are very large. They are sufficient everywhere to require not merely close attention but an amount of business skill and shrewd foresight beyond that demanded by ordinary business of equal extent. The trustees cannot be the architects or the builders; but their work, if confined to its

proper province, would be so important that unless it were well performed, that of architects and builders would be imperfect. They should plan liberal things for the work, but should not leave the execution, as now, chiefly to one man. Under such conditions the bond between the boards would be close, for in frequent conferences each would become familiar with the general conditions and needs of the other, so that they would work, not merely in harmony, but also with the view to mutual helpfulness.

The writer has been informed that this plan is impracticable; that it has in itself the seeds of destruction; the faculties would be self-perpetuating bodies; conservatism would be crystallized; it is hard enough now to get rid of incompetent or antiquated professors, it would be impossible then; available funds would be applied to salaries and not to development; jealousies would paralyze the work; *et cetera* to the end of a list which does credit to its author's power of imagination.

An answer in part would be *Tu quoque*, for certainly trustees are usually self-perpetuating bodies and it is equally certain that crystallization of conservatism in trustee boards has not been the least of the difficulties with which energetic faculties have had to contend. It is quite possible that salaries might be increased, or that an effort would be made to increase them so that a college instructor could live in modest comfort upon his salary. But there is no need of trustee supervision to prevent selfish grasping of funds. Chairs have been divided, new courses established, new methods introduced, the grade of instruction elevated—all upon the initiative of the faculties, and this in face of the fact that such expansion means decreasing salaries.

With educational matters under control of the faculties more attention would be paid to the qualifications of candidates for appointments than to the qualifications of their supporters; there would be fewer instructors of the type which some regard as burdensome; a college professorship would not be a haven of rest in which a failure might be anchored by his friends; expansion at the expense of efficiency would cease; there would be an end to extreme specialization in narrow groups but a wiser specialization in studies of a different type. No doubt mistakes, and many of them, would be made, as college professors are like other men; but the faculties are less likely to err in their management than are those who know very little about educational affairs.

It has been suggested that strong men would not serve as trustees; but the suggested conditions would change the actual conditions very little so far as most of the trustees are concerned. It is altogether probable that able men would be much readier to serve than they are now. A man who would not entrust any part of his business to a college professor simply because he does not understand it, can hardly

hold college work in high esteem when he finds that, though almost wholly uninformed respecting it, he is thought competent to select the managers and to direct the method. It is not surprising that some of our modern trustees entertain little respect for college professors; the only wonder is that so many of them entertain any respect whatever. Under the proposed method, however, the trustee would be no longer a mere name, he would hold office with definite duties and definite responsibilities, whose nature he would understand. He could not fail to become familiar with some portion of the institution's work, for conference would bring every trustee into contact with representatives of the faculties. His personal interest in one department or another would be apt to take practical shape.

As business principles would prevail in the management, funds for endowments could be obtained with less difficulty because there would be less dread of waste through bad investment. Patrons would be more ready to found departments, equipped with men, materials and buildings, seeing in them more enduring monuments than mere memorials of stone.

The writer has been a college professor for thirty-three years. Familiar with the changes for good and ill to which this article refers, he has felt compelled to write without reserve and it may be with some emphasis, that the conditions may be brought sharply before those who really control the future of American colleges and universities. He appeals to that business common sense which characterizes the great majority of college trustees. American colleges and universities have outgrown their swaddling clothes; no amount of patching can make them fit; the new garments must be of different cut and of different material.

## THE WORLD-VIEW OF A SCIENTIST: ERNST HAECKEL'S PHILOSOPHY.\*

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IN 1892 Ernst Haeckel, the celebrated biologist, delivered an address before a society of naturalists, in which he outlined his creed, his 'Glaubensbekenntniss eines Naturforschers.' This address was printed under the title 'Monism as a Bond between Religion and Science,' and is now in its tenth edition. In 1899 a more elaborate account of Haeckel's philosophy was given to the world in a book called 'The World Riddles.' Within a few weeks after the appearance of this work 10,000 copies has been sold. It was at once translated into English and figured prominently in the lists of the most popular books of the day in our country. The magazines and even daily papers have published review after review of the 'World Riddles'; pamphlets and books have been written about it, and the interest still continues.\* The Academy of Turin, Italy, has declared the 'World Riddles,' to be the best book written during the last four years of the nineteenth century, and has awarded to its author the Bressa prize of 10,000 lire. The work has raised the feelings of many usually tranquil persons to a higher pitch of excitement, provoking extravagant expressions of admiration from some, and words of passionate indignation from others. There is joy in the camp of the Haeckelites, where the author is glorified as the greatest philosopher of the age, while in the ranks of the opponents there is angry contempt for a man who, so it is said, is an absolute ignoramus in matters of philosophy and in everything outside of his own *Fach*, and some critics are even willing to call in question his standing as a biologist. The turmoil is increasing, the angry voices are growing louder, and we hear words of reproach and insult on both sides, which we are not accustomed to hear from the lips of men of science. Some of the attacks which have been made upon Haeckel have passed the bounds of the respectable. One fire-eater, a Christian theologian, has taken the matter so to heart as to make an entirely personal affair of it. 'My remarks,' he says, 'are an attack upon Haeckel's honor, and are intended as such.'† The conflicts between the realists and

\* Lecture delivered at Cornell University under the auspices of the Sage School Philosophical Club.

† Schmidt, 'Der Kampf um die Weltraethsel,' mentions 72 German titles, to which may be added at least two more, making with his own work 75.

‡ Loofs, 'Anti-Haeckel.'

nominalists during the middle ages could not have been more bitter than this Haeckel controversy threatens to become, and we need have no fear, so far as I can see, that the occupation with intellectual things is blunting the emotional side of the modern thinker's soul.

It is not my intention to join in the hue and cry against this man who has dared to offer the world a *Weltanschauung*, nor am I willing to stamp his work as unworthy of notice. It is true, Haeckel has provoked a fair share of the abuse that has been heaped upon him by his own intolerant attitude, but after all two wrongs do not make a right. I believe that it will be worth our while to hear patiently what Haeckel has to say, and then to subject his philosophy to the tests by which it will be judged at last when the discordant voices of the present are hushed and the author and his critics are sleeping in their quiet graves. A work that has made such an impression upon an age as the 'World Riddles' can not be ignored or thrown out of court without a hearing, and the hearing must be impartial and temperate, such a hearing as it is bound to receive at the bar of history. It expresses the views of large numbers of natural scientists to-day, although few would dare to make public confession of their faith, as the fearless Jena biologist has done; and as an expression of opinion coming from such a quarter, it deserves attention. I shall therefore try in what follows to give an exposition of Haeckel's thought, and to examine its value as a theory of the universe.

And first let us turn to our philosopher's theory of knowledge.\* Our true knowledge, he says, is real in its nature; it consists of ideas (*Vorstellungen*) which correspond to really existing things. It is true we cannot know the innermost essence of this real world, of the thing in itself,† but we are convinced by impartial and critical observation and comparison that the external world makes the same impressions upon the sense-organs and brain of all normal rational individuals, and that the same ideas are formed by all persons whose organs of thought function normally. All our knowledge depends upon two physiological functions—upon sensation and upon the combination of the impressions thus gained, by association. The experiences which we receive from the external world through our sense-organs and sense-centers in the brain are transformed into ideas by other brain-centers, and these are combined into inferences by association. These inferences are both inductive and deductive, processes which have equal value. Other complicated brain operations, the formation of chains of reasoning, abstraction and conception, imagination, consciousness, thought and philosophy, are all functions of the ganglionic cells of the cerebral cortex.‡

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\* See particularly 'Die Weltraethsel,' pp. 337ff.

† See also pp. 437f, *op. cit.*, and 'Monismus,' p. 40.

‡ See also 'Weltraethsel,' pp. 19f.



But our sense-activity is limited; we can discover only a part of the qualities possessed by the objects of the external world. The civilized man transforms his sense-impressions into specific sensations in the sense-centers of the cortex, and combines these by association in the thought-centers into ideas or presentations, and by further combination of the idea-groups he finally reaches connected knowledge. But this knowledge always remains unsatisfactory, unless the fancy supplements the insufficient combining power of the understanding and by association of memory-images combines remote cognitions into a connected whole. In this way new ideas arise which alone explain the perceived facts and satisfy the causal need of the reason.

The ideas which fill the gaps in our knowledge, or take its place, we may call belief (*Glaube*). We are forced to belief in science. We surmise or assume that a certain relation exists between two phenomena although we do not know it with certainty. In the case of knowledge of causes we form a hypothesis. But only such hypotheses can be admitted in science which do not contradict known facts, *e. g.*, in physics, the doctrine of ether-vibrations; in chemistry, the assumption of atoms and their affinity; in biology, the doctrine of the molecular structure of the living plasma.

The explanation of a larger series of connected phenomena by the assumption of a common cause we call a theory. Here, too, faith or belief in the scientific sense is indispensable, here, too, the poetic fancy fills the gap which the understanding leaves in the knowledge of things. A theory can therefore be regarded only as an approximation to truth; it can always be supplanted by a better theory. But theory is indispensable in science, for theory alone explains the facts by assuming causes. Hence whoever wishes to do entirely without theory and to construct pure science upon nothing but 'certain facts' relinquishes all knowledge of causes and the satisfaction of the causal need of the reason.\* Examples of such theories are the theory of gravitation, the cosmological nebular theory, the principle of energy, the atomic theory, the vibration theory, the cell theory, the theory of descent. They explain a system of natural phenomena by assuming a common cause for all the particular facts of their territory. This cause itself may be unknown in its essence or be a merely provisional hypothesis. Gravitation, energy itself, ether, the atom, heredity, may be regarded by sceptical philosophers as 'mere hypotheses,' as products of scientific belief, but they are indispensable until they are replaced by a better hypothesis.

This theory of knowledge is almost identical with that offered by Epicurus three centuries before Christ. With respect to the problem

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\* See also 'Monismus,' p. 37.

of the origin of knowledge it is an extremely naïve form of empiricism and associationism. It is the old naïve story about sensations putting themselves together and forming ideas, of ideas putting themselves together and forming thought, personality, and all the other higher processes of consciousness.\* It is true Haeckel does incidentally speak of innate knowledge *à priori* in connection with innate instincts, which he explains as having originally been acquired empirically through race-experience,† but, so far as I see, this view does not affect his theory. Haeckel's empiricism is as unsatisfactory as it is simple, and has about as much value as the old theory of creation has in Haeckel's own science. Kant and modern epistemology seem to have made no impression whatever upon the great German biologist.

With respect to the problem of the nature of knowledge Haeckel's position is somewhat vacillating. He tells us that we do not know the inner essence of things in themselves; indeed, he afterwards hints that perhaps there are no such things in themselves for all we know. At the same time space and time are realities, objective realities, real entities: the existence of space and time is now definitely proved.‡ Here we seem to get a jumble of nearly all possible standpoints, of realism, semi-realism and idealism—one after another. That is (1) there is a thing in itself; we do not know its essence, however, but only its effects upon us; (2) for all we know there may be no thing in itself, we do not know and we do not care, we can get along without it; (3) space and time are realities, that is, either things in themselves or the attributes of things in themselves.

The same uncertainty prevails with respect to another point. Haeckel is a dogmatist and sceptic by turns, as the occasion suits him. We cannot know everything with certainty, we cannot get along without faith in science. The theories of science are articles of faith, provisional assumptions which may be overthrown at any time. Among such hypotheses Haeckel enumerates nearly all the great theories of the different sciences and also his own philosophical system§. But this humility is merely a passing stage with our philosopher; his attitude is generally dogmatic; the tone of his book is that of a man who is absolutely sure of his result. Thus after having told us that certainty is impossible in science, that we must fill the gaps in our knowledge by faith, he declares dogmatically that the existence of ether, cosmo-ether, as real matter, is to-day a positive fact and not a mere hypothesis."§ We can prove its existence by electrical and optical experiments;

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\* See 'Weltraethsel,' p. 141.

† P. 144.

‡ P. 283.

§ See Preface to 'Weltraethsel.'

|| Pp. 260f.

indeed, we can *see* the vibrating ether.\* It is likewise a certain historical fact that man is descended from apes, etc.† The discovery of the fossil ape-man of Java proves conclusively the descent of man from the ape.‡ The existence of space and time is also definitely proved. The historical evolution of the human soul from a long series of higher and lower mammalian souls must be regarded as a scientifically proved fact.

We are now ready to take up Haeckel's metaphysics. We shall first discuss the principles upon which his entire system rests and then consider their application to inorganic nature, organic nature and the psychical world.

In the celebrated address which Du Bois-Reymond delivered in the year 1880, and which was afterwards published as the 'Seven World Riddles,' he proposed seven problems: (1) The essence of matter and energy; (2) the origin of motion; (3) the origin of life; (4) the apparently purposive arrangement of nature; (5) the origin of sensation and consciousness; (6) rational thought and the origin of language; (7) the question of free will. Questions 1, 2 and 5 he regards as impossible of solution or transcendent; 3, 4 and 6 are difficult, but can be solved. On question 7 he is undecided. Haeckel makes short work of these riddles. The problem of matter and energy, the problem of motion and the problem of consciousness are solved, he thinks, by his conception of substance; the problem of life, the teleological problem and the problem of reason by the modern theory of evolution, while the free will problem is no problem at all, but a dogma based on mere illusion.

The conception of substance is therefore Haeckel's fundamental principle. Let us see what it means. There is one underlying principle two different aspects.§ This substance is infinite, indestructible and eternal; it fills the infinite space and is in eternal motion. The matter and energy therefore in the universe are constant. This gives us the laws of the conservation of matter and of energy, which really form one single law, the law of substance, the cosmological ground law, the law of the constancy of the universe, which follows necessarily from the principle of causality. This universal substance reveals to us two different aspects, two fundamental attributes: matter, the infinite extended substance-stuff, and mind (*Geist*), the all-embracing substance-energy. It is God and nature at the same time; body and mind

\* 'Monismus,' p. 16.

† 'Weltraethsel,' p. 97.

‡ P. 100. See also pp. 18, 73.

§ See 'Weltraethsel,' pp. 243ff.

|| P. 15.

(or matter and energy) are inseparably connected.\* God is not an external being, acting from without, but a divine power or moving spirit, the cosmos itself; the phenomena of surrounding nature, organic as well as inorganic, are merely different products of one and the same original force, different combinations of one and the same original matter.† All the individual objects in the world, all the individual forms of existence, are merely transitory forms of the substance, accidents or modes. These modes are corporeal things, material bodies, when we consider them under the attribute of extension (as filling space); forces or ideas, when we regard them under the attribute of thought (or 'energy'). Matter (the stuff filling space) and energy (the moving force) are two attributes of one substance.‡

This view Haeckel calls monism, and tries to distinguish from materialism as follows: (1) Our pure monism is neither identical with theoretical materialism, which denies mind and resolves the world into a sum of dead atoms, nor with theoretical spiritualism (recently termed *Energetik* by Ostwald), which denies matter and regards the world as a spatially arranged group of energies or immaterial natural forces. (2) Matter can never exist and act without mind, nor mind without matter. 'We adhere to the pure and unambiguous monism of Spinoza,' says Haeckel; 'matter, as the infinitely extended substance, and mind (or energy) as the sentient (*empfindend*) or thinking substance, are the two fundamental attributes or ground properties of the all-embracing divine world-being, the universal substance.'§

If we interpret Haeckel's system in the light of the preceding statements, we certainly reach a kind of monism. Mind and matter are both aspects of an underlying substance. There is no difficulty in understanding what Haeckel means by the material aspect of the substance: it is the space-filling, extended stuff. It is not so easy to see, however, what the other phase of substance, the mental aspect, is. This attribute the philosopher calls mind or *Geist*, thought, the sentient side, energy, the moving force. In the chapter on substance we are left under the impression that these attributes are not independent entities, but attributes of something behind them, of a thing in itself called the substance. This impression is strengthened by Haeckel's concluding reflections at the end of his book:

We confess at the outset that we know just as little of the innermost essence of nature to-day, as did Anaximander and Empedocles 2,400 years ago,

\* P. 23.

† 'Monismus,' p. 13.

‡ 'Weltraethsel,' pp. 249f.

§ 'Weltraethsel,' p. 23. 'Monismus,' p. 27: "For our monism an 'immaterial living spirit' is as unthinkable as a 'dead spiritless matter'; in every atom both are inseparably combined. The other systems conceive force and matter as two essentially different substances."

Spinoza and Newton 200 years ago, or Kant and Goethe 100 years ago. Yes, we must even confess that the real essence of the substance becomes more wonderful and mysterious the more deeply we penetrate into the knowledge of its attributes, matter and energy, the more thoroughly we become acquainted with its numberless manifestations and their evolution. What is behind the knowable phenomena as a 'thing in itself' we do not know even to this day. But remaining true to his general tendency to be inconsistent with himself our author goes on to say: But what do we care about this mystical 'thing in itself' anyhow, when we have no means of investigating it, when we do not even know clearly whether it exists or not. Let us therefore leave it to the 'pure metaphysicians' to ponder fruitlessly over this ideal ghost, and let us rejoice instead as 'true physicists' in the enormous advances which our monistic philosophy of nature has actually made.\*

We see, Haeckel's conception of substance changes like a chameleon before our very eyes. We are first told that there is a thing in itself, then that we do not know what it is, and finally that we do not even know that it is. We are naïvely told that the notion of substance will solve all riddles, make all things clear to us, then we are informed that it is a mystery, the greatest mystery of all, and finally it vanishes into thin air before our very gaze, and turns into a phantom which perhaps does not even exist. After making the conception of substance do service as a principle of explanation for 436 pages of his book, after having employed it as the support of real attributes, space, time and energy, Haeckel suddenly dismisses it as an utterly useless piece of metaphysical furniture.

But these are not the only inconsistencies in the doctrine of substance. We are told that substance is unknowable, that matter and force are its attributes. We are told that God, the thing in itself, is an intramundane being and acts in the substance as force or energy.† That is, the thing in itself is force. Yes, perhaps the original hypothetical chemical element, the prothyl, is the substance; ‡ perhaps the world-ether is the creating god-head.§ What does all this mean? The substance perhaps does not exist; the substance does exist, but is unknowable; the substance has real attributes, and we know them; the substance is energy; the substance is perhaps prothyl; the substance is perhaps the world-ether. Haeckel is certainly right in his remark that consistent thinking is a difficult business.

There is another point worth noting at this place which will come up again. Haeckel speaks of the mental aspect of the substance as mind, thought, sensation (*Empfindung*), energy, moving force. This is something like Schopenhauer's will, only that it is not a substance, but the attribute of a substance. As an attribute distinct from the

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\* 'Weltraethsel,' pp. 437 ff.

† 'Weltraethsel,' p. 333.

‡ 'Weltraethsel,' p. 426.

§ 'Monismus,' pp. 16, 37.

other attribute, matter, it must be immaterial, something of the same nature as consciousness, only not conscious on the lower stages of existence. It seems to account for all movement and thought in the world.

Now that we have become acquainted with Haeckel's fundamental principles, let us observe what application is made of them. We shall take up in order the inorganic world, organic nature and psychic life.

The substance fills infinite space as a continuum. It is endowed with a mechanical form of activity, with a striving (*Streben*) to become dense or to contract. In this way little centers are formed of the parts of the universal substance which Haeckel calls pyknotoms, and which possess sensation (*Empfindung*) and impulse or striving (*Streben*), will-movements of the simplest kind, and hence are in a certain sense animated.\* The atoms are not dead mass particles, but living elemental particles, endowed with the power of attraction and repulsion; love and hate are merely different expressions for this power of attraction and repulsion.† These original atoms are probably of the same size and essence, but they are not divisible. Their form is most likely spherical; they are inert (in the sense of physics), unchangeable, inelastic, not penetrable by ether. They have another quality, chemical affinity, an inclination to combine and to form little groups in a uniform way. These fixed groups of original atoms are the so-called elemental atoms, the known indecomposable atoms of chemistry. Hence the qualitative differences of our chemical elements are conditioned solely by the different number and configuration of the homogeneous original atoms. We do not know what is the nature of these original atoms themselves; perhaps it is prothyl.‡

These atoms do not float in empty space, but in a continuous extremely thin intervening substance which represents the non-contracted part of the original substance. In this way the substance, which in its original state of rest has the same density throughout, differentiates into two parts: the pyknotoms, ponderable matter, and the intervening ether, the imponderable matter. The result of this separation or differentiation is a constant struggle between these antagonistic parts of substance, and to this struggle all physical processes are due. As was said before, these atoms are not dead and movable by external forces only; they possess sensation and will (in the lowest degrees, of course), they experience pleasure in the process of contraction (*Verdichtung*), pain in the process of tension (*Spannung*); they strive after the first and struggle against the last. Hence atoms are endowed with a universal 'soul' of the most primitive kind. The

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\* 'Weltraethsel,' pp. 250ff.

† 'Monismus,' p. 14.

‡ 'Monismus,' p. 17.

same is true of molecules or mass-particles, which consist of two or more atoms.\* But these elementary psychical activities which are attributed to the atoms are unconscious processes. Consciousness and soul-life are not identical terms; consciousness forms but a part of soul-phenomena; the largest part of the latter is unconscious.† There is no immaterial substance; experience never reveals such a thing, no force that is not bound to matter, no form of energy that is not mediated by movements of matter.

There is no difference between organic and inorganic nature. All phenomena are explained by physico-chemical forces in each realm. The doctrine of the vitalists is absurd. The peculiar chemical-physical properties of carbon—particularly of the carbon compounds—are the mechanical causes of the peculiar movements which distinguish the organic from the inorganic world. Life, in other words, is the product of inorganic nature, the living plasm originated from inorganic carbon compounds.‡ The universe is a unity, all natural forces are one. All the phenomena of organic life are subject to the universal law of substance, as much so as inorganic phenomena.

The higher forms of life are developed from the lower in accordance with the principles of the theory of evolution as advanced by Darwin. That man is descended from the higher apes is now an absolutely proved fact. The idea of purpose, the teleological explanation, which was eliminated from physical science long ago, can not be accepted in biology. The theory of natural selection proposed by Darwin explains the origin of so-called purposive organisms by purely mechanical causes. There is no purposive impulse discoverable anywhere in organic life; everything is the necessary result of the struggle for existence, which acts as a blind regulator and not as a foreseeing God, and which causes the transformation of organic forms by the reciprocal action of the laws of heredity and adaptation. Nor is there any such purposiveness in our moral life or in history, individual or racial. Mechanical causality explains everything.

We turn now to Haeckel's philosophy of soul, to which he devotes one third of the entire space of the 'Weltraethsel.'§ The soul is a natural phenomenon; hence psychology is a branch of natural science, particularly of physiology. The so-called psychologists are ignorant of anatomy and physiology, hence the largest part of psychological literature is to-day worthless waste paper. The prevalent conception of soul life regards soul and body as two different beings, says Haeckel, and this view has nothing to stand on. Soul life is a sum total of vital

\* 'Weltraethsel,' p. 259. See also 'Monismus,' p. 14.

† 'Weltraethsel,' pp. 206f.

‡ 'Weltraethsel,' pp. 296ff.

§ Pp. 101-243.

phenomena which are like all others bound to a definite material substratum called the psychoplasm.\* In this sense our view is materialistic. The processes in the lower forms of soul life, excitability, reflex movement, sensibility (*Empfindlichkeit*) and the impulse of self-preservation are directly conditioned by physiological processes in the plasm of their cells, by physical and chemical changes, which may be explained partly by heredity, partly by adaptation. The same may be said of the higher forms of soul life, for they have developed from the lower forms.

A study of comparative psychology and folk psychology, of ontogenetic and phylogenetic psychology, will show that organic life, in all its gradations, develops from the same forces of nature, from the physiological functions of sensation and movement. The plasm is the indispensable bearer of the psyche. The psyche, or soul, is not a separate being; the term psyche or soul is a collective term for the sum-total of the psychic functions of the plasm. In this sense the soul is a physiological abstraction, like the concept metabolism or generation. The 'soul' can not function without a certain chemical and physical composition of the psychoplasm.

All living organisms are sensitive (*empfindlich*); they distinguish the states of the surrounding world and react upon the same by certain changes within themselves. Light, heat, mechanical and chemical processes in the environment, act as stimuli upon the sensitive psychoplasm and cause changes in its molecular composition. There is an ascending scale of soul life, from the simplest forms of organic life where the entire protoplasm is sensitive and reacts, down to the most developed form, where we have a centralized nervous system and conscious sensation, the highest psychic function. We have cellular ideas, histonal ideas, unconscious ideas of the ganglionic cells, conscious ideas in brain cells, all of them being physiological functions of their psychoplasm. Only on the highest stages of animal organism does consciousness develop as a special function of a particular central organ of the nervous system. When the ideas become conscious, and when certain brain centers become highly developed, making possible an extensive association of conscious ideas, the organism becomes fitted to perform the highest functions which we characterize as thinking and deliberation, understanding and reason. We have the same stages in the development of memory and the association of ideas. There are many psychic products of this association of ideas, among them the unity of consciousness. Reason, the instincts, the emotions and the will are explained similarly. All these phases of psychic life are at first unconscious, all are functions of more or less complicated forms of organic matter, and all are subject to physical laws. The great riddle

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\* See also 'Monismus,' p. 21.



of the origin and nature of the soul is solved by phylogenetic psychology. The human soul is evolved from a long series of other mammalian souls. The historical evolution of the human soul out of a long series of higher and lower mammalian souls must be regarded as a scientifically proved fact.

Consciousness is a natural phenomenon like all the other soul activities. Consciousness is inner intuition, perception, *Anschauung*, an inner reflection or mirroring. We may divide it into world-consciousness and self-consciousness. The former embraces all possible phenomena of the external world which are possible to our knowledge; the latter is an inner mirroring of our own soul activity, of all ideas, sensations, strivings, and will acts.\* Consciousness and psychical life are not identical; psychical life extends farther than consciousness. Unconscious sensations, ideas and impulses also belong to soul life; indeed, this field is larger than the other.

Consciousness is bound to a centralized nervous system. The presence of a nervous central organ, highly developed sense-organs and association-groups, is essential to the existence of unitary consciousness. Protists have no developed ego-consciousness; their sensations and movements are unconscious. In short there is no consciousness until we reach the higher animals. The elementary psychic activities are all unconscious. The riddle of consciousness is no riddle at all. The neurological problem of consciousness is only a special case of the all-embracing cosmological problem, of the problem of substance. The problem of consciousness is a physiological problem, and as such to be reduced to the phenomena of physics and chemistry. Consciousness is therefore only a part of the higher soul activity, and as such dependent upon the normal structure of the corresponding soul organ, the brain. It is absolutely dependent upon the chemical changes of the brain substance. It is not an immaterial being, but a physiological function of the brain. The new-born child is without consciousness; consciousness is a late development, arising first when the child learns to talk.

It is only in the significant moment when the child says I for the first time, when its ego feeling becomes clear, that its self-consciousness begins to sprout, and with this the opposition to the external world.

With the death of man all physiological activities cease, and with them the 'soul,' that is, that sum of brain functions which psychical dualism regards as a separate being, independent of the other manifestations of the living body. The protozoa are just as mortal in the physiological, and hence also in the psychological, sense as the metazoa. Energy and matter are inseparably connected. We distinguish between the psychical energy (sensation, presentation, willing) and psychical

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\* 'Weltraethsel,' pp. 197ff. See also 'Monismus,' pp. 22f.

matter, by which alone the same can act, that is, the living plasma. The soul is actual; it is the sum of the physiological functions of the material organs. The human soul is a collective term for a sum of brain functions, and these are like all other life processes conditioned by physical and chemical processes, and hence like all the rest subject to the law of substance.

Let us now see what has become of Haeckel's original monistic theory. According to the original proposition there is one underlying substance of which matter and energy are the attributes. What this substance is, no one knows; perhaps it does not exist at all; perhaps it is force; perhaps prothyl, perhaps ether. But never mind that. We have the two aspects of it in extended space-filling stuff, and the sentient energy. All of a sudden this unitary substance begins to turn itself into a plurality of atoms or pyknatoms; the one becomes the many, monism becomes pluralism. How is this to be explained? It is all very simple to Haeckel. Atoms have souls, feelings and desires, and these properties cause the atoms to contract.

Without the assumption of an atom-soul, says Haeckel in another place,\* the most common and most general phenomena of chemistry are inexplicable. Pleasure and pain, desire and aversion, attraction and repulsion must belong to all mass-atoms; for the movements of the atoms which must take place in the formation and separation of every chemical combination can be explained only if we ascribe to them sensation and will (*Empfindung und Wille*).

That is, the physical pluralism is explained by assuming a pluralism of forces. But why the unitary substance should desire to differentiate we are not told. But ignoring this difficulty, we note that these atom-souls or soul-atoms, these properties of sensation and will, cause the atoms to contract, and hence cause motion. That is, the attribute of energy, sentient force, mind, thought, or whatever else Haeckel may choose to call it, causes motion, makes matter move, produces a change in the other attribute. Almost in the same breath we are told that there is no form of energy which is not caused by movements of matter.† That is, the energy causes the movement, and the motion causes the energy. These statements not only contradict each other, but are out of harmony with the original standpoint of Haeckel, according to which mind and matter are attributes of an underlying substance, dependent upon this and not upon each other.

Haeckel's pure monism, we see, seems to turn into the much-despised dualism. But this is only a passing stage in the philosophical drama. We are hurried on rapidly to the denouement in the chapters on the soul, where the so-called psychical processes become the functions of physiological processes, of physical and chemical changes. We

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\* 'Perigenesis der Plastidule,' pp. 38f.

† 'Weltraethsel,' pp. 255f.

have already become acquainted with Haeckel's philosophy of mind; let us here simply accentuate the phases of it which do not agree with the fundamental principles. Soul life is the sum-total of vital phenomena which are all bound to a material substrate, conditioned by physiological functions. Soul is a collective term for the sum-total of the psychic functions of the plasm. 'Soul' is a collective term for a sum of brain functions, which are, like all life-activities, conditioned by physical and chemical processes. Soul life is unconscious until we reach the higher animals where it becomes conscious. Consciousness, however, is merely a development from the lower forms of psychic life and, like these, a function of physiological processes. It is dependent on the chemical changes of the brain; it is a physiological problem and as such solved by physics and chemistry. The sentient energy with which we began, which was at least equal in dignity with matter at the outset, and which assumed importance enough in the scheme to cause the matter to move, to attract and to repel, is now made the function of matter. Matter is the substrate, the substance; soul or mind the function of matter, housed in the latter and dependent upon it. Matter has become king; energy or mind its slave. Our so-called pure monism has changed into materialism, if not in the sense that it reduces everything, energy included, to matter and motion, at least in the sense that it makes this energy an attribute, a function of matter.

Besides the inconsistencies which we have noticed all along the line, there are difficulties in the system upon some of which we have already lightly touched. The continuous substance filling infinite space and endowed with infinite energy must do something if a cosmos is to be formed. It begins to differentiate and to form atoms. We are told why it does so: it has the unconscious impulse to do so, it is endowed with the properties of love and hate, which are only different names for attraction and repulsion. Why the infinite substance should want to do all this, we are left to figure out for ourselves. It is worth noting here, however, that Haeckel introduces the conception of purposive impulse into his explanation of the cosmos, an unconscious impulse or striving, it is true, but still a force attempting to account for the movements of the atoms. He does not therefore repudiate the teleological explanation *in toto*, as he claims to do, but only conscious teleology.

But in spite of all this the theory does not explain how these animated atoms floating in the ether can produce a world. We have here the same old difficulty which was presented to us by the first Greek atomists. In fact it is somewhat increased. Each pyknotom acts spontaneously; it is not a dead thing buffeted into place by other dead things, but a living thing that seeks its place, that strives to be united with other atoms which also strive, and their harmonious strivings give us a world. This is certainly a mystery of mysteries. Why the little atoms

should band themselves together and form molecules, why the molecules should fall into line and form larger bodies of matter, is not explained.

The same difficulty meets us, of course, in the philosophy of organic life. Haeckel supplies us with any number of animated pyknatoms, but we are at a loss what to do with them. How are they to form organisms? Of course, it is just as easy for them to form a simple piece of protoplasm as it is for them to form a planetary system, but there is poor consolation in that when it is a mystery how they can do either. Moreover the mysteries multiply a thousandfold when we pass from the very simplest form to the higher organisms. It is perhaps easy enough to describe what happens, to watch the process of cell division under the microscope, to trace the development through a series of stages, but why should the atoms group themselves in such a way as to form now a polyp, now a man. Each cell has its soul, it is true, unconscious impulse; and combinations of cells have corporate souls in turn, but they sit there helpless, unable to do anything; indeed what can they do, being merely a sum of vital phenomena, a collective term for the sum-total of physiological functions of the psychoplasm? The theory of evolution can not help us here, and the great Darwin frankly confessed that much. It can help us to see that if a certain form is given, that form will tend to survive if it is adapted to its surroundings, but why it should be in the first place, and why it should develop new and more appropriate characteristics in the course of time, it cannot tell us. As has been said by Schurman,\* the theory of evolution may explain the survival of the fittest, but it can not explain the arrival of the fittest.

It is strange that Haeckel should have found it necessary to endow his atoms with souls, and then have such a dread of attributing a principle of unity to organic forms. If the atom can have a soul or energy that makes it seek out some atoms and avoid others, why not endow the organism with a soul or force that will do something? I do not mean to advocate the renewal of the doctrine of vitalism in biology, after the fashion of Reinke† and other modern biologists, but I do not see why a man who gives atoms and cells and groups of cells souls, and who uses the atom-souls as a principle of explanation, should draw the line at organic forces or souls. If vitalism and teleology are acceptable in the inorganic world, why should they be so utterly out of the question in the organic realm?

The philosophy of mind is also full of difficulties. The existence of psychical life is not explained, but assumed. The substance is endowed from the beginning with sentient energy, energy that feels pleasure and

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\* 'The Ethical Import of Darwinism.'

† 'Die Welt als That.'

pain, loves and hates, has desires and aversions, but these states are all unconscious. Unconscious sensations, pleasures, pains and impulses are greater riddles than the things they are manufactured to explain. Haeckel seems to feel this when it comes to organic life, for here he identifies these unconscious processes with physical and chemical forces, though he is vacillating on his point as usual; the physical processes are sometimes the forces themselves, sometimes the functions of these forces. Out of these unconscious processes consciousness arises in the brains of higher animals. The thing is as simple as it can be. Ideas which have been unconscious mirror themselves in the brain, begin to look at themselves. Consciousness develops as a subjective mirroring of the objective processes in the neuroplasm of the soul cells\* and the thing is done. What could be fairer than that? And then these mirrored ideas, these ideas or rather brain processes that have suddenly taken it into their heads to look at themselves, add themselves together and form personalities and all higher processes of mind. The whole problem of existence is a problem of arithmetic. Atoms add themselves together to form bodies, bodies add themselves together to form worlds, ideas add themselves together to form thought, science, philosophy. Instead of answers to problems we get new and more difficult problems. It is no explanation of soul life to assume it as an attribute of the substance; it is no explanation of consciousness to deduce it from unconscious processes; it is no explanation of the human mind to conceive it as a sum-total of ideas.

This gives us Haeckel's philosophy of nature, his philosophy of life and his philosophy of mind. He believes that he has solved for us the problem of the essence of matter and energy, the origin of motion, the origin of life, the purposive arrangement of nature, the origin of thought and language, the origin of simple sensation and consciousness. The problem of matter and energy is solved by making matter and energy attributes of an underlying substance which is a greater riddle than they, and which perhaps does not even exist. We are never told what the essence of any of these things is. Afterwards matter seems to become the substance and energy its function. Energy is conceived as sentient force, as unconscious psychical life, and all the processes of soul life and consciousness are regarded as different forms of it or as functions of it. Matter, in other words, is the bearer of the different forces of nature, from the forces of attraction and repulsion or unconscious love and hate up to consciousness. Matter is king, energy is the subject. The origin of motion is not explained either. We are told that the substance is in eternal motion: 'motion is as immanent and original a property of the substance as sensation.'† We are also

\* 'Weltraethsel,' p. 151.

† On page 253 the substance seems to be conceived as originally in a state of rest.

told that force or sentient energy is the cause of motion. If we say motion is original and eternal, we do not explain it, but assume it. If we say it is the effect of force or energy, then we are explaining it by creating a new problem. The origin of life is explained in a general way as the product of inorganic nature; the living plasm originates from inorganic carbon compounds. The physico-chemical properties of carbon are the mechanical causes of the movements of organic bodies. But what are these physical and chemical properties? If they are themselves movements, then we have simply pushed the problem back a station; if they are forces or the so-called sentient energy, then we have avoided vitalism in the organic world by previously introducing it into the inorganic world. As for the problem of the purposeful arrangement of nature, we must agree with Haeckel that the theory of evolution throws a great deal of light upon it, but we can not agree with him that it removes all difficulties and solves all riddles, as we have already pointed out.

In conclusion let us take up Haeckel's ethics and religion. The practical laws, he declares, must be in harmony with a rational *Weltanschauung*. Our ethical system must therefore be in harmony with the unified conception of the cosmos. The universe forms a single complete whole, the mental and moral life of man forms a part of this cosmos, hence our natural order is a unitary one. We have not two separate worlds, a physical-material world and a moral-immaterial world, but one.

The monistic cosmology has shown that there is no personal God; comparative and genetic psychology has shown that there is no immortal soul; monistic physiology has shown that there is no freedom of the will. The doctrine of evolution shows that the eternal, necessary laws of nature which govern the inorganic world are valid also for the organic and moral world. This destroys the Kantian dualism in ethics. But there is also a positive side to ethical monism. It shows that the feeling of duty does not rest upon an illusory categorical imperative, but upon the real ground of the social instincts which we find in all higher gregarious animals. It regards as the highest aim of ethics the establishment of a healthy harmony between egoism and altruism. Man has duties towards himself and duties towards others. Both impulses, egoism and altruism, are natural laws which are equally essential to the existence of family and society. Egoism makes possible the self-preservation of the individual, altruism that of the species. The social duties are only higher developments of the social instincts. In civilized man all ethics, theoretical and practical, is connected as a normative science with his philosophy and religion. The golden rule is the fundamental law: Love your neighbor as yourself. Several christian rules of morality contradict this rule: (1) Contempt of self; exaggeration of

love of neighbor at expense of self; (2) contempt of body; (3) contempt of nature; (4) contempt of civilization; (5) contempt of family-life; (6) contempt of women.

As to religion Haeckel has this to say. Many scientists regard religion as a thing of the past. They think that the clear insight into the evolution of the world which we have obtained completely satisfies not only the causal need of our reason, but all the highest emotional needs of our nature. This view is in a certain sense true. For a perfectly clear and consistent conception of monism, the notions of religion and science become identical. Only a few decided thinkers reach, however, this view, fewer still have the courage or feel the need of expressing it.

Modern science must not only destroy the illusions of superstition, but erect a new edifice for the human emotions: a place of reason in which we may reverently adore the true trinity of the nineteenth century, the trinity of the true, the beautiful, and the good.

Just as the ancient Greeks embodied their ideals of virtue in the forms of gods, we can give our ideals of reason the forms of goddesses. The Goddess of Truth dwells in the temple of nature, in the green forests, upon the blue seas, on the snow-covered mountain-peaks. The ways of approach to this goddess are loving investigation of nature and its laws, the observation of the infinite world of stars by means of the telescope, and of the infinitely small world of cells by means of the microscope, but not senseless prayers and ceremonies.

Our ideal of virtue largely coincides with the christian ideal, as expressed in the Gospels and Paul's Epistles. The best part of christian morality consists in the rules of humanity, of love and forbearance, of compassion and beneficence. We place as much value, however, upon egoism as upon altruism; perfect virtue consists of a harmony between these.

The extension of our knowledge of nature, the discovery of countless beautiful forms of life, has awakened a new sense of the beautiful in us. Every blade of grass, every bug and butterfly, reveal beauties which we usually pass by. The admiration with which we regard the starry heavens and the microscopic life in a drop of water, the awe with which we examine the wonderful action of energy in the moved matter, the reverence which we feel in the presence of the law of substance,—all these are parts of our emotional life which come under the notion of natural religion.

Our monism also teaches us that we are children of the earth and therefore mortal, that we can enjoy the glories of this planet for a little while.

The modern man who possesses science and art—and hence also religion—needs no special church, no narrow enclosed space in which to worship. For everywhere in open nature, where he turns his eyes upon

the infinite universe or upon a part of it, everywhere he finds besides the hard struggle for existence the true, the beautiful and the good everywhere he finds his church in glorious nature herself. Still, it will correspond with the particular needs of many persons to have beautiful temples and churches to which to retire, and these they should have.

We have examined Haeckel's philosophy and have pointed out its inconsistency and inadequateness. It violates the fundamental requirements of scientific hypothesis; it is not consistent with itself, and it does not explain the facts. It is so full of contradictions that its opponents will have no difficulty in citing passages from the 'World Riddles' convicting the author of almost any philosophical heresy under the sun, while its defenders will be equally successful in proving by means of other quotations that the charges are unfounded. There is a great deal of truth in what von Hartmann says with respect to Haeckel's philosophy in his 'Geschichte der Metaphysik':

Haeckel is therefore an ontological pluralist, since he conceives nature as a plurality of separate substances (atoms); a metaphysical dualist, since he assumes two metaphysical principles (force and matter) in every single substance; a phenomenal dualist, since he recognizes two different fields of phenomena (external mechanical occurrence and internal sensation and will); a hylozoist, since he ascribes life and soul to every part of matter; a philosopher of identity, since he regards one and the same kind of substances as the ground of both fields of phenomena; a cosmologic monist, since he denies the teleological uniformity in nature and admits only causal law; and a mechanist, since he regards all causal processes as mechanical processes of material particles.\*

The fact is Haeckel's philosophy is no system at all, but a conglomeration of different systems; a metaphysical pot-pourri, a thing of shreds and patches. Perhaps this is one of the reasons of its popularity—*Wer vieles bringt wird jedem etwas bringen!*

Haeckel's 'World Riddles' proves conclusively that no man can neglect philosophy with impunity, and justifies the existence of a discipline like philosophy. Men will philosophize, even natural scientists—that is plain—and so long as they continue to do that, it is essential that they do it well. And they can not do it well without being trained to the work. It is just as impossible for a man to ignore the history of philosophy and to attempt to originate a system without regard to the race's experiences in system-building stretching over a period of 2,500 years or more, as it is for him to accomplish anything in physics or biology without profiting by the intellectual labors of the past and present in these fields. The man who tries to construct a system of philosophy in absolute independence of the work of his predecessors can not hope to rise very far beyond the crude theories of the beginnings of civilization. Haeckel, of course, is not wholly unac-

\* Vol. II., p. 456.



quainted with the history of philosophy, but his utterances usually make the impression on one that he has never done any serious work in this line, that his knowledge is largely based on hearsay, as it were. He certainly seems to be ignorant of modern psychology, otherwise he could not speak of it deprecatingly as he does. His criticisms may perhaps fit the psychology of fifty or a hundred years ago; they surely are not apt to-day. Here Haeckel appears to be fighting windmills of his own making. It is also plain that he is unfamiliar with modern epistemology and that a closer acquaintance with this subject would have saved him from falling into error and contradiction. Haeckel is fond of accusing men like Wundt, Helmholtz, Virchow, Du Bois-Reymond and others of his age, who started out as materialists and afterwards abandoned the conceptions of their younger days, of cowardice or senility or both. It is barely possible, however, that a deeper insight into the mysteries of nature and a finer appreciation of the inadequacy of the materialistic hypothesis convinced these men of the error of their ways. Haeckel prides himself on having retained the courage of his youthful convictions. I think myself that he deserves credit for saying what he really believes, but the fact that he believes what he believes is no sign to me that his friends are in their second childhood, but that Haeckel is still in his first, so far as philosophy is concerned.

## EELS AND THE EEL QUESTION.

BY M. C. MARSH,

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HISTORY recites an incident in which eels played the part of an executioner. The sentence a rich Roman, Vedius Pollio, passed upon his offending slaves was, 'Away to the *Muræna*.' Slave-fattened eels were a Roman delicacy, and there was probably more gastronomy than justice in this edict. Ever since, and long before, for that matter, eels have occupied a unique and conspicuous place in popular interest. For the antiquity of their history, for the diversity of rôles they have played, for the many-sidedness of their career and in their importance, eels rival any group of animals below the sons of Adam.

If one were to follow eels—meaning here the common eel and not the lamprey, the *Muræna*, or the conger, which have histories of their own—backward in literature, the journey would probably reach the dawn of history. It would be difficult to say where they first entered written records, but that they have ever been the subject of curious attention is apparent. While they doubtless first engaged man's interest by way of his stomach, they were early found worthy of his intellect. Aristotle, wise man of the first European civilization, who explained all things, discoursed wisely and ponderously of eels, and the eel question may be said to have begun with him and his contemporaries. Three thousand years have passed, Aristotle is gone, but the eels and the eel question are still with us and the wise men of our century still concern themselves with both.

What is here called the eel question is one upon which the last word will not be said for some time to come. But it has changed its form and we have it upon a rather firmer foundation than that of the ancients. It began in the mystery attaching to the generation of eels. They were as the leaves of the trees for numbers; but the course of nature in reproducing other creatures each after its own kind did not seem to be exemplified in eels. Hence the mystery. 'Eel-spawn' was of the same material as a mare's nest and pigeon's milk.

The teachings on the subject were various. They were the offspring of Jove. This belief, however, originated in the humorous reflection of a Greek poet to the effect that as children of uncertain paternity were ascribed to Jupiter, he must be the progenitor of eels. They were said to be bred of the mud; of decaying bodies in the water; from dew,

of a particular sort and falling in certain places; from the transformation of horse-hairs, and from electrical disturbances. A reverend bishop once communicated to the Royal Society a contribution on the subject of the origin of eels which in substance averred that he had seen young eels on the thatching of a cottage and that the eggs were adhering to the reeds of the thatching before they were cut, and were finally hatched on the roof by the heat of the sun. *Helmont*, an ancient writer, is specific and gives a recipe for producing eels. Two pieces of turf with May dew upon them were to be taken and the grassy sides apposed and placed in the sun. After a few hours an 'infinite quantity of eels' were generated. *Helmont* doubtless felt so sure of this that he regarded trying it a superfluous inconvenience, having no use for young eels. In the 'Piscatory Eclogues' is a reference in the same strain:

Say, canst thou tell how worms of moisture breed,  
Or pike are gendered of the pickrel weed?  
How carp without the parent seed renew  
Or slimy eels are formed of genial dew?

*Aristotle* wrote: 'The eel is neither male nor female and is procreated from nothing.' He explained that they were produced from the slime of their bodies, which they scraped off against the pebbles or stones or by contact with each other in their sinuous migrations. This sounds fishy to the twentieth century, but it is easy to see that to *Aristotle* there should be something in it. There was the slime—that was evident enough. It was purposive in amount, it gave the slipperiness to a creature which is notoriously slippery. The remarkable abundance of eels required a theory of reproduction on a grand scale. And as for their rubbing together, a mass of wriggling and intertwining eels, the well-known 'eel-ball,' suggested nothing more strongly. What more simple and, for those times, natural!

Now there is a curious mixture of stumbling truth and preposterous error in the development of the eel question from this time forward. There was another teaching concerning the source of eels. Some who examined them discovered many small worm-like creatures in their internal machinery and insisted that these were the young and were produced alive from the parent eel—that is, that the eel was viviparous. This was certainly a much more natural and credible explanation, but it was scorned by *Aristotle* and *Aristotle* was correct. He said they were not eels, but were worms, and modern observations sufficiently uphold him. Yet the contrary opinion was held by the scientists of the middle ages, and names which are written high and imperishably on the scroll of fame subscribed to it. *Leeuwenhoek*, the discoverer of bacteria, and the renowned *Linnaeus* believed that eels were not spawned and hatched but were born.

This idea, entirely erroneous, was corroborated later by a correct observation. This time it was in another direction that the investigator came to grief—so slippery was the eel question. He was not examining an eel, but an eel-pout, a fish very far removed from the eel, but so resembling it externally that the ichthyologists have, for a specific name, called it *anguillaris*, eel-like. And it has been popularly known as ‘mother-of-eels.’ This eel-like fish is really viviparous, it produces its young alive, and they resemble small eels. The learned doctor thought he had solved the eel question. But he hadn’t. To add to the confusion, another authority reviewed this work on the eel-pout and decided, being influenced by the previous real mistakes of the same nature, that the supposed young eels were only worms. This was plausible, yet he was wrong, for they were undoubtedly legitimate little eel-pouts, mistaken for little eels. Every one, it appears, who took up the question, managed from a basis of truth to reach a wrong conclusion.

Aristotle held that eels were also produced from the ‘bowels of the earth,’ by which he meant nothing more than common earthworms, which he curiously conceived to be thus related to Mother Earth. Other opinion maintained that eels were the offspring not of eels, but of other kinds of fishes, or of animals that were not even fishes. This heterodoxy was too much for Aristotle, but to this day is prevalent in some form among eel fishermen in various parts of the world. As for instance, that the ‘aal-mutter’ referred to, the eel-pout, really produces eels; that eels pair with water snakes; and in Sardinia that the well-known *Dytiscus* beetle is responsible for eels.

If these conflicting theories seem to us a ludicrous and amusing hodge-podge, it must not be forgotten that they were the wisdom of bygone days. Out of them the eel question resolved itself into a serious problem which interested the whole biological world, and to which the first talent in science addressed itself and on which voluminous and pretentious treatises appeared. Buffon, the naturalist, remarked that he considered the question of the generation of eels one of the most puzzling in natural history. Very appropriately it remained for the century of Isaac Walton to first assert that eels were not the subjects of a special dispensation for their replenishment, and that the mystery of their generation was the same mystery that envelops the rest of the kingdom of life. This not very brilliant announcement seems to have been put forth as a purely academic deduction. There were no observations in the modern sense, and the author of the ‘Compleat Angler’ was not particularly enthusiastic over it. He merely mentions it without subscribing, and says: ‘But most men differ about their breeding,’ and then after citing at some length what ‘some say’ and ‘others say,’ remarks: ‘But that eels may be bred as

some worms, and some kinds of bees and wasps are, either of dew or out of the corruption of the earth, seems to be made probable by the barnacles and young goslings bred by the sun's heat and the rotten planks of an old ship, and hatched of trees.'

The passing of Aristotelianism and the revival of the sciences, in the sixteenth century, was the occasion of this renewed interest in eels. It was not, however, until the eighteenth century that sex in eels was definitely recognized. Sancassini, a surgeon of Comacchio, in Italy, visited the eel fisheries at that famous place of eels, and chancing to be struck with the appearance of a large one, his professional instinct led him to use his knife. The result caused him to send it to Vallisneri at the University of Padua, who recognized with enthusiasm the true ova and forthwith communicated this fact to the Academy at Bologna. Vallisneri has since been appropriately honored by the bestowal of his name upon a water plant well known to all—eel-grass. But the immediate effect of his announcement was an eel controversy. Eels became the burning topic of the hour among the professors, the best-known names of the time are associated with the discussion, and Bologna became the storm-center of the eel question. Another specimen similar to the first increased the agitation. But Valsalva, of anatomical fame, showed that there were certain appearances in almost any fat and well-favored eel that strongly simulated what Vallisneri had described, and in brief, hinted that the alleged eggs were globules of uninteresting adipose. An enthusiast offered a reward for an eel that should contain undoubted eggs. Of course he got it. His joy was short-lived, for a critical inspection showed that mercenary considerations had led the fisherman to fill the specimen with foreign eggs. This irreverence, and at this juncture, disturbed the seriousness of the situation and the eel question slumbered for over half a century. Then, again from Comacchio—whence emanated many of the errors and the final truth—another eel falling into initiated hands marked the crisis in the eel question. Among these privileged ones was the famous Galvani, and in grave council assembled, he agreed with the others that it was the counterpart of Vallisneri's historic eel of seventy years before, and was a precious specimen and must be sent to the naturalist Mondini. And Mondini, in a publication which is classical, first described in accurate terms the female eel, and lifted the eel question out of the uncertain field of speculation to a basis of solid fact.

Not immediately, however. Spallanzani a few years after visited the Comacchio region for the sole purpose of studying eels and reported a negative to Mondini's observations, which accordingly suffered a nearly total eclipse lasting many years. In 1850 Rathke was able to describe an eel in full roe, the first that ever came into the

hands of an investigator, the eggs of Mondini's eel being immature. This important event was the final blow that settled the sex question as far as eels are concerned. Over twenty years afterward, however, the German Fishery Association in Berlin was led by renewed interest in eels, due to the stimulus of Syrski's work on the male eel, to offer a reward of fifty marks for an eel in full roe. The eel was to be submitted to Professor Virchow, and the royal superintendent of fisheries undertook to forward the responses. It seems that about every German newspaper 'from the Rhine to the Vistula and from the Alps to the sea,' gave publicity, with a result creditable to them, but overwhelming to the royal superintendent. His delight at the popular interest in eels was succeeded by astonishment and that by horror. His postal expenses compelled him to announce that all eels and communications should be forwarded direct to Virchow. The public complied and the great German savant was obliged to cry enough and beg for mercy. People wrote and sent their specimens, parts of eels, contents of eels, thread worms from eels and above all, stories of eels and of eggs in eels, but seldom an eel intact and none in the desired condition. They usually ate the eel and sent various and often irrelevant portions of its anatomy, with a request that the fifty marks be remitted by return mail. If this prize contest had no scientific results, it contributed to the merriment of the German nation. The comic papers cartooned the incidents and announced that in the future the scientists desired only smoked eels.

To Mondini is due the credit which has largely gone to Rathke of first demonstrating sex in eels. History repeated itself as often before and since in according the honors of priority elsewhere than they belonged. However, all these observers shared in determining an important and historic phase of the eel question, which, while there are still interesting queries connected with the natural history of eels, has now merged itself with the general and special problems of biology and is no longer paramount as in the olden days.

Eels themselves, as such, are no mystery, but a familiar and commonplace factor in our economy. From the epicurean standpoint extremes meet in them—they excite a gastronomic horror in minds appropriately constituted and a peculiar delectation in the gourmand in whom suggestion is not strong enough to appeal against the keen delight of a sensitive and discriminating palate. The eel has ever occupied an extreme position. He is apt to be loathed or loved. It is characteristic of him that he never did anything by halves. What he does he does with all his might. In breeding his offspring were legion and filled the seas. In his contact with the human race, he ingratiated himself into the affections of a whole nation, or was rejected utterly.

The Greeks and Romans seem to be first in their regard for the eel, and many tales come down to us of the esteem in which he was held in their ancient times. The Romans cultivated eels, tamed them, made pets of them; and the orator, Hortensius, rival of Cicero, wept bitterly at the death of his favorite *muræna*. They even sacrificed their slaves to the eel ponds, a practice quite possible to men who plundered nature to serve peacocks' brains and parrots' tongues at their tables. The Egyptians are said by one account to have abhorred eels utterly, but it is certain that at one time eel-worship shows them to have also judged the eel to rank with the gods. The Scotch taboo the eel entirely, while the Hebrew race placed it under the ban which applies to scaleless creatures of the fish tribe. The conger eel is scaleless, but the common eel does not deserve this calumny, for its minute oblong scales, curiously arranged in groups instead of imbricated regularly as in the common fishes, are easily seen on careful inspection. The ancient Anglo-Saxon, on the other hand, was passionately fond of eels, which passed current as a medium of exchange. The race has always been partial to them and Londoners of to-day consume them in great quantities. Some ancient peoples used them in sacred offerings. Terracina, a seaport of Italy, being besieged by the Turks, the inhabitants vowed twenty thousand eels per annum to St. Benedict. The account relates that a 'fond memory of stewed eels' touched the saint and the siege was raised. He got his eels, and the Benedictine monks have been accustomed to render the yearly tribute to their saintly patron.

The prominence of eels among fishes is of course largely dependent upon their great abundance and almost world-wide distribution. Our common American eel is found from the Gulf of St. Lawrence to Mexico, but is absent from Hudson Bay and the Arctic Ocean and is present in the eastern Pacific only by transplantation at the hands of man. It inhabits both the sea and inland waters, but was unknown above the falls of Niagara until artificially introduced. Its natural history even yet is not as well known as would be expected. Most fishes which live alternately in fresh and salt water are anadromous, and feeling the sea their proper home migrate at certain seasons up the rivers, where they spawn in fresh waters and return to the salt until the next season. But the eel has been supposed to reverse this process, and, being at home in the sweet water, to descend to the sea to deposit the eggs, which are numbered in millions, and then die, its span of life naturally ended. The young eels resulting, driven by the impelling force of instinct, must then find their way back to the haunts of their parents. Well-known facts speak for this view. Young eels in the spring are known to ascend streams in countless numbers, and the phenomenon has long been well recognized as eel-fairs, or eel-fares.

In some regions this is an event of the spring much looked forward to. The little eels are known as elvers—a corruption of eel-fare—and are boiled and pressed into cakes—eel-cakes—which become for the time being an important article of food.

Both elvers and adults, however, are found above obstructions in the rivers which seem to make impassable barriers. It is certain that the young display the greatest persistence in climbing streams, and evidence is not wanting that to get around obstacles they leave their native element and make a land journey. The stories on this point do violence even to the somewhat lax canons which by tradition and present practice are supposed to govern the history of the tribe of fishes. There is no doubt that they can wriggle for some distance over favorable ground, as through wet grass. Albertus Magnus writes in 1545: 'The eel also comes out of the water in the night time into the fields where he can find pease, beans, and lentils.' Another writer contradicts pointedly in differing from this opinion. He says: 'They eat fish, do not come on the land and do not eat pease, but remain in the water always and are nocturnal animals.' But Bach, a Prussian naturalist, insists that eels do devastate the pea patches and avows that the peasants fish for them with the plow by cutting a furrow before day-break, which intercepts their retreat, and that sometimes for the same purpose sand or ashes are used, which adheres or dries the slime on their bodies, making locomotion impossible. On the other hand, it is related that eels stranded by the drying of pools adjacent to larger waters have not attempted the short journey necessary to return to the main stream, and that the presence of eels far overland is to be attributed to poachers who throw them away in flight from pursuit.

It is not to be doubted that the necessity of water breathing is no bar to short overland journeys. The moisture of the grass or ground which is a necessary condition of such wanderings probably replaces somewhat for breathing purposes the natural medium which the eel leaves and to which his return can not be long delayed. Many fish can suspend respiration for quite a while without suffering injury. Concerning this habit a curious opinion is expressed by an English writer not so many years ago. He says, speaking of the eel, 'The curious air-bladders, so-called—which are really intended as reservoirs for water to moisten the gills of the fish when traveling out of the water—have been held to prove that it is properly an air-breathing creature, which occasionally, like some snakes, sojourns in the water for reasons of its own.'

The eel seems to have taken its name, and in more languages than one, from its suggestion of the snake. The Anglo-Saxon *aal* is derived from the Finnish for slimy, while the scientific name is the



Latin for snake, *Anguilla*. Many English names of places are compounded of eel—witness Elmore, Ellesmere, and Ely. Of the latter Fuller, in 'Worthies of Cambridgeshire,' has this illuminating explanation: "When the priests of this part of the country would still retain their wives in spite of whatever the pope and monks could do to the contrary, their wives and children were miraculously turned into eels, whence it had the name Ely. I consider this a lie." Like other objects of popular interest which include elements of mystery, eels are the subject of the most extravagant tales. Some of these are quite analogous to the threadbare story of the live frog found in the interior of a solid rock. A New England paper some years ago heralded that 'a live and active eel, a few days since, was dug out from a depth of five feet in the soil of Exeter, New Hampshire.' Doubtless this eel is exhumed annually. The tenacity of life of frogs and eels affords the starting point for these legends. Likewise to the voracity of eels may we credit an ancient chronicle that in England a few of them were one dark night observed to consume entirely a stack of hay. It may be in a spirit of emulation that some German carp—importation of the Government—artificially transplanted to the pond of a western farmer, came out one night and ate up the crop of buckwheat on a neighboring field. Elvers are reported to climb trees and the tale might not be incredible, provided any imaginable reason for such conduct could be assigned, for by their persistence they sometimes ascend the perpendicular barrier of a dam a short distance. This they accomplish by the partial drying of those that first essay the ascent, which therefore stick to the boards and afford a slight foothold for the next comers, which wriggle a little higher and then in turn stick fast and perish.

These stories might be multiplied *ad nauseam*, but more interesting are a few facts about the symbolic significance of the eel. His slipperiness long ago passed into a proverb. Among the pictorial writings of the Egyptians the representation of an eel held by the tail denoted 'a man vainly pursuing a fugitive object.' A Greek expression of similar import reads, 'You've an eel by the tail.' It is not so well known that an eel figures also in an emblem of quite opposite meaning—certainty instead of uncertainty. It is quite impossible to hold one in any ordinary clutch of the hand. The intervention of a fig leaf, however, makes the grasp secure, and the Egyptians depicted an eel rolled up in a fig leaf when they wished to express certainty regarding things that were *a priori* uncertain.

## THE STORY OF A WORD—MAMMAL.

BY DR. THEO. GILL,  
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THE time for the final consideration of words commencing with M for the great English Dictionary is now very near at hand, and I venture to offer suggestions respecting one in very general use whose etymology has been misunderstood and erroneously stated in all the published English and American dictionaries; that word is mammal or mammals. I have already explained the significance of the word in a periodical devoted mainly to ornithology (*The Osprey*), but probably few readers of THE POPULAR SCIENCE MONTHLY are acquainted with that magazine and the data are here given in another form, and with many additional facts.

In the great Century Dictionary, a deservedly esteemed work, and which may generally be implicitly trusted, the etymology of mammalia is given as 'NL. (sc. *animalia*), neut. pl. of LL. *mammalis* (neut. sing. as noun, *mammale*), of the breast: see *mammal*,' and, under mammal, we have 'a. and n. [=OF. *mammal*=Sp. *mamal*=Pg. *mamal*, *mammal*=It. *mammale*, n.; < NL. *mammale*, a mammal, neut. of LL. *mammalis*, of the breast, < L. *mamma*, the breast].'

All this is misleading, if not erroneous. The name mammalia was first coined and used by Linnæus in 1758, and was formed directly from the Latin; it had nothing to do with French, Spanish, Portuguese or Italian words. The concept of which the Linnæan word is the expression is as remote from a popular notion as could well be, and even the necessity for the word (or an analogous one) can be appreciated really only by the educated or, *pro tanto*, the scientifically educated. Buffon and Pennant, for example, could not realize the reason for its use.

It is noteworthy that in the Century Dictionary even the very word that might have given the clue to the formation of mammal is cited and yet the excellent professional etymologist who worked on it was not guided into the right path. With the hint given to him, he failed to see the point. Evidently, then, the etymology is not as obvious as it might seem to be.

Often, indeed, in looking over etymologies, we have been impressed with the insufficiency of philological learning alone for the solution of knotty questions. A living knowledge of the objects named is often

requisite for a full understanding of the significance or aptness of the names.

It was one of the happiest inspirations of Linnæus to segregate all the mammiferous animals—the hairy quadrupeds, the sirenians, and the cetaceans—in a single class. No one before had appreciated the closeness of the relations of the several types, and there was no name for the new class (or concept) as there was for all the others.\* A name, therefore, had to be devised. It was another happy inspiration that led Linnæus to name the class *mammalia*. Those who are familiar with the works and ratiocination, and especially the nomenclature of the great Swede, may divine his thoughts and share with him in the execution of his ideas, although he did not give etymologies. For those ‘animalia’ which are animals *par excellence* he would coin a name which would recall that fact. (Animal, be it remembered, is often used in popular converse in the sense of mammal.)

The name in question was evidently made in analogy with *animalia*. In *animalia*, the principal component was *anima*, the ‘vital principle’ or animal life. (Old Nonius Marcellus well defined and contrasted the word—‘animus est quo sapimus, anima qua vivimus.’) The singular of the word was animal. In *mammalia*, the essential component is *mamma*, breast; the singular should be mammal. The terminal element (-al) was coincident with rather than derived directly from the Latin suffix (-alis) which expressed the idea of resemblance or relationship; anyway, it was used in substantive form, and the idea of possession or inclusion was involved, as in the case of animal, capital, feminal, tribunal—all well-known Latin words. In fine, a mammal is a being especially marked by, or notable for having, mamma.

The truth embodied in the word was almost immediately appreciated by naturalists at least, and the class of mammals has been adopted ever since the Linnæan period by zoologists. Naturally the new Latin name was to some extent replaced by names in the vernacular tongues of most nations.

In the accommodating English alone the Latin word was adopted with only a change in its ending, and thus the class name *mammals* was introduced, and the singular form—*mammal*—followed as a matter of course, and by chance (or rather the genius of language) exactly coincided in *form* with the singular of the Latin word.

Not only had the name nothing to do with the alleged derivative Latin words. It was not admitted at all into the vernacular speech of

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\* The assertion of Owen that Aristotle fully recognized the class of mammals under the name *Zootoca* is without proper foundation. Long ago, in the *American Naturalist* (VII, 458), I showed that different passages in Aristotle's books negated such a statement and that the word *zootoka* was not used as a substantive.

France, Spain, Portugal or Italy. The naturalists and lexicographers of those countries failed even to appreciate its etymological aptness and beauty. First, the French had to introduce a new word to correspond—mammifères or the breast-bearers. The other Latin races followed; the Spanish and the Portuguese with mamíferos, and the Italians with mammiferi. None of the words quoted in the Century Dictionary are even given as nouns in the ordinary dictionaries of those languages—not even in the great dictionary of Littré. Littré, however, has the words mammalogie, mammalogique and mamma-logiste.

Of course the Germans coined a word from their vernacular—Säugethiere or suckling animals: the cognate nations imitated; the Dutch with Zoogdieren, the Swedish with Däggdjuren, and the Danes and Norwegians with Pattedyrene.

The first writer to use the English word Mammals to any extent was Doctor John Mason Good. In 'The Book of Nature' (1826), in the second lecture of the second series, 'On Zoological Systems,' he specifically introduces it. Quadrupeds is not appropriate 'and hence it has been correctly and elegantly exchanged by Linnaeus, for that of *Mammalia*,' and he concludes, 'as we have no fair synonym for it in our own tongue, I shall beg leave now, as I have on various other occasions, to render *mammals*.' He repeatedly used the English form elsewhere in 'The Book.' I have been unable to find any use of the word in its singular number, however.

The singular form—mammal—has been indicated as rare or unusual. One might look through many volumes on mammals as well as on general natural history and not find it. As a matter of fact, however, it may be frequently used. Let us go, for example, into a laboratory when they are assorting a miscellaneous lot of bones gathered from some fossil ossuary. Such expressions may be heard as 'that *seems to be* a mammal bone'; 'that *is* a mammal bone'; 'that *is a mammal* bone'; 'that *is a mammal* bone'—or the substantive mammal alone may be used. Further, a whale may be alluded to as a gigantic mammal or a mammal giant.

The earliest English author to use the singular form to any extent was Richard Owen. In his 'History of British Fossil Mammals and Birds' (1846), for example, he alluded to a mastodon as 'this rare British Fossil Mammal' (p. xxii), and asserted that he knew 'of no other extinct genus of mammal which was so cosmopolitan as the mastodon' (p. xlii); he said that 'the *Myrmecobius* is an insectivorous mammal, and also marsupial' (p. 40), and he claimed, conditionally, that 'the *Meles taxus* is the oldest known species of mammal now living on the face of the earth' (p. 111).

Even the word in plural form was grudgingly admitted. The Latin

form *mammalia* was long preferred. The chief translators of the 'Règne Animal' rendered *mammifères* by *mammalia*; Blyth alone substituted *mammalian* in its place. Owen, in the work already cited in which *mammals* was used on the title-page, employed *mammalia* in the text more frequently than *mammals*, and yet he used the English form more than any of his contemporaries. Popular as well as scientific writers avoided the English word as one alien to the genius of the language. Some preferred the word *mammifers* when they would use an anglicized term.

By reason of the general ignorance of the etymology of the word *mammalia*, and the dislike of it, on account of the misapprehension that it was an imperfect or clipped word, the early French naturalists devised one of their own—*mammifères*—and this early took root and has been universally adopted by French writers. It was to some extent adopted by English writers of the first half of the century under the form *mammifers*. Robert Chambers, in his anonymous 'Vestiges of Creation,' frequently used it and Hugh Miller, in his antidotes to the heresy of the Vestiges, sometimes did. Miller, in his 'Old Red Sandstone' (1841), also accepted the singular form in his statement (Chapter IV.) that 'the *mammifer* takes precedence of the bird, the bird of the reptile, the reptile of the fish.' The use of the word, nevertheless, was never general. The derivative adjective, however, was much more frequently adopted for a time.

Lyell, in his 'Principles of Geology,' almost invariably used the word *mammalia*, but accepted the adjective *mammiferous* instead of *mammalian* and even of *mammaliferous*. (He admitted *mammifers* in his 'Glossary,' but did not otherwise use it.) This, naturally, was an example which others followed. It was not until the first half of the century had been past for some time that the English word came generally into use.

The science which treats of mammals had to be named. *Mammalogy* was naturally thought of, but many objected to it. The French, who would not tolerate *mammal* or *mammaux*, although they had no objection to the analogous *animal* and *animaux*, on the whole took kindly to *mammalogie* or *mammologie*. Substitutes, it is true, were offered; Desmarest proposed *mastologie* and De Blainville *mastozoologie* and the latter was admitted by Littré in his great dictionary, but they did not secure a permanent foothold and *mammalogie* is the term now generally used.

The objection to *mammalogy* was and is that it is a hybrid and also a badly compounded and clipped word. It is formed of the Latin *mamma* (a breast or teat) and the Greek *λόγος*; the true meaning is a discourse on breasts rather than breast-bearing animals. Greek nouns also generally have the vowel *o* rather than *a* before the second

component. Consequently suggestions were made to correct the word to mammology if not mammalology. Others would compound a name of two Greek constituents (*θήρ*, a wild beast, and *λόγος*). Therology was the result. Dr. John D. Godman, in his 'American Natural History' (1824), entitled the first (and only published part) 'Mastology,' thus borrowing a word first used by Desmarest. The writer of the long article on mammalia for the Edinburgh Encyclopædia (1819) coined the word Mazology (*μαζος*, a breast, and *λόγος*, discourse'). None of these words has found general admission into the language. Notwithstanding the philological objections, mammalogy of late years has been generally accepted and general consensus establishes its right of being.

I have derived the terminal form of words ending in -ology from *λόγος* rather than *λογία*, which latter has sometimes been given, because the only Greek word *λογία* (occurring in the first Epistle to the Corinthians, 16: 1, 2) means 'a collection for the poor,' and therefore *λογία* is misleading and has misled several to my knowledge. The Greek words *dikologia*, *etymologia*, *philologia* and *theologia* of course are good precedents for the English words ending in -ology and consequently we may use, as a suffix, *-λογία* (but not simply *λογία*) in explanation of the etymology.

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#### SUPPLEMENTARY NOTE.

While reading the proof of the preceding article I found reason to fear that, through my desire to be concise and not discursive, I might give a misleading idea of the originality of Linnæus. The concept of the class of Mammals did not spring Minerva-like from the head of the Swede, but the great English naturalist of the seventeenth century (John Ray), to whom Linnæus owed so much, was suggestive in this as in other cases. Ray, in his 'Synopsis Methodica Animalium Quadrupedum et Serpentina Generis' (1693, p. 53), gave an 'Animalium Tabula generalis' in which he bracketed the terrestrial or quadruped mammals with the aquatic as 'Vivipara,' and contrasted them with the 'Ovipara' or 'Aves.' The Vivipara are exactly coextensive with Mammalia but the word vivipara was used as an adjective and not as a noun. Linnæus did not catch up with this concept till 1758 when he advanced beyond it by recognizing the group as a class and giving it an apt name. To go farther into details is tempting, but would be out of place here.

## A YEAR OF WEATHER AND TRADE IN THE UNITED STATES.

BY PROFESSOR ROBERT DEC. WARD,  
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THAT weather conditions affect trade and industry has long been known, but few studies of these relations have yet been made.\* The hope of being able to determine, in a somewhat critical way, the dependence of trade and industry in the United States upon the general weather conditions from week to week, has induced the writer to give some attention to this subject for a year past. The sources of information have been the *Climate and Crop Bulletins*, and the *Monthly Weather Review*, of the Weather Bureau, and the well-known trade journals, *Bradstreet's* and *R. G. Dun and Co.'s Review*. The Weather Bureau publications emphasize the meteorological side alone; the two journals last named aim to present a true statement of trade conditions without any special prejudice in favor of meteorological controls.

The first summer month of 1901† began with decidedly cool weather east of the Mississippi River, and heavy rains in many eastern districts. This unseasonable weather was the key of the trade situation. Retail trade throughout the east was interfered with by the 'lack of sunny weather'; the growth of crops was retarded, and cotton and cereals were high. Manufacturers of umbrellas, rain clothing, rubbers and heavy footwear alone reported 'an exceptional demand.'

The second week of June was, on the whole, more favorable. In the east, where the temperatures were more nearly normal, there was an improved retail demand for summer wearing apparel, and this was also true of the northwest, where needed rains had 'quieted apprehensions as to the spring-wheat outlook.' The stimulation in trade in summer goods led to increased orders for fall merchandise. Dairy and garden products fell in price, as production increased with warmer weather. On the Pacific coast, the third week of June averaged decidedly cool, and trade was retarded in consequence. At a number of cities situated in a district where the average daily temperature excess was 3°-6°, the 'warmer weather created a demand for *summer goods*.'

\* A noteworthy article in this connection, 'The Influence of Rainfall on Commerce and Politics,' by H. H. Clayton, appeared in the *POPULAR SCIENCE MONTHLY* for December, 1901, pp. 158-165.

† This investigation includes the period June, 1901—June, 1902.

while over the Plateau the average daily *deficiency* of temperature was  $6^{\circ}$ – $11^{\circ}$ , and there were *unfavorable* effects of the *cool* weather. These are interesting examples as showing, in degrees, what excess or deficiency of temperature stimulated or depressed trade in this particular case. In the Middle South Atlantic States, where there were exceptionally heavy rains, corn suffered from lack of cultivation, and trade was checked.

During the latter part of June, and in July, large sections of the United States east of the Rocky Mountains suffered from prolonged drought. Record-breaking temperatures were observed at a large number of stations, readings of  $100^{\circ}$  and above occurring in many places for several days in succession during part of the month. The daily temperature excess frequently reached  $5^{\circ}$ – $10^{\circ}$ , or more. During this long spell of hot weather the rainfall was markedly deficient over many sections east of the Rocky Mountains, and hence there resulted a drought of far-reaching extent. About the middle of July, corn began to suffer severely. Locally, some damage was done to wheat and to oats, while cotton was also injured over considerable sections of the South. Occasional local rains helped to make good part of the damage to corn and cotton. The chief interest, so far as crops were concerned, centered in the condition of corn.

The first effect of the extreme heat, and one that lasted through July, was a marked stimulation of retail trade in summer clothing of all kinds, straw hats, sporting goods, and the like. The continuance of the heat over much of the country had the effect of carrying the sale of summer goods beyond the usual time. Another effect of the hot weather—and this an unfavorable one—was the curtailment of almost all branches of trade other than that in summer goods. A report from Boston, to the effect that ‘buyers were few, and only necessities prompted purchases,’ puts the case clearly enough. The decrease in ‘shopping’ led to an increase in orders by mail. The intense heat was, however, not necessarily adverse to general retail trade, provided crop prospects were favorable. This was clearly brought out in such reports as one from St. Louis, where trade ‘was sustained by the result of the wheat harvest.’ On the other hand, trade may not respond immediately, even when crop prospects are bright, for when the weather is fine, and farmers are busy in the fields, they have no time to go to town to trade.

The heat of the first week of July ‘caused a practical suspension of industrial activity in many cities.’ Numerous prostrations from heat caused humane employers to close their mills during the most distressing hours, thus somewhat restricting the output. In regard to the effect of the weather upon the steel-workers’ strike in Pittsburgh, one of the trade journals reports that the striking employees were ‘mostly content to take a rest during the hot weather,’ and consequently were not so anxious that a settlement should be reached.



During the second week in July, business was reported as of a 'midsummer character,' *i. e.*, normal, in the east, and here the temperatures for the week were nearly, or even slightly below, normal. The statement from Louisville is representative: 'A few recent days of nominal summer weather have given a spurt to retail trade.'

The third week of the heat and drought affected not only the trade of that particular week, but led to the cancellation of many orders previously given. These cancellations came from the drought-stricken districts, and were naturally a disturbing factor in the trade situation in many Western and Southern cities.

The week ending July 22 brought local showers over portions of the drought-stricken districts, and although these showers were in most cases but scattering, there was a noticeable improvement in crop outlook and business in the sections where the rains fell. A characteristic report from St. Louis (July 19) stated emphatically that 'the business situation hinged upon the question of rain.' During the week ending July 29 also, 'advices of lower temperature and moderate rains came as a great relief to business throughout the country.'

The cattle, meat, dairy and produce markets all showed marked effects of the excessively hot weather. At the very outset, the perishable nature of butter and eggs, and the shortened milk supply, caused a rise in price, which was well maintained. A number of sugar-of-milk factories shut down. Fruits and vegetables became scarce, and advanced in price. Consequently there was a great demand for canned goods, the price of which at once tended upward. This demand continued strong for many weeks, and had it not been for the drought, the year 1901 would have been a poor one for packers and jobbers of canned goods, because they had carried over a very heavy supply from the previous season. The decreased sales of fresh meat during the heated term caused an advance in the price of hides at Boston.

The drought and consequent lack of pasturage in the southwest led to record-breaking shipments of cattle and hogs to market at Kansas City, the receipts for the month exceeding those for July, 1900, by 263,000 head. This extraordinary rush of live stock resulted in an over-supply of young cattle. Buyers dictated prices. The situation in the hide market was much complicated. Tanners were able to hold down the price of hides. Smaller requirements in the way of corn for fodder, and restricted subsequent arrivals of cattle, were expected.

Of all the economic aspects of the heat and drought of July, the greatest interest attaches to the prices of stocks and cereals. During the second week of July, reports of heavy damage to corn and oats in the Missouri valley belt caused the market to 'break badly.' The heaviest declines came in the stocks of railroads which were likely to be affected

by a partial failure of the corn crop in the southwest, such as the Atchison and the Rock Island. Reports that rain was likely to fall in Kansas caused a rally from the low figures. During the week ending July 20, in spite of the short corn crop, the large wheat yield made it evident that the cereal production of the west as a whole would furnish abundant traffic for the railroads. The appearance of rain in parts of the west led to considerable repurchasing of railroad stocks by capitalists who had sold Granger and Pacific stocks on the unfavorable crop outlook of two weeks before. Atchison common stock rose ten points; Rock Island was a very strong feature, 'and the Grangers generally responded promptly to the improvement in the corn-crop outlook.'

The highest non-corner prices for corn since 1894 were paid during the week ending July 27. The damage to crops in the territory tributary to the Union Pacific in Kansas and Nebraska 'raised strong doubts as to the possibility of any increase in the four per cent. dividend on the common stock.' Union Pacific was one of the most prominent stocks in volume of transactions, and sold down very sharply from 104½ to 93¼. St. Paul fell from 164 to 152½, and the other Grangers were similarly affected.

Under the influence of the extreme heat, summer travel was reported as the heaviest in years; this gave the transportation interests large earnings, while the hotels and stores in sections frequented by summer visitors did an excellent business. Much money was left in summer resorts, and collections there were consequently good during succeeding months. While the carriage of wheat and of live-stock by the Granger roads during July was very heavy, the shipments of oats and corn fell off sharply, the movement of corn to seaboard points declining 72 per cent. as compared with that in July, 1900. Foreign commerce was seriously affected. In Scotland, Russian and Algerian maize practically supplanted American corn. The heat interfered with building, so trade in paints, oils and other building requisites was checked. Meats were in less demand, and wholesalers in some cases reduced prices in order to move fresh meats in storage. The hot weather was unfavorable for the curing of fish. The consumption of milk increased, and there was a scarcity in many cities. The demand for ice was so great that there was difficulty in chartering vessels in which to ship ice from Maine.

After about a month of intense heat and of drought, lower temperatures and good rains were experienced over most of the drought-stricken districts. The relief to trade was immediate and general. In the great corn States, more than usual of the year's crop had been planted late, and this late corn improved greatly, although early corn was practically ruined. A large spring-wheat crop was assured by the rains. Cotton-crop conditions at the south were also improved, and

trade reports were consequently more cheerful from southern cities. An abundance of forage supplies was now certain. The western farmers regained courage; the rush of cattle and hogs to market stopped. The pressure in this line being removed, many of the cattle which had been sent to market were not slaughtered, but were kept to be fattened. Hence a great accumulation of skins was no longer expected. The most unfavorable trade reports naturally came from the central west and southwest, where the loss from drought had been greatest. Kansas City, however, reported that anxiety had been followed by 'a feeling of relief and hopefulness.' Cancellations stopped, as country merchants took new courage. July bank clearings at Kansas City were the largest on record, because of the heavy receipts of cattle and hogs, but for the country as a whole bank clearings for July were adversely affected by the heat and drought. Fluctuations in corn continued, as conflicting reports of greater or less loss were given currency. Good spring-wheat reports, and liberal arrivals at interior cities, weakened prices of that staple. Cotton was weaker, owing to the arrival of needed rains.

While the tide of trade turned distinctly after the drought, and there was a generally cheerful tone everywhere on account of the seasonable weather and favorable crop outlook, the heat and dry weather continued to affect trade in various ways for many weeks. The shortage in corn and potatoes led to an increased demand for rice, and trade in canned goods and dried vegetables was stimulated by the scarcity of fresh vegetables and fruit. In the southwest, especially, the scarcity of fruit and vegetables gave the local commission houses a large business in fruit and produce. Meats and dairy products remained high, 'partly owing to the fear of smaller supplies later in the season, due to the early marketing of young and unfattened stock,' and partly because of the high price of corn. As late as September 7 nearly all the lumber mills in Oregon closed down on account of the unsatisfactory condition of the market resulting from the crop shortage in eastern sections.

The special feature of the week ending August 17 was the effect upon southern trade of a West India hurricane, which gave very heavy rains over some of the southern states, and on the Louisiana coast alone did damage to growing crops, chiefly rice, estimated at \$1,000,000.

At the end of the second week in September, with the coming of cooler weather, summer travel fell off decidedly in Maine and elsewhere, and retail trade in many of the larger cities improved with the return of the summer absentees.

Abnormally cool weather, with local frosts, prevailed east of the Rocky Mountains during the week ending September 21. Corn, cotton and dairy products advanced in consequence. The immediate effect of these lower temperatures was to stimulate the demand for fall and

winter supplies at cities situated in the region of maximum temperature deficiency. Coal and stoves became active. While the greater part of the country was unusually cool, the North Pacific coast averaged slightly warmer than usual. And we note that retail trade at Portland, Ore., was quiet because of the 'continuance of summer weather.' Railroad earnings in September were adversely affected by the lessened grain movement in the west, and by the damage done by the hurricane on some of the southern railroads.

October was warmer and drier than usual throughout nearly the whole country. This being a month when cool weather is needed for 'seasonable trade,' the keynote of the month may be found in the statement that where cool, trade conditions were good, and coal, furs, winter clothing, stoves, liquors, etc., were active, and where abnormally warm, retail merchandise distribution was retarded, but the handling of crops, and outdoor work, including building, were helped. The later on in October the warm weather continued, the more unfavorable were its effects on 'seasonable trade.' Towards the end of the month, hot weather interfered with the 'kill' of cattle, and caused a scant offering of hides; hence prices held well. The shortage in freight cars, which was a conspicuous feature throughout October and the following months, did not cause any serious inconvenience in the case of coal, because of a small demand due to the high temperature. Failures for October showed an increase in the south, where the backward state of cotton checked trade and delayed collections.

The colder weather of November stimulated trade in heavy clothing, shoes and groceries, and caused an increased demand for oysters and for coal, but rubber footwear was quiet throughout the month, owing to dry weather. The cold weather also started the tide of winter travel to California. Eggs rose in price. At the south, the backward cotton crop was a check to trade. A warm wave during the second week of November checked retail demand in the lower Mississippi Valley, and thence east to the Atlantic Ocean, the depression in trade accompanying the warm wave in its eastward progress. The car shortage in the east, already referred to, was complicated by the unusual movement of corn and oats west to the drought-stricken states, but it was seen that lower temperatures would relieve the situation by stopping lake transportation, and restoring thousands of cars to inland traffic. Abundance of snow in Maine at the end of November facilitated lumbering and caused a demand for sleighs, and distinctly colder weather put the market for anthracite on a firm basis.

Between the 14th and 19th of December, the minimum temperature records for the second decade of that month were broken in all districts from the South Atlantic and Gulf coasts northwest to the upper

Mississippi and Missouri valleys, including the middle Rocky Mountain slope and the Ohio Valley. There were also very heavy rains in eastern sections about the middle of the month. The exceptionally cold weather immediately stimulated retail trade in winter goods in many places. Eggs, poultry and potatoes advanced. In the New York stock market, the cold gave strength to the anthracite group of railroads, because it was certain that coal consumption would increase at once, but floods in the mining regions of Pennsylvania curtailed the coal supply, interfered with transportation, and cut down railroad earnings. Building was interfered with by the cold, and the receipts of wheat fell off because of the interruption of railroad traffic. As regards railroad earnings for 1901 as a whole, the southwestern roads were unfavorably affected by the poor corn crop, and the southern roads by the late cotton crop.

January was mild and generally dry, especially during the first two decades, but closed with ample snow covering over the winter-wheat states. Retail distribution of heavy clothing, boots and shoes, and rubber goods, was checked by the mild weather, and the loss of snow retarded lumber operations. The high temperature, however, stimulated the demand for spring goods at wholesale, and building, and the demand for building materials, were active. The snows of the end of the month were favorable for winter-wheat, and furnished water for cattle, and therefore improved the tone of the stock market, especially in the case of northwestern securities. But these same snows interfered with transportation interests and with trade, except that in winter clothing and rubber footwear. The future, as one trade journal had it, profited at the expense of the present.

During the first two weeks of February, snow obstructed traffic by railroads, cutting down receipts of live stock, corn, wheat and coal, and causing the banking of mills and furnaces because of lack of coal. Country roads were blocked, and country merchants were kept away from town. This increased orders by mail. Farmers could not reach their banks, and this interfered with the free circulation of money. During the second week of February, it was reported that as a result of the long drought in the southwest, water was scarce, and railroads had to haul it a hundred miles in places. At St. Louis, 'local retail trade was decreased by reason of the dangers of ice-covered sidewalks and streets.' Loaded car movement at St. Louis and Indianapolis was below that for preceding years, snow blockades throughout the west and north having compelled the railroads to reduce the number of cars per train. There resulted a notable decrease in Atlantic exports of flour, and a crowding of side-tracks at division points with loaded cars waiting to be moved.

Heavy snow and sleet storms during the last week of February did great damage to telegraph and telephone wires in some of the large eastern cities. Mail and transportation facilities were seriously interrupted. Stock exchange transactions in New York and other cities were limited to local orders, and this restricted sales. Trade in overshoes and rubbers was larger during this week than for the two preceding months. Floods and high water interfered with iron and steel production, with transportation interests, and with the coal output. The crippling of the railroads, which caused an unusual demand for structural materials, was noticed by 'the street,' but had little effect except upon the anthracite stocks, although March earnings were cut down by the February snowstorms.

Mild weather in the northwest early in March, and later on in the east, prevented loggers from getting out their entire cut, and led to the breaking up of many camps. By the middle of March the sidetracks were being cleared of the cars stalled there by the February storms; shut-down mills were running again; the advent of spring weather acted as an important stimulant to most lines of trade and industry; butter and eggs were lower; the demand for building materials increased, and weather reports regarding wheat began to claim careful attention. According to one trade journal, 'each cloud is telegraphed as heralding copious rains, while a ray of sunshine means drought.' The injury to crops during the summer of 1901 made stocks peculiarly sensitive to indications of drought. During the week ending March 22, the most severe cold wave and snowstorm of the month caused cattle losses in Dakota which were estimated at 2-5 per cent. Milder weather soon followed, and somewhat relieved the strain on the coal trade.

The opening of lake navigation in April began greatly to facilitate traffic at the north. The week ending April 26 was one of contrasts. Heavy snows interfered with farm work in Montana, the Dakotas and Minnesota, while hot winds in the central valleys and middle Atlantic States brought unusually high maximum temperatures, which were detrimental to crops. In consequence, weather reports had more influence than usual in shaping the prices of cereals, which advanced until reports of general rains in the southwest caused a decline of 2 cents a bushel on wheat. The 'versatile' weather of the week produced erratic fluctuations in the security and cereal markets.

Much was heard during the spring of 1902 about the high price of beef and of other meats. These high prices were at least partly due to the large cattle receipts of the preceding fall, there being little inducement to carry stock through the winter, with corn at 60 cents a bushel instead of 20 or 30 cents. The high price of beef led to the

consumption of pork products, poultry, etc., which depleted supplies and raised prices in these lines. The natural consequence of a short corn supply was thus seen to be higher prices for cattle and hogs.

During the first week of May, nearly the entire country east of the Rocky Mountains had highly favorable temperature conditions, but the unsettled crop conditions in the southwest were the reason of a failure to give much support to Missouri Pacific and Atchison stocks. Throughout May unusually heavy rains in the northwest retarded farm work and interfered with trade there. During the week ending May 24, Chicago, where the average daily temperature excess was  $12^{\circ}$ , reports 'the feature in the drug trade was the increased call for soda-water supplies caused by the hot weather.' The coal strike, which had begun to attract considerable attention, was much less of a burden on the general public than it would have been if the weather had been cooler.

The examples above given, which are but a few of those that are available, show clearly enough something of the effects of the weather upon trade, industry and financial transactions. No attempt has been made to estimate the financial loss or gain due to the weather conditions of any single week, or month, or of the year as a whole. Approximate estimates of this kind can be, and often are, made in individual cases, as in the case of the damage done by some storm to crops or to transportation interests in some particular section, or in that of the money value of one rain to cereals, fruits and vegetables in a time of drought. But it has seemed to the writer that no useful purpose could be served by attempting, in the present article, to make any such rough estimates as are alone possible.

The principal object of this investigation was to ascertain, if possible, whether the relation between weather and trade could be expressed in fairly exact meteorological terms. In order to study this subject, the Weather Bureau charts showing the weekly (or, in winter, the monthly) temperatures and precipitation, and the departures from the normal temperatures and precipitation were used. On these several charts the stations were located at which trade was reported as having been affected by the weather. Cities where trade had showed effects which were ascribed to the temperature were noted on the charts showing departures from the normal temperature, a sign being used in each case to show whether the effect was beneficial or otherwise. Cities where the reports indicated favorable or unfavorable effects of precipitation were noted in like manner, on the charts showing the departures from the normal precipitation. In some weeks there was found an extraordinary agreement, the good effects of 'seasonable' weather upon trade being found at cities situated within, or close to, districts of normal temperature or precipitation, while the unfavorable effects of ex-

cessive or deficient temperatures were indicated at cities within districts of too high or too low temperature, respectively. Similarly, the depressing effects upon trade of too much, or too little, precipitation were found in those portions of the country where there had been an excess or a deficiency of rainfall. So close were these relations in some weeks that it was possible to state in degrees, or in inches, the amount of the excess or deficiency of temperature or of rainfall which were needed to stimulate or to depress trade (*e. g.*, the third week in June; and the weeks ending September 21 and April 14). So close an agreement is, however, exceptional. A careful study for the year in question of all the trade reports in which mention was made of weather control, and a close comparison of these reports with the temperature and rainfall charts, failed to give any such exact results as were hoped for.

The final outcome of this consideration may be briefly stated as follows: As the result of the experience of many years, trade is in a condition of such very close and delicate adjustment to the average weather of any particular month, or even week, that 'seasonable,' *i. e.*, normal weather, other things being equal, usually means 'seasonable' trade. The case is not unlike that of a row of card houses which, when left undisturbed, *i. e.*, under normal conditions, stand, but when interfered with by any unexpected or abnormal influence, fall down. Thus, when meteorological conditions are unseasonable, trade at once reflects the change, and suffers. Trade is, however, subject to many and widely-varying controls; hence the problem of the particular controls which affect it in any one week is a very complex one, and the key is not always, or sometimes even at all, to be found in local weather conditions. The trade of a city is often largely dependent upon orders coming from a distance. Hence, although the weather in the city may be unfavorable, and local trade depressed, orders from the tributary district may suffice to overcome this depression, and keep trade up to its usual standard, and *vice versa*. Again, while seasonable weather promotes active trade among the inhabitants of a city, the farmers round about may take advantage of this opportunity to work in their fields, and trade in the country districts suffers because the farmers are too busy to make purchases. Furthermore, the relation between temperature and precipitation on the one hand, and crops on the other (and hence, indirectly, the control of weather over trade) cannot be expressed in any simple way. This is partly because the effect of the weather of any one week upon crops, and upon trade, depends largely on the weather of the preceding weeks. Thus, if there has been enough rain, high, or even unusually high, temperatures may be needed to promote the growth of crops, while on the other hand, if the rainfall has been deficient, high temperatures may be very injurious. The proper distribution, in time and in amount, of temperature and precipitation in their relation to crops is a subject which itself still needs much careful study.



MENTAL AND MORAL HEREDITY IN ROYALTY. II.

BY FREDERICK ADAMS WOODS, M. D.,  
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*Evidence from the House of Hohenzollern in Prussia.*

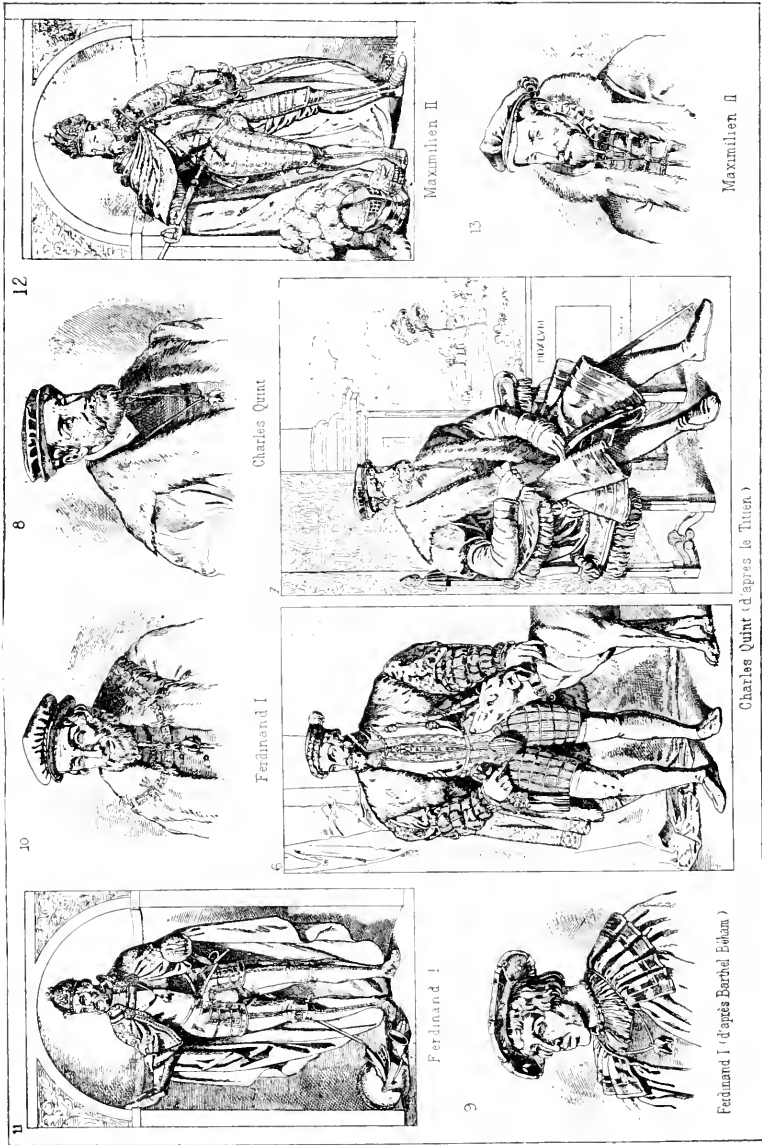
Here we find a very different condition. Let us begin with the founder of the family's influence, Frederick William, the Great Elector of Brandenburg. The great elector (1620-1688) was a man of the highest attainment and force of character. He received his country in a very desolate condition and accomplished the greatest results with the least resources. He was one of the ablest men in Germany in his time. On looking up his pedigree one finds his father a weak scion of a family not then illustrious, his mother not much above mediocrity, but a granddaughter of William the Silent.

There is every reason to believe that the great Elector was one of numerous geniuses descended from William the Silent, even if he did stand as far away from him as a great grandson. He was a first cousin of the famous Prince Rupert, and his two sisters were Sophia, Duchess of Brunswick (10), and Elizabeth of Palatine (9), a very profound intellect. This relationship was by the way of Frederick IV. of Palatine, who had married a daughter of William the Silent, by Anne, a daughter of Maurice of Saxony, a celebrated general.

Every union from now on to Frederick the Great brings in again the brilliant strain. Frederick William, the Great Elector, married a daughter of Frederick Henry, the distinguished stateholder (8). She was granddaughter of William the Silent (10), and great granddaughter of Caspard de Coligny, the great admiral of France (10). Their son, Frederick I. of Prussia, showed none of the genius, but he married a sister of George I., and therefore a daughter of the same great Duchess of Brunswick (10). Her father also was distinguished and ranks in 7 (Ernest Augustus, Elector of Hanover).

This queen of Frederick I. was Sophia Charlotte. She had high ideals and an important influence over political actions. She was really profoundly interested in astronomy, prehistoric remains and moral philosophy, and formed a warm friendship with Leibnitz. Von Heine- man says she was generally called the 'Philosophical Queen.' She is placed in grade 8. Their only son was Frederick William I., a most remarkable character. He was not very intellectual and especially despised literature, but was a man of iron will with great ability in

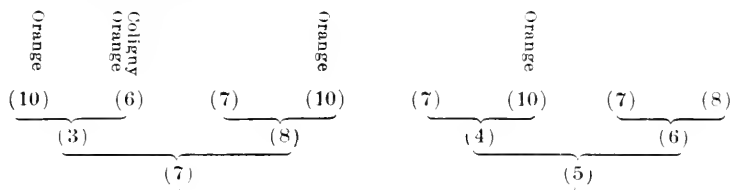
this line, and succeeded in carrying out his strange determinations. He it was who collected the giant army of Prussia. In his avariciousness and bigotry, as well as in his facial features, he so much resembled his



cousins the Guelphs (a house of Hanover), of England, that one is inclined to believe he got them all from the same source. He is placed in grade 7. His queen was an amiable and virtuous woman. She

was his own cousin and by the Orange branch. Thus now this great stock is repeated four times in the pedigree. Besides this we have four other great grandparents of high standing.

Thus the pedigree stands for intellect:



It will be noticed that only two are below mediocrity. From this remarkable union were produced, out of ten children, five of the most illustrious persons contained in this study. These were Frederick the Great (10). Henry, his almost equally great brother\* (9). Charlotte, Duchess of Brunswick (8), had a remarkable mind, literary tastes and fine character. Wraxall said of her that he scarcely ever met a woman in any walk of life who possessed an understanding more enlarged and cultivated. Amelia (9), 'endowments of mind said to have been extraordinary,' had a remarkable talent for music† and Louisa Ulrica, Queen of Sweden (10), was called the 'Minerva of the North.' The other five included Frederica Sophia, of Baireuth, whose memoirs are considered very interesting. These other grades are 7, 5, 5, 3.

Frederick the Great also had a number of nephews and one niece who were very richly endowed mentally. As some of these would escape mention elsewhere they are here enumerated:

1. Gustavus II. of Sweden (9).
2. Sophia Albertina, his sister (8).
3. Augustus Frederick of Prussia (8); reputed the first artillery officer in the Prussian army.
4. Louis, a son of Ferdinand of Prussia (8); distinguished talents.
5. Amelia Duchess of Saxe-Weimar (9); the distinguished patron of genius, of Wieland, Herder, Goethe, etc.
6. Charles William Ferdinand (8) of Brunswick; celebrated commander.\*
7. William Adolphus (8) of Brunswick; generally brilliant, and an author.

Such a union of high talents, found here about Frederick the Great, is certainly remarkable and bears out Galton's idea that of all great men, the greatest commanders have the greatest number of eminent relations.

Frederick the Great had in the first degree of relationship, in spite of having no direct descendants, one in 10, two in 9 and one in 8. In second degree two in 9, five in 8. Three of his great-

\* Lippincott.

† Wraxall, 'Berlin Mem.,' Vol. I., pp. 209, 294.



CHARLES V.



*Maximilianus II*  
*Ferdinandus filius*  
*nat. 11. Julii 1527*  

*Boiorum Dux Elector*  
*et Adelaidis filius*  
*Bohavorum. natus 1602*  
*1686. 1726.*

MAXIMILIAN II.



*Maria d'Ungharia Regina*  
*1527. 1586.*

MARY, QUEEN OF HUNGARY.



*Maria d'Ungharia Regina*  
*1527. 1586.*

MARIA, DAUGHTER OF FERDINAND I.

grandparents were in grade 10. It is very easy to account for this high wave of intellect, for in the first place among the sixty-two ancestors who lie in five degrees of remoteness, one finds only two in a grade below 4 and only one below 5. These were Frederick I. of Prussia and George William of Brunswick, who were in 3; both lie remote. This alone is remarkable, and I doubt if the same would be true of any other chart, or indeed of any other family.

In the second place one sees the House of Orange four times in the fifth generation. This of itself would probably create only a small effect since this entire generation is considered to have only 31½ per cent. of influence, but we see here a fortunate selection of the best, and four of its greatest descendants are found among the third degree of remoteness, and one in the second degree. Then the remaining part of the pedigree is filled in with what is best in the House of Brunswick, together with Elenora d'Olbrenze, a remarkable character.\* She was of a good Dutch Huguenot family.

Among the forty included in this group (all ancestors of Frederick the Great to third degree, with nieces and nephews) we find five in 10, four in 9, six in 8, seven in 7, or nine of these forty are geniuses 9 or 10; and 22 are high in the talent class. There is a strong literary and musical bent among the descendants, and hereditary influence can be traced through both the mother and paternal grandmother of Frederick the Great, straight back to the House of Orange, from which it probably came. This is in spite of the fact that Frederick's father was entirely hostile to literature. The bent appeared decidedly in five of the ten. In the others it seems to have been absent. The pedigree calls for about half of them to show this imaginative type of mind, if we couple to the pedigree this idea: that strong mental characteristics do not freely blend, but tend to jump about, and, if appearing at all, appear in almost full force in those who inherit them in any conspicuous degree.

Whatsoever in Frederick the Great's fraternity environment would not properly account for either the appearance of the artistic taste or the fact only half showed it. This literary bent should be compared with Hanover, where eighty-seven persons show only four authors and these are every one of them in the extreme background and consequently do not influence the House itself. Among the House of Hanover a number of the princes were fond of study but none were authors.

Regarding the moral side among the Hohenzollerns, there were only a few who fell short. It corresponds perfectly in a general way with the pedigree. It is noteworthy that here as in Hanover no atrocious and violent characters appeared in the family, nor were any

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\* See Wilkins, 'Love of an Uncrowned Queen.'



MARIA, DAUGHTER OF CHARLES V.



ALBERT, SON OF MAXIMILIAN II.



LOUIS XIII.



*Philip III by the Crown  
 and Council of Austria  
 etc. etc. H. Hoffmann.*

PHILIP III.



CHARLES III.

introduced in the pedigree. In this respect these countries should be compared with Russia, Spain, France and Italy.

Frederick the Great and his brother Henry left no descendants. In the next generation the great qualities died out in the house, because only two of the males had heirs and these were not the gifted members of the family. One, William Augustus, was weak and fond of pleasure, and was the son who resembled his grandfather, Frederick I. He married Louisa, a daughter of Ferdinand Albert, of Brunswick, an insipid woman of no gifts, with an ancestry virtuous and literary, but not talented politically.\* They had a son, Frederick William II., and a daughter; the son, who had the best of education and example, was a virtuous man of average capacity, but timid and irresolute. As Frederick William II., who was *not* brilliant, married a woman below the average capacity and of a mediocre family, by the next generation all brilliancy was removed to one great-great-grandparent, out of the sixteen the children had, and to eight of the thirty-two great-great-great-grandparents; which according to Galton would be a factor of extremely small value; so it is not surprising that it never came out again in this line, unless Wilhelm der Grosse and the present Kaiser be equal to them and represent extreme reversion. Their abilities are probably derived from fresh combinations.

Among the collaterals similar dilution, or lack of any issue at all, can be shown. Thus one of the greatest strains of intellect the world has ever seen finally disappeared. Quite unconsciously on their part it was formed. Its formation appears to be due to a remarkable combination of ingredients of blood, three sources of the best from the great House of Orange were united with the Great Elector of Brandenburg, who probably himself received his genius from the house of Orange. Its disappearance might well have been due to dilution in some branches, to accident or sterility in others. Probably the only strain in modern times, in royalty or out, that can show such a quantity of eminent relationship, and of such a high degree, is the same region about William the Silent that we have shown we consider the origin of this. The relation of this blood to the course of Prussian, German and even to the world's history should not be overlooked.

If it is accepted that these characters were what they were owing largely to heredity, then it follows that Prussia's rise under the Great Elector, her growth under Frederick William I.'s vigorous policy, and subsequent greater growth under Frederick II., together with the seven years' war, must, since historians all ascribe great influence to these sovereigns, find their ultimate explanation in these charts of descent. The theories of heredity appear to be very nearly satisfied. If we con-

\* See Brunswick.



FERDINAND II.



FERDINAND III.



LEOPOLD I.



CHARLES II.



sider that opportunities or the times were the chief causes, we must have a wonderful knowledge of all the intricate effects of this medium in order to explain the character in this way. The theory of chances seems here to be in danger, while the theory of heredity can be shown to be pretty well satisfied by the laws of heredity.

*The Hapsburg Lip.*

The accompanying illustrations show one of the best known and most conspicuous facial peculiarities among the royal families, the great swollen protruding lip of the Hapsburgs which can be traced with its varying degrees of intensification through no less than eighteen generations, coming out in at least forty-one of the various descendants.

Its first appearance, according to history, was in Cymburga, who was born in the last part of the fourteenth century, and became the wife of Ernst, the second patriarch of the House of Hapsburg.\* In its latest manifestation it appears at the present day with diminished strength and modified form in the young king of Spain. This is a remarkable instance of the force of heredity in perpetuating a physical trait, and has been thought to be an instance of prepotency, the male line being able to transmit a deeply rooted peculiarity, the features from the maternal side having no influence in counteracting it.

As an example of prepotency, the Hapsburg lip was cited by Darwin.† To quote his words :

It would appear that in certain families some one ancestor and after him others in the same family must have had great power in transmitting their likeness through the male line; for we cannot otherwise understand how the same features should so often be transmitted after marriage with various females as has been the case with the Austrian Emperors.

The same idea is expressed by Strahan, 'Marriage and Disease,' p. 64. As a matter of fact this feature, the big lip, was maintained and transmitted in no more remarkable way than the neurosis was, and for the same reason, namely, intermarriages in their own family, and time and time again the selection of those who exhibited the feature rather than those who did not.

In almost every generation there were some who showed the peculiar lip and there were always some who did not inherit it in any degree at all, and this is also paralleled by the mental abnormality. Therefore since there was an increasing number in each successive generation who were free from the peculiarity, the average of all descendants in each generation would give a diminution of the quality in question, and we have no prepotency at all, but merely

\* Coxe, 'Austria,' I., p. 297.

† Darwin, 'Animals and Plants,' II., p. 65.



CHARLES VI.



ELIZABETH LOUISE.



ELIZABETH FARNESE.



DON CARLOS.

what we might expect were the features transmitted in the same way as the mental and moral qualities.

The following is a list in each generation of those who exhibited this peculiarity. A study of the charts of descent shows that these were the ones who were repeatedly chosen as the progenitors of the following generations. At the same time there were at least as many more whose lips were in no way peculiar, but these were almost never the ones selected to become direct ancestors of the ruling houses of Austria, Spain and France. They are graded in the following classes: slight, somewhat marked and very marked. The ones whose pictures are shown are marked with an asterisk.

First generation:

Cymburga—died in the early part of the  
Fifteenth century.

Third generation:

Maximilian I., Emperor, 1459-1519.

Fifth generation:

* Charles V., Emperor, 1500-1558,	Considerable.
* Ferdinand I., Austria, 1503-1564.	Considerable.
* Mary, Queen of Hungary, 1501-1558,	Considerable.

Sixth generation:

Philip II., Spain, 1527-1598,	Marked.
* Maximilian II., Austria,	Marked.
* Maria, daughter of Ferdinand I.,	Slight.
* Maria, daughter of Charles V.,	Very marked.

Seventh generation:

* Philip III., Spain, 1578-1621,	Somewhat.
Marguerite, wife of Philip III.,	Marked.
* Ferdinand II., Austria,	Marked.
Marie de Medici, wife of Henri IV. of France,	Marked.
(Cosimo de Medici, her ancestor, also had a large lower lip.)	
* Albert, son of Maximilian II.,	Considerable.

Eighth generation:

Philip IV., Spain, 1605-1665,	Very marked.
* Ferdinand III., Austria,	Slight.
* Louis XIII., France,	Marked.
Charles, son of Philip III.,	Somewhat.

Ninth generation:

* Leopold I., Austria, 1640-1705,	Extremely marked.
* Charles II., Spain,	Marked.
Anne of Austria, wife of Louis IV.,	Somewhat.
Charles II. of England,	Marked.

Tenth generation:

Joseph I., Austria,	Slight.
* Charles VI., Austria,	Marked.

Eleventh generation:

Maria Theresa, Austria, 1717-1780,	Slight.
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Louis, Duke of Burgundy, father of Louis XV.,	Slight.
Twelfth generation:	
Louis XV., France, 1710-1774,	Somewhat.
Don Philip of Parma, son of Philip V. of Spain,	Somewhat.
* Charles III. of Spain,	Marked.
* Elizabeth Farnese, wife of Philip V. of Spain,	Marked.
Ferdinand VI. of Spain, 1713-1759,	Somewhat.
Joseph II., Austria,	Slight.
Leopold II., Austria,	Slight.
Thirteenth generation:	
Maria Louisa, wife of Charles IV., Spain,	Slight.
* Elizabeth Louisa, daughter of Louis XV., and wife of Philip, Duke of Parma,	Marked.
Fourteenth generation:	
Ferdinand VII., Spain, 1784-1833,	Slight.
Louis XVI., France,	Slight.
Charles X., France,	Somewhat.
* Don Carlos, first pretender, son of Charles IV. of Spain,	Marked.
Sixteenth generation:	
Francis d'Assio, king of Spain,	Slight.
Eighteenth generation:	
Alfonso XIII., present king of Spain,	Somewhat.

Thus we see a tangible physical trait, avowedly due to heredity, obeying the same principle as the mental and moral qualities, tending on the whole to become eliminated as time goes on, since the entire number in each successive generation was certainly increased, while the proportionate amount of its appearance is less and less, still skipping about, however, and occasionally reappearing with almost equal force in those who inherited it at all.

I have examined the portraits of some three hundred other members of the royal families and find the same principles evident—that one sees strong general facial resemblance usually only among the closely related—but that striking peculiarities may jump a generation or two, and then reappear in some of the descendants. Also one sees that general blends are not common, but that each child tends to ‘favor’ one or the other of its parents or more rarely a distant ancestor.

## A NEW THEORY OF LIGHT AND COLOURS.\*

BY SIR ISAAC NEWTON.

SIR,—To perform my late promise to you, I shall without further ceremony acquaint you, that in the beginning of the year 1666 (at which time I applied myself to the grinding of optic glasses of other figures than spherical,) I procured a triangular glass prism, to try therewith the celebrated phenomena of colours. And for that purpose having darkened my chamber, and made a small hole in my window shuts, to let in a convenient quantity of the sun's light, I placed my prism at his entrance, that it might be thereby refracted to the opposite wall. It was at first a very pleasing diversion to view the vivid and intense colours produced thereby; but after a while applying myself to consider them more circumspectly, I was surprised to see them in an oblong form; which according to the received laws of refraction, I expected would have been circular. They were terminated at the sides with strait lines, but at the ends, the decay of light was so gradual, that it was difficult to determine justly what was their figure; yet they seemed semicircular.

Comparing the length of this coloured spectrum with its breadth, I found it about five times greater; a disproportion so extravagant, that it excited me to a more than ordinary curiosity of examining from whence it might proceed. I could scarce think, that the various thickness of the glass, or the termination with shadow or darkness, could have any influence on light to produce such an effect; yet I thought it not amiss, first to examine those circumstances, and so tried what would happen by transmitting light through parts of the glass of divers thicknesses, or through holes in the window of divers sizes, or by setting the prism without, so that the light might pass through it, and be refracted before it was terminated by the hole: but I found none of those circumstances material. The fashion of the colours was in all these cases the same.

Then I suspected, whether by any unevenness in the glass, or other contingent irregularity, these colours might be thus dilated. And to try this, I took another prism like the former, and so placed it, that the light passing through them both, might be refracted con-

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\* This letter communicated to the editor of the transactions of the Royal Society on February 6, 1672, contains the first statement of Newton's discovery of the different colors and refrangibility of the rays of light.

trary ways, and so by the latter returned into that course from which the former had diverted it. For, by this means, I thought the regular effects of the first prism would be destroyed by the second, but the irregular ones more augmented, by the multiplicity of refractions. The event was, that the light, which by the first prism was diffused into an oblong form, was by the second reduced into an orbicular one, with as much regularity as when it did not at all pass through them. So that, whatever was the cause of that length, it was not any contingent irregularity.

I then proceeded to examine more critically, what might be effected by the difference of the incidence of rays coming from divers parts of the sun; and to that end measured the several lines and angles, belonging to the image. Its distance from the hole or prism was 22 feet; its utmost length  $13\frac{1}{4}$  inches; its breadth  $2\frac{7}{8}$ ; the diameter of the hole  $\frac{1}{4}$  of an inch; the angle, which the rays, tending towards the middle of the image, made with those lines in which they would have proceeded without refraction, was  $44^{\circ} 56'$ . And the vertical angle of the prism,  $63^{\circ} 12'$ . Also the refractions on both sides the prism, that is, of the incident and emergent rays, were as near as I could make them equal, and consequently about  $54^{\circ} 4'$ . And the rays fell perpendicularly upon the wall. Now subducting the diameter of the hole from the length and breadth of the image, there remains 13 inches the length, and  $2\frac{3}{8}$  the breadth, comprehended by those rays, which passed through the centre of the said hole, and consequently the angle of the hole, which that breadth subtended, was about  $31'$ , answerable to the sun's diameter; but the angle which its length subtended, was more than five such diameters, namely  $2^{\circ} 49'$ .

Having made these observations, I first computed from them the refractive power of that glass, and found it measured by the ratio of the sines, 20 to 31. And then, by that ratio, I computed the refractions of two rays flowing from opposite parts of the sun's discus, so as to differ  $31'$  in their obliquity of incidence, and found that the emergent rays should have comprehended an angle of about  $31'$ , as they did, before they were incident. But because this computation was founded on the hypothesis of the proportionality of the sines of incidence and refraction, which though, by my own experience, I could not imagine to be so erroneous as to make that angle but  $31'$ , which in reality was  $2^{\circ} 49'$ ; yet my curiosity caused me again to take my prism. And having placed it at my window, as before, I observed, that by turning it a little about its axis to and fro, so as to vary its obliquity to the light, more than an angle of 4 or 5 degrees, the colours were not thereby sensibly translated from their place on the wall, and consequently by that variation of incidence, the quantity of refraction was not sensibly varied. By this experiment therefore, as well as

by the former computation, it was evident, that the difference of the incidence of rays, flowing from divers parts of the sun, could not make them, after a decussation, diverge at a sensibly greater angle, than that at which they before converged; which being at most but about 31 or 32 minutes, there still remained some other cause to be found out, from whence it could be  $2^{\circ} 49'$ .

Then I began to suspect whether the rays, after their trajection through the prism, did not move in curve lines, and according to their more or less curvity tend to divers parts of the wall. And it increased my suspicion, when I remembered that I had often seen a tennis ball, struck with an oblique racket, describe such a curve line. For, a circular as well as a progressive motion being communicated to it by that stroke, its parts on that side, where the motions conspire, must press and beat the contiguous air more violently than on the other, and there excite a reluctancy and reaction of the air proportionably greater. And for the same reason, if the rays of light should possibly be globular bodies, and by their oblique passage out of one medium into another acquire a circulating motion, they ought to feel the greater resistance from the ambient aether, on that side where the motions conspire, and thence be continually bowed to the other. But notwithstanding this plausible ground of suspicion, when I came to examine it, I could observe no such curvity in them. And besides (which was enough for my purpose) I observed, that the difference between the length of the image and diameter of the hole, through which the light was transmitted, was proportionable to their distance.

The gradual removal of these suspicions, at length led me to the experimentum crucis, which was this: I took two boards, and placed one of them close behind the prism at the window, so that the light might pass through a small hole, made in it for the purpose, and fall on the other board, which I placed at about 12 feet distance, having first made a small hole in it also, for some of that incident light to pass through. Then I placed another prism behind this second board, so that the light trajected through both the boards, might pass through that also, and be again refracted before it arrived at the wall. This done, I took the first prism in my hand, and turned it to and fro slowly about its axis, so much as to make the several parts of the image, cast on the second board, successively pass through the hole in it, that I might observe to what places on the wall the second prism would refract them. And I saw, by the variation of those places, that the light tending to that end of the image, towards which the refraction of the first prism was made, did in the second prism suffer a refraction considerably greater than the light tending to the other end. And so the true cause of the length of that image

was detected to be no other, than that light consists of rays differently refrangible, which, without any respect to a difference in their incidence, were according to their degrees of refrangibility, transmitted towards divers parts of the wall.

When I understood this, I left off my aforesaid glass works, for I saw, that the perfection of telescopes was hitherto limited, not so much for want of glasses truly figured according to the prescriptions of optic authors, (which all men have hitherto imagined,) as because that light itself is a heterogeneous mixture of differently refrangible rays. So that, were a glass so exactly figured, as to collect any one sort of rays into one point, it could not collect those also into the same point, which having the same incidence upon the same medium are apt to suffer a different refraction. Nay, I wondered, that seeing the difference of refrangibility was so great, as I found it, telescopes should arrive to that perfection they are now at. For measuring the refractions in one of my prisms, I found that supposing the common sine of incidence upon one of its planes was 44 parts, the sine of refraction of the utmost rays on the red end of the colours, made out of the glass into the air, would be 68 parts, and the sine of refraction of the utmost rays on the other end 69 parts: so that the difference is about a 24th or 25th part of the whole refraction; and consequently, the object glass of any telescope cannot collect all the rays which come from one point of an object, so as to make them convene at its focus in less room than in a circular space, whose diameter is the 50th part of the diameter of its aperture; which is an irregularity, some hundreds of times greater than a circularly figured lens, of so small a section as the object glasses of long telescopes are, would cause by the unfitness of its figure, were light uniform.

This made me take reflections into consideration, and finding them regular, so that the angle of reflection of all sorts of rays was equal to their angle of incidence; I understood that by their mediation optic instruments might be brought to any degree of perfection imaginable, provided a reflecting substance could be found, which would polish as finely as glass, and reflect as much light as glass transmits, and the art of communicating to it a parabolic figure be also attained. But there seemed very great difficulties, and I have almost thought them insuperable, when I further considered, that every irregularity in a reflecting superficies makes the rays stay five or six times more out of their due course, than the like irregularities in a refracting one: so that a much greater curiosity would be here requisite, than in figuring glasses for refraction.

Amidst these thoughts I was forced from Cambridge by the intervening plague, and it was more than two years before I proceeded further. But then having thought on a tender way of polishing,



proper for metal, whereby as I imagined, the figure also would be corrected to the last; I began to try what might be effected in this kind, and by degrees so far perfected an instrument (in the essential parts of it like that I sent to London,) by which I could discern Jupiter's four concomitants, and showed them divers times to two others of my acquaintance. I could also discern the moon-like phase of Venus, but not very distinctly, nor without some niceness in disposing the instrument.

From that time I was interrupted till this last autumn, when I made the other. And as that was sensibly better then the first (especially for day objects,) so I doubt not, but they will be still brought to a much greater perfection by their endeavours, who, as you inform me, are taking care about it at London.

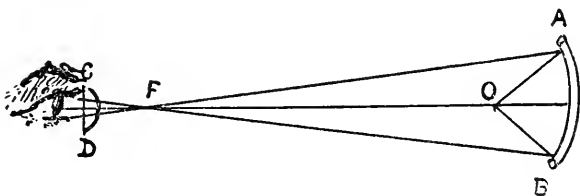


FIG. 1. [FIGURE 13, PLATE 14, IN THE ORIGINAL.]

I have sometimes thought to make a microscope, which in like manner should have, instead of an object glass, a reflecting piece of metal. And this I hope they will also take into consideration. For those instruments seem as capable of improvement as telescopes, and perhaps more, because but one reflective piece of metal is requisite in them, as you may perceive by the diagram, (fig. 13, pl. 14,) where *AB* represents the object metal, *CD* the eye glass, *F* their common focus, and *O* the other focus of the metal, in which the object is placed.

But to return from this digression, I told you, that light is not similar, or homogeneous, but consists of difform rays, some of which are more refrangible than others: so that of those, which are alike incident on the same medium, some shall be more refracted than others, and that not by any virtue of the glass, or other external cause, but from a predisposition, which every particular ray has to suffer a particular degree of refraction.

I shall now proceed to acquaint you with another more notable difformity in its rays, wherein the origin of colours is unfolded: concerning which I shall lay down the doctrine first, and then, for its examination, give you an instance or two of the experiments, as a specimen of the rest.—The doctrine you will find comprehended and illustrated in the following propositions:—

1. As the rays of light differ in degrees of refrangibility, so they also differ in their disposition to exhibit this or that particular colour. Colours are not qualifications of light, derived from refractions, or reflections of natural bodies (as it is generally believed,) but original and connate properties, which in divers rays are diverse. Some rays are disposed to exhibit a red colour, and no other; some a yellow, and no other; some a green, and no other, and so of the rest. Nor are there only rays proper and particular to the more eminent colours, but even to all their intermediate gradations.

2. To the same degree of refrangibility ever belongs the same colour, and to the same colour ever belongs the same degree of refrangibility. The least refrangible rays are all disposed to exhibit a red colour, and contrarily, those rays which are disposed to exhibit a red colour, are all the least refrangible: so the most refrangible rays are all disposed to exhibit a deep violet-colour, and contrarily, those which are apt to exhibit such a violet colour, are all the most refrangible. And so to all the intermediate colours, in a continued series, belong intermediate degrees of refrangibility. And this analogy betwixt colours, and refrangibility, is very precise and strict; the rays always either exactly agreeing in both, or proportionally disagreeing in both.

3. The species of colour, and degree of refrangibility proper to any particular sort of rays, is not mutable by refraction, nor by reflection from natural bodies, nor by any other cause, that I could yet observe. When any one sort of rays has been well parted from those of other kinds, it has afterwards obstinately retained its colour, notwithstanding my utmost endeavours to change it. I have refracted it with prisms, and reflected it with bodies, which in day-light were of other colours; I have intercepted it with the coloured film of air interceding two compressed plates of glass; transmitted it through coloured mediums, and through mediums irradiated with other sorts of rays, and diversely terminated it; and yet could never produce any new colour out of it. It would, by contracting or dilating, become more brisk, or faint, and by the loss of many rays, in some cases very obscure and dark; but I could never see it change in specie.

4. Yet seeming transmutations of colours may be made, where there is any mixture of divers sorts of rays. For in such mixtures, the component colours appear not, but, by their mutual allaying each other, constitute a middling colour. And therefore, if by refraction or any other of the aforesaid causes, the difform rays, latent in such a mixture, be separated, there shall emerge colours different from the colour of the composition. Which colours are not new generated, but only made apparent by being parted; for if they be again entirely mixed and blended together, they will again compose that colour,

which they did before separation. And for the same reason, transmutations made by the convening of divers colours are not real; for when the difform rays are again severed, they will exhibit the very same colours, which they did before they entered the composition; as you see, blue and yellow powders, when finely mixed, appear to the naked eye green, and yet the colours of the component corpuscles are not thereby really transmuted, but only blended. For, when viewed with a good microscope, they still appear blue and yellow interspersedly.

5. There are therefore two sorts of colours. The one original and simple, the other compounded of these. The original or primary colours are, red, yellow, green, blue, and a violet-purple, together with orange, indigo, and an indefinite variety of intermediate gradations.

6. The same colours in specie with these primary ones may be also produced by composition: for a mixture of yellow and blue makes green; of red and yellow makes orange; of orange and yellowish green makes yellow. And in general, if any two colours be mixed, which in the series of those, generated by the prism, are not too far distant one from another, they by their mutual alloy compound that colour, which in the said series appears in the midway between them. But those which are situated at too great a distance, do not so. Orange and indigo produce not the intermediate green, nor scarlet and green the intermediate yellow.

7. But the most surprising and wonderful composition was that of whiteness. There is no one sort of rays which alone can exhibit this. It is ever compounded, and to its composition are requisite all the aforesaid primary colours, mixed in a due proportion. I have often with admiration beheld, that all the colours of the prism being made to converge, and thereby to be again mixed as they were in the light before it was incident upon the prism, reproduced light, intirely and perfectly white, and not at all sensibly differing from a direct light of the sun, unless when the glasses, I used, were not sufficiently clear; for then they would a little incline it to their colour.

8. Hence therefore it comes to pass, that whiteness is the usual colour of light; for, light is a confused aggregate of rays indued with all sorts of colours, as they are promiscuously darted from the various parts of luminous bodies. And of such a confused aggregate, as I said, is generated whiteness, if there be a due proportion of the ingredients; but if any one predominate, the light must incline to that colour; as it happens in the blue flame of brimstone; the yellow flame of a candle; and the various colours of the fixed stars.

9. These things considered, the manner how colours are produced by the prism, is evident. For, of the rays constituting the incident light, since those which differ in colour, proportionally differ in

refrangibility, they by their unequal refractions must be severed and dispersed into an oblong form in an orderly succession, from the least refracted scarlet, to the most refracted violet. And for the same reason it is that objects, when looked upon through a prism, appear coloured. For the difform rays, by their unequal refractions, are made to diverge towards several parts of the retina, and there express the images of things coloured, as in the former case they did the sun's image upon a wall. And by this inequality of refractions they become not only coloured, but also very confused and indistinct.

10. Why the colours of the rainbow appear in falling drops of rain, is also from hence evident. For, those drops which refract the rays disposed to appear purple, in greatest quantity to the spectator's eye, refract the rays of other sorts so much less, as to make them pass beside it; and such are the drops on the inside of the primary bow, and on the outside of the secondary or exterior one. So those drops, which refract in greatest plenty the rays apt to appear red, towards the spectator's eye, refract those of other sorts so much more, as to make them pass beside it; and such are the drops on the exterior part of the primary, and interior part of the secondary bow.

11. The odd phænomena of an infusion of *lignum nephriticum*, leaf gold, fragments of coloured glass, and some other transparently coloured bodies, appearing in one position of one colour, and of another in another, are on these grounds no longer riddles. For, those are substances apt to reflect one sort of light, and transmit another; as may be seen in a dark room, by illuminating them with similar or uncompounded light. For, then they appear of that colour only, with which they are illuminated, but yet in one position more vivid and luminous than in another, accordingly as they are disposed more or less to reflect or transmit the incident colour.

12. From hence also is manifest the reason of an unexpected experiment, which Mr. Hook, somewhere in his micrography, relates to have made with two wedge-like transparent vessels, filled the one with red, the other with a blue liquor: namely, that though they were severally transparent enough, yet both together became opaque; for, if one transmitted only red, and the other only blue, no rays could pass through both.

13. I might add more instances of this nature; but I shall conclude with this general one, that the colours of all natural bodies have no other origin than this, that they are variously qualified to reflect one sort of light in greater plenty than another. And this I have experimented in a dark room, by illuminating those bodies with uncompounded light of divers colours. For, by that means, any body may be made to appear of any colour. They have there no appropriate colour, but ever appear of the colour of the light cast upon them,

but yet with this difference, that they are most brisk and vivid in the light of their own day-light colour. Minium appears there of any colour indifferently, with which it is illustrated, but yet most luminous in red; and so bise appears indifferently of any colour with which it is illustrated, but yet most luminous in blue. And therefore minium reflects rays of any colour, but most copiously those indued with red; and consequently when illustrated with daylight, that is, with all sorts of rays promiscuously blended, those qualified with red shall abound most in the reflected light, and by their prevalence cause it to appear of that colour. And for the same reason bise, reflecting blue most copiously, shall appear blue by the excess of those rays in its reflected light; and the like of other bodies. And that this is the entire and adequate cause of their colours, is manifest, because they have no power to change or alter the colours of any sort of rays, incident apart, but put on all colours indifferently, with which they are enlightened.

These things being so, it can be no longer disputed, whether there be colours in the dark, nor whether they be the qualities of the objects we see, no nor perhaps whether light be a body. For since colours are the qualities of light, having its rays for their entire and immediate subject, how can we think those rays qualities also, unless one quality may be the subject of and sustain another; which in effect is to call it substance. We should not know bodies for substances, were it not for their sensible qualities, and the principal of those being now found due to something else, we have as good reason to believe that to be a substance also.

Besides, whoever thought any quality to be a heterogeneous aggregate, such as light is discovered to be. But, to determine more absolutely what light is, after what manner refracted, and by what modes or actions it produces in our minds the phantasms of colours, is not so easy. And I shall not mingle conjectures with certainties.

Reviewing what I have written, I see the discourse itself will lead to diverse experiments sufficient for its examination, and therefore I shall not trouble you further, than to describe one of those which I have already insinuated.

In a darkened room make a hole in the shut of a window, whose diameter may conveniently be about a third part of an inch, to admit a convenient quantity of the sun's light; and there place a clear and colourless prism, to refract the entering light towards the further part of the room, which, as I said, will thereby be diffused into an oblong coloured image. Then place a lens of about three feet radius (suppose a broad object glass of a three-foot telescope,) at the distance of about four or five feet from thence, through which all those colours may at once be transmitted, and made by its refraction to convene

at a further distance of about ten or twelve feet. If at that distance you intercept this light with a sheet of white paper, you will see the colours converted into whiteness again by being mingled. But it is requisite, that the prism and lens be placed steady, and that the paper on which the colours are cast be moved to and fro; for by such motion, you will not only find at what distance the whiteness is most perfect, but also see how the colours gradually convene, and vanish into whiteness, and afterwards having crossed one another in that place where they compound whiteness, are again dissipated and severed, and in an inverted order retain the same colours which they had before they entered the composition. You may also see, that if any of the colours at the lens be intercepted, the whiteness will be changed into the other colours. And therefore that the composition of whiteness be perfect, care must be taken that none of the colours fall beside the lens.

In the annexed design of this experiment, ABC expresses the prism set endwise to sight, fig. 14, pl. 14, close by the hole F of the window EG. Its vertical angle ACB may conveniently be about 60 degrees: MN designs the lens. Its breadth  $2\frac{1}{2}$  or 3 inches. SF one of the straight lines, in which difform rays may be conceived to flow successively from the sun. FP and FR two of those rays unequally refracted, which the lens makes to converge towards Q, and after decussation to diverge again. And HI the paper, at divers distances, on which the colours are projected; which in Q constitute whiteness, but are red and yellow in R,  $r$ , and  $\rho$ , and blue and purple in P,  $p$ , and  $\pi$ .

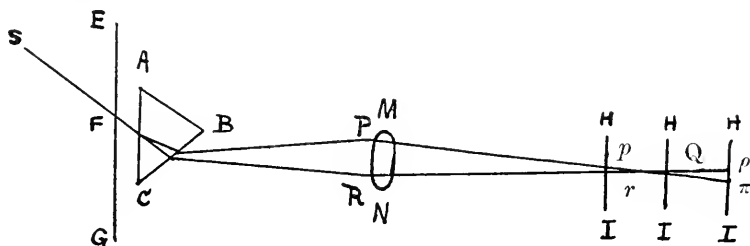


FIG. 2. FIGURE 14, PLATE 14, OF THE ORIGINAL.

If you proceed further to try the impossibility of changing any uncompounded colour, (which I have asserted in the 3d and 13th propositions) it is requisite that the room be made very dark, least any scattering light mixing with the colour disturb and allay it, and render it compound, contrary to the design of the experiment. It is also requisite, that there be a perfecter separation of the colours than, after the manner above described, can be made by the refraction of one single prism, and how to make such further separations, will scarcely be difficult to them that consider the discovered laws of re-

fractions. But if trial shall be made with colours not thoroughly separated, there must be allowed changes proportionable to the mixture. Thus, if compound yellow light fall upon blue bise, the bise will not appear perfectly yellow but rather green, because there are in the yellow mixture many rays indued with green, and green being less remote from the usual blue colour of bise than yellow, is the more copiously reflected by it.

In like manner, if any one of the prismatic colours, suppose red, be intercepted, on design to try the asserted impossibility of reproducing that colour out of the others which are pretermitted; it is necessary, either that the colours be very well parted before the red be intercepted, or that together with the red the neighbouring colours, into which any red is secretly dispersed, (that is, the yellow, and perhaps green too) be intercepted, or else, that allowance be made for the emerging of so much red out of the yellow green, as may possibly have been diffused, and scatteringly blended in those colours. And if these things be observed, the new production of red, or any intercepted colour will be found impossible.

This I conceive is enough for an introduction to experiments of this kind; which if any of the Royal Society shall be so curious as to prosecute, I should be very glad to be informed with what success; that, if anything seem to be defective, or to thwart this relation, I may have an opportunity of giving further direction about it, or of acknowledging my errors, if I have committed any.

## DISCUSSION AND CORRESPONDENCE.

ARE FELLOWSHIPS ALMSGIVING  
OR INVESTMENTS?

To the Editor:—In his admirable article, 'University Building,' in the August number of THE POPULAR SCIENCE MONTHLY, President Jordan has made some assertions that seem in a measure contradictory, and which may tend to retard the very spirit of research which he so heartily commends.

He says: "The whole system of fellowships for advanced students is on trial, with most of the evidence against it. The students paid to study are not the ones who do the work. When they are such they would have done the work unpaid. The fellowship system tends to turn science into almsgiving, to make the promising youth feel that the world owes him a living." Mr. Carnegie's gift of \$10,000,000, for the promotion of research work, will scarcely engender a spirit of pauperism among scientists who are enabled by this means to carry on more extended investigations. On the contrary what a thrill of enthusiasm flashed round the world when the announcement of the gift was made! What a stimulus to the prosecution of advanced work was the recog-

nition of the need of opportunity to work!

Let us contrast the following statements, which occur in the last paragraph of the article, with what has been already quoted: "As men of science are needed, they cannot make themselves. Those with power can help them. This fact has given the impulse to the far reaching gifts of Stanford, Rockefeller, Carnegie and Rhodes. These are not gifts but investments, put to the credit of the country's future. The people too have power. The same feeling of investment has led them to build their state universities and to entrust to them not only the work of personal culture but of advancement in literature, science and arts."

If Dr. Jordan regards the fellowship system as a kind of almsgiving, bestowed needlessly, and as developing undue arrogance in the promising student, how can he commend the acceptance of the munificent gifts of Stanford, Rockefeller and Rhodes? Is not the bestowal of a fellowship likewise an investment which stimulates and helps the individual, just as the larger gifts help the whole people? MRS. W. A. KELLERMAN.

COLUMBUS, OHIO.



## THE PROGRESS OF SCIENCE.

*THE CARNEGIE INSTITUTION  
AND THE MARINE BIOLOGICAL  
LABORATORY.*

THE first information made public in regard to the policy of the Carnegie Institution, beyond the original outline presented by Mr. Carnegie in his deed of gift and some very general statements made by President Gilman and other members of the executive committee, is the announcement that the corporation of the Marine Biological Laboratory at Woods Hole has voted to transfer its buildings and equipment to the trustees of the Carnegie Institution. This gift can not be accepted until the trustees hold their November meeting, but it was stated to the corporation of the laboratory that the executive committee of the Carnegie Institution would recommend that the laboratory be made a branch of the institution and liberally developed, money being appropriated for buildings and \$20,000 a year for current expenses. It is rumored further that a geophysical laboratory will be established at Washington and supported on a large scale.

The Carnegie Institution, the Woods Hole Laboratory and science in America are face to face with complicated circumstances, and difficult problems are involved in any solution. The institution can contribute greatly to the development of science either by establishing and conducting several great laboratories or by cooperating with existing agencies. The majority of American men of science prefer the latter course and will regret the apparent decision of the executive committee to recommend the acquisition of a biological laboratory. It may be said that the various scientific and educational

institutions throughout the country and their officers are selfish, hoping to share in the distribution of funds or fearing a new rival. It has, however, also been suggested that the officers of the Carnegie Institution may aggrandize the institution rather than contribute in the most effective manner to scientific research. We, however, believe that both the officers of the institution and the scientific men of the country are entirely sincere in their efforts to make the Carnegie Institution the most potent factor possible for the advancement of science. The executive committee of the institution has appointed advisory committees of men of science in different subjects, and these committees are securing evidence and preparing reports. It is perhaps proper that these reports and even the names of the members of the committees should be kept secret until the executive committee has made its report to the trustees. We hope, however, that the trustees will not commit the institution to any irrevocable policy in November, but will make public all the alternative suggestions presented and permit careful consideration and full discussion before final plans are adopted.

Whether or not it is advisable for the Carnegie Institution to conduct a marine biological laboratory rather than cooperate with the Fish Commission and the various existing laboratories may be an open question, but it is undoubtedly true that most of those interested in the Woods Hole laboratory regret that it has been found necessary to turn it over to the Carnegie Institution. The Woods Hole laboratory is the only institution of national importance that has been conducted by

scientific men. The present organization of the laboratory is a corporation, composed of those interested in the research work of the laboratory, which elects trustees, chiefly biologists representing different universities. This democratic form of government must surely be the ideal of scientific men. They may endure the usual board of trustees composed of men of affairs who delegate authority to a president; they may even realize the business efficiency of such an organization; but they look forward to the time when they will choose their own leaders and define their own policy. The laboratory at Woods Hole has illustrated both the strength and weakness of a democratic organization. There has been friction in the management, and the finances have never been in a satisfactory condition. On the other hand, there has been enthusiasm, self-sacrifice and a high ideal of research. If the Woods Hole laboratory is directed from Washington it will go forward with the efficiency of the scientific departments of the government, and will be practically one of these, being for all essential purposes coordinate with the Fish Commission or the Geological Survey, but with scarcely one fiftieth of the income. There will not, however, be found a director who will devote himself to the service of the laboratory without dreaming of receiving a dollar's salary, or men of science ready to give freely the time and money of which they have so little to spare. Those connected with the laboratory will no longer seek to give what they can, but rather to get what they can, and the whole spirit of the place will change.

Just for a handful of silver he left us,  
 Just for a riband to stick in his coat—  
 Found the one gift of which fortune bereft us,  
 Lost all the others she lets us devote;  
 They, with the gold to give, doled him out silver,  
 So much was theirs who so little allowed:  
 How all our copper had gone for his service!

#### SCIENCE IN AMERICAN JOURNALS.

THE fact that the *Forum* and the *International Monthly*, both of which include science in their scope, have abandoned monthly publication and will hereafter appear but four times a year is somewhat disquieting; it seems to indicate that journals maintaining a high standard are not well supported in this country. We have left only the *North American Review* and THE POPULAR SCIENCE MONTHLY, in addition to the monthlies that depend chiefly on politics, fiction or literary gossip. The *North American Review* has at times tended to rely more on the names signed to its articles than on their contents, and must on the whole be regarded as a political rather than as a literary journal. THE POPULAR SCIENCE MONTHLY has a limited and definite field, for which it is urgently needed and in which it is adequately supported; but the larger part of its contents can not be regarded as literature. We keep within the limits of obvious truth in stating that this journal in its special field has set a standard for other nations which they have not yet met. The same is true of our illustrated monthlies which reflect all degrees of taste and refinement. They have carried mechanical illustration and the short story to a singular point of perfection. But it can not be claimed that photo-engraving and the short story are the highest forms of art. The editor of one of our most prosperous monthlies has recently stated that a magazine should never contain any thing that could as well have been published the month before. The requirements of true literature are the reverse; nothing is literature that could not as well be published a year hence. The magazine seems likely to devour its own offspring, for while there come forward many new writers of short stories, but few survive. A month's life does not encourage a writer to do his best work, and we have in

fact no short stories such as those of Hawthorne and Poe. Weekly journals of literature have also declined. *The Critic* could not continue as a weekly and *The Nation* has become a compilation from the *Evening Post*.

Corresponding with the wide diffusion of physical comfort in a democracy we have an abundant supply of Sunday newspapers, illustrated magazines and current novels. These are well adapted to the readers for whom they are manufactured and demonstrate a degree and extension of intelligence which is all that could be expected, and is on the whole highly satisfactory. But there appears to be no intellectual development corresponding with the large fortunes accumulated by our captains or knights—as the case may be—of industry. As far as journals and reviews are concerned, we must frankly admit our inferiority to Great Britain and France. This does not, however, mean that we should or shall remain quietly or permanently in this position.

We are here especially concerned with science; but we do not admit that science and literature can be divorced. Science supplies to literature both method and subject matter, whereas clear and correct expression is essential to science. There are a few American men of science who have admirable command of the language they write, but the men with exceptional powers of expression are rarer and the average is lower than in France or in Great Britain. The treatment of science in the newspapers and magazines is also less satisfactory here than abroad. Articles of excellent quality are often published, but fads and charlatanism are exploited with equal apparent authority, and the reader must become entirely bewildered, having no means of discriminating one alleged scientific article from another, and the entire scientific miscellany is given about the same attention and credence as the columns devoted to the gossip from Sara-

toga. Some newspapers and magazines are better than others, but there appears not to be a single one of them that submits its scientific contributions to an expert. Hence while the literary taste of the community is mediocre, its scientific sense is practically non-existent.

#### A GRADUATE SCHOOL OF AGRICULTURE.

THE Graduate School of Agriculture, which held a four weeks' session during the month of July at the Ohio State University, Columbus, Ohio, marks an important step of progress in agricultural science and education in the United States. This school was the outcome of a happy thought which came to Professor Thomas F. Hunt, dean of the College of Agriculture and Domestic Science of the Ohio State University, while he was attending the convention of the Association of American Agricultural Colleges and Experiment Stations at San Francisco in 1899. Seeing how inadequate were the opportunities at such short conventions for the discussion of anything more than the most general problems of agricultural science and education it occurred to him that it would be a good plan to establish a summer school for advanced students of agriculture at which leading teachers and investigators from the agricultural colleges and experiment stations and the United States Department of Agriculture should present in some regular way summaries of the recent progress of agricultural science, illustrate improved methods of teaching agricultural subjects and afford a somewhat extended opportunity for the discussion of live topics drawn from the rapidly advancing science of agriculture. This idea received the cordial approval of President Thompson of the Ohio State University, and on the recommendation of these two men the board of trustees of the university voted to establish such a school

and generously made provision for the financial support of its first session.

The Association of American Agricultural Colleges and Experiment Stations at its convention in 1901 favored the plan for the school and voted that, if the success of the first session seemed to justify its continuance, it be made a cooperative enterprise under the control of the association. Hon. James Wilson, Secretary of Agriculture, also expressed his cordial approval of this movement, and, on his advice, Dr. A. C. True, director of the Office of Experiment Stations, consented to act as dean and other officers of the Department of Agriculture to be members of its faculty. Under these favorable auspices there was a little difficulty in securing a strong faculty. As actually organized this included 35 men, of whom 26 are professors in agricultural colleges, 7 are leading officers of the Department of Agriculture, and 2 are officers of the New York State Experiment Stations. Courses were offered in agronomy, zootechny, dairying, and breeding of plants and animals. The school was housed in the substantial and well-equipped agricultural building of the university, where were illustrated the most approved apparatus of instruction in soil physics, dairying and other agricultural subjects. Besides the livestock of the university farm, leading breeders of Ohio furnished choice animals for the stock-judging exercises.

General problems of agricultural science and pedagogy were discussed at the inaugural exercises and at Saturday morning conferences. Among the topics thus treated were the history of agricultural education and research in the United States; the organization of agricultural education in colleges, secondary schools, nature study courses, correspondence courses, farmers' institutes and various forms of university extension; what constitutes a science of agriculture; educational values of courses in agriculture; methods and

values of cooperative experiments. Through social assemblies, visits to typical Ohio farms, and much informal discussion wherever the students met each other, the educational influences of the school were greatly extended. Seventy-five students were in attendance. These were drawn from 28 states and territories, including such widely separated regions as Maine, Oregon, California, New Mexico and Alabama. There was one student from Canada and one from the Argentine Republic. There was also one woman, and the colored race was represented by teachers from the Tuskegee Institute and the North Carolina Agricultural College. Twenty-seven of the students are professors or assistant professors in agricultural colleges, thirty-one are assistants in the agricultural colleges and experiment stations, nine are recent college graduates, and eight are engaged in farming.

Considering the character of the faculty and students, it goes without saying that the whole period of the session was occupied with the most earnest and profitable work. Without doubt the influence of this school will be felt throughout the country in the improvement of courses of instruction in agriculture and the strengthening of the lines and methods of investigation of agricultural subjects. In other ways the school will exert a beneficial influence. So rapid has been the accumulation of materials for a real science of agriculture during the past few years that even professional students of agriculture have not realized how large a mass of knowledge is already available for molding into a systematic body of truth which may be utilized for pedagogic purposes, as well as for inductions of scientific and practical value. The summaries given by the experts gathered at this graduate school have emphasized this fact and shown in a striking manner that agricultural education and research may now be properly and efficiently organ-

ized with reference to the science of agriculture itself, rather than be, as heretofore, very largely a matter of the sciences related to agriculture. This will serve to stimulate greatly the movement already begun for the reduction of the materials of agricultural science to 'pedagogic form' for use in colleges and secondary schools, and for the reorganization of agricultural institutions of research on the basis of the divisions and subdivisions of agriculture, instead of physics, chemistry, botany and other primary and secondary sciences. The day will thus be hastened when the science of agriculture will rank with such tertiary sciences as geology, geography and medicine as one of the great systems of knowledge of direct benefit to mankind.

We are without doubt in this country just on the edge of a great popular movement for the improvement of the conditions of rural life through the improvement of the rural schools. As one phase of this movement there will come the broadening of the instruction in the principles of agriculture so that in addition to college courses we shall have secondary courses in ordinary and special high schools and even some elementary instruction in the common schools. In establishing the lines and methods of secondary and elementary instruction in agriculture so that it may be useful and attractive to the masses of our rural youth, the leaders in agricultural science gathered in the Graduate School of Agriculture this summer will play an important part, and it is believed that they have gone out from this school with much inspiration to renewed efforts in this direction. For both the thorough establishment of the science of agriculture and the wide popularization of this science the new school will, it is believed, be an efficient agency.

It is to be hoped therefore either that some other university will open its doors for a second session of the

school another year, or that the Association of Agricultural Colleges and Experiment Stations will assume this burden, or that through the cooperation of the association with universities and the Department of Agriculture the Graduate School of Agriculture may become a permanent institution.

#### BIOGRAPHIES OF EMINENT CHEMISTS.

AUGUST WILHELM VON HOFMANN is the subject of a biography published on the 8th of April, 1902, as an extra number of the Reports of the German Chemical Society, that date being the 84th anniversary of the birth of the distinguished chemist. It was begun by Dr. Tiemann, for many years Hofmann's assistant, but after his untimely death it was completed by Emil Fischer and Jacob Volhard, assisted by others, all of whom had been pupils of the energetic master. Of Hofmann's career several sketches have already been published, as 'Memorial Lectures of the Chemical Society [of London],' read May 5, 1893, the first anniversary of his death; these were 'Personal Reminiscences' by Lord Playfair, as well as by Sir Frederick Abel, and the 'Origin of the Coal-Tar Industry,' by Dr. Perkin, and 'The Scientific Work of Hofmann' by Professor Armstrong. Notwithstanding these valuable contributions to the subject by English contemporaries and fellow-workers, the biography issued by the German Chemical Society will long be the standard. It portrays more in detail Hofmann's strong personality, his relations to society especially during his long residence in London, his pleasure travel with agreeable souvenirs of the visit to the United States in 1883, and narrates anecdotes illustrating his genial disposition and humor; at the same time the volume does not neglect summarizing his fruitful chemical researches carried on through a period of more than fifty years with never-dying industry and enthusiasm. The

number and variety of the discoveries made in the laboratory by Hofmann but faintly reflect his truly extraordinary capacity for hard work; even after passing his seventieth birthday he occasionally worked in the laboratory until two or three o'clock in the morning.

One of Hofmann's most valuable series of investigations was his study of coal-tar derivatives; begun in 1845 it reached a lofty point in 1858 and culminated in the discovery of a long line of magnificent dyes whose hues and names have become household words; it is true that all aniline colors are not Hofmann's own, but he worked out the fundamental principles governing their existence, and pointed out the way for their creation by the labors of his pupils and others. Hofmann was an energetic and agreeable lecturer to classes in the university and he excelled in devising original and brilliant experiments for illustrating these lectures; some of these he made known through his 'Introduction to Modern Chemistry,' published in 1865, and in articles contributed to the *Berichte* in succeeding years (1871-1882). Hofmann was married four times and had eleven children born to him, eight of whom survive him. The biography is illustrated by two portraits of the eminent chemist, one representing him in the twenty-eighth year, and the other in the seventy-third year of age.

It is rather singular and hardly creditable to French authors that no adequate biography of the centenarian chemist, Michel Eugène Chevreul, has as yet appeared. Chevreul was born August 31, 1786, and on the occasion of his hundredth birthday he was presented with a gold medal, with ceremonies that included addresses from men of distinction. An account of this function was published at Rouen, in 1886, illustrated by an engraved portrait of the veteran chemist and with a facsimile of the medal. In the same year there appeared at Paris a

full catalogue of Chevreul's contributions to science, numbering 547 different articles and extending from 1806 to 1886. This is, however, incomplete, for Chevreul did not die until April 9, 1889, and his literary activity continued to the end. Chevreul's 'Researches on Fats' (1823) forms the starting point of one of our great industries and his essay on 'Colors—their Application to Industrial Arts,' has borne valuable fruit. An obituary of Chevreul by A. W. von Hofmann appeared in the Reports of the German Chemical Society in 1889.

One of the greatest benefactions conferred on mankind by modern science was the method of manufacturing common soda invented by Nicolas Leblanc. The biography of this little appreciated and poorly rewarded chemist was published in 1884 by his grandson, Auguste Anastass.

After the outbreak of the Revolution in France the industrial needs of the country became more and more pressing, the Academy of Sciences offered a prize of 12,000 *livres* for a practical method of manufacturing carbonate of soda from common salt; this problem attracted the attention of a modest physician devoted to chemical studies, Nicolas Leblanc. The history of his chemical success, and his practical misfortunes, his financial distress, and his shocking death by his own hand make very sad reading; this tragic event occurred in 1806.

An appendix to this biography has also a sad interest; it is an inventory of the apparatus and chemicals contained in the laboratory of Lavoisier, made five months after his execution, and signed by Nicolas Leblanc.

Henry Morton, who died May 9, 1902, will be best remembered as a physicist, but he began his scientific career as a professor of chemistry. An artistic and beautifully illustrated 'Biographical Notice of Dr. Morton' forms a volume prepared by his friends, Coleman Sellers and Albert R.

Leeds, and printed for private circulation in 1892; this portrays his career as an exceedingly versatile man endowed by nature with the gifts of artist, poet, linguist and inventive ability, as well as those attributes which caused him to become widely known as a successful scientist. One of Dr. Morton's intellectual feats deserves recording; while still a college undergraduate he translated and designed an artistic monograph on the Rosetta Stone, which was afterwards reproduced by lithography in all its gay colors. His contributions to science are briefly narrated; his success in filling the responsible position of president of the Stevens Institute of Technology for many years, and his great generosity to the same, will require another volume yet to be written.

#### THE COMPARATIVE GROWTH OF BACTERIA IN MILK.

At the last meeting of the American Society of Bacteriologists Professor H. W. Conn described a series of experiments, the design of which was to determine what species of bacteria develop in milk during the first twenty-four hours and what species disappear. The general purpose of the experiments was to determine as far as possible the relation of milk bacteria to the healthfulness of milk. The conclusions presented by the paper were as follows: (1) Milk freshly drawn from the cow contains a large variety of bacteria. (2) For the first six hours and sometimes more, there is no increase in the number of bacteria, even when the milk is kept at 70°. On the contrary, there is commonly a decrease due to what has been called the 'germicide power' of milk. (3) In the fresh milk the largest number of bacteria are streptococci, which come, in most cases, directly from the udder of the cow. (4) During the first forty-eight hours there is a very great increase in the number of bacteria, but the number present after one or two

days' growth is quite independent of the number present at the start. In many cases milk, which when fresh contained a small number of bacteria, at the end of forty-eight hours contained a number far greater than other samples of milk which at the outset had a larger number of bacteria present. (5) During the first forty-eight hours there is a considerable increase in the number of streptococci, followed by their decrease and final disappearance. (6) At the outset the number of lactic bacteria is extremely small, so small as, at times, quite to escape observation. (7) These lactic bacteria are, at least in the series of experiments described, derived from sources external to the cow and never, or rarely, from the milk ducts. (8) The lactic bacteria, though very few in number at the outset, increase far more rapidly than any other types, so that within twenty-four hours they are commonly in the majority, and by the end of forty-eight hours they commonly comprise considerably over ninety per cent. of all the bacteria present.

#### SCIENTIFIC ITEMS.

DR. CHARLES KENDALL ADAMS died at Redlands, Cal., on July 27. He was president of Cornell University from 1885 to 1892, when he resigned and became president of the University of Wisconsin. This post he held actively until 1901, when he retired on account of ill health.

PRESIDENT DAVID STARR JORDAN has been successful in securing a valuable collection of fishes in the Bay of Apia, Samoa, some four hundred and fifty species, many of them new, having been collected.—Gen. A. W. Greely, chief of the U. S. Signal Service, has returned from Alaska, where he had been inspecting the work on the Government telegraph line from Valdez to Eagle City.—Mr. F. H. Newell, chief hydrographer of the U. S. Geological Survey, has gone to the West to supervise in

connection with the work in irrigation authorized by Congress. Surveying parties are in the field in California, Oregon, Washington, Montana, Utah, Nevada, Idaho, Arizona and Colorado.

A STATUE of Pasteur was unveiled at his birthplace, Dôle, Jura, on August 3.—The centenary of the death of Bichat, the celebrated anatomist and physiologist, was commemorated on July 22, under the auspices of the French Society of the History of Medicine.—The centenary of the birth of the Norwegian mathematician, Niels Henrik Abel, will be celebrated at Christiania in September. Abel was born in 1802 and died at the early age of twenty-seven years, but in this short period attained rank among the foremost mathematicians of the century.—A memorial to John Fitch, who is said to have been the first to apply steam to the running of a boat, has been erected in Warminster, Pa. It bears the inscription: "John Fitch here conceived the idea of the first steam-boat. He ran a boat with side-wheels by steam on a pond below Davisville in 1785. Bucks County Historical Society."—A bronze tablet has been unveiled at Lafayette College in memory of the late James H. Coffin. The inscription reads as follows: "In memory of James Henry Coffin, LL.D. Long a main-stay of Lafayette College, professor of mathematics, natural philosophy and astronomy, 1846-1873; vice-president and college treasurer, 1863-1873. A tireless teacher and administrator, an officer of the church, a friend of the slave. A member of the National Academy of Sciences, author of 'Winds of the Globe.' He annexed the atmosphere to the realm of science, and searched the highways of the winds and the paths of vagrant storms. Born in Williamsburg, Mass., September 6, 1806; died in Easton, February

6, 1873. The class of 1866 has erected this tablet."

PROFESSOR W. E. RITTER, of the University of California, has secured funds for the erection of a marine laboratory at San Pedro, which will be used as a center for the biological study of the Pacific coast.—Mr. W. H. Evans, of the office of Experiment Stations, U. S. Department of Agriculture, has returned from Porto Rico, where he was in conference with Mr. F. D. Gardner, in charge of the Porto Rico Station, with reference to the selection of a permanent site and the development of the station there.—The French Minister of Agriculture has established an office for agricultural information, the object of which is to act as a bureau of correspondence and a means of popularizing scientific agriculture.—Queensland has given up its weather bureau, and the services of Mr. C. L. Wragge and others have been dispensed with. It is hoped that an arrangement may be made by which the service will be continued by the federal government.—Mr. J. Pierpont Morgan has presented to the Museum of the Jardin des Plantes, Paris, the collection of precious stones formed by Mr. George F. Kunz for the Buffalo Exhibition.

THE Berlin Academy of Sciences has announced that its academic prize of 5,000 Marks, will be awarded in 1904 for an investigation of the kathode rays and in 1905 for an investigation of the theory of functions of several variables which admit of linear substitution. The income of the Cothenius legacy—\$2,000—for 1904 will be awarded for investigations of new varieties of grain. The papers may be written in English and must be presented without the name of the author to the Bureau of the Academy, Universtät Strasse, 8, Berlin.







*Carl Schuster*

# THE POPULAR SCIENCE MONTHLY.

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## A STUDY IN PLANT ADAPTATION.

BY PROFESSOR J. W. TOUMEY,  
YALE UNIVERSITY.

EVERY one interested in plants knows that they are very dependent upon their surroundings. The atmosphere and soil conditions that suit one species are often totally unsuited to another. In the process of development the different species become structurally and physiologically modified with the change of environment; they take on certain adaptations, where they succeed best, which particularly fit them to their surroundings.

Every plant in order to grow must receive material from the outside and must get rid of waste matter. The plant does not differ in any essential respect from the animal in this regard. So also, the plant, in order to continue from generation to generation, must bear offspring and leave them in situations favorable to their growth.

In all seed-plants the food materials are essentially the same. The ability of a plant, however, to avail itself of these materials depends very largely upon a close correlation between the structure and the physiological activities of the plant organs and its environment. Thus a plant like the apple will not succeed in a hot and arid climate, while, on the other hand, the date will not thrive beyond the limits of the desert.

The sensitiveness of many plants to a slight change in soil or climate and the necessity for a perfect adaptation to a particular environment are illustrated in the very restricted range of many of our native trees and shrubs.

On the Pacific coast the Monterey cypress is only found growing naturally over a strip of territory, south of the Bay of Monterey, about

two miles long and two or three hundred yards wide, and over a still smaller area a little farther south. The California fan-palm only occurs in a few canyons of two mountain ranges in the southern part of the state. The western hop hornbeam is only known to grow over a few square rods of territory in the Grand Canyon of the Colorado river in Northern Arizona. In eastern United States, *Torreya* only grows in a narrow strip on the eastern bank of the Appalachian River in Florida: while the Florida yew, which grows in the same region, occupies a still less extended area.

In such cases as these it is likely that the structural and physiological adaptations of the different plant organs have not kept pace with the natural changes in environment. As a result, these trees are not only unable to extend their present range, but are poorly fitted to persist where they now grow and consequently are disappearing. These old types of trees have in the course of ages become inflexible and fixed and are no longer in perfect accord with their environment. More modern types, as illustrated in the various genera of Cactaceae, are more generalized and very readily take on structural and physiological modifications which fit them better to their present environment. It is interesting to note that many of the species which appear to be out of accord with their natural environment often do well under cultivation. The gardener's care in subjecting them to different environmental conditions, particularly as regards food supply, seems to stimulate them and give them new vitality, thus causing them to succeed better than more modern types perfectly in accord with their natural environment. In the latter case overstimulation, induced by cultivation, may from the standpoint of vitality do more harm than good.

The Monterey cypress, although now nearly extinct as a wild plant, is one of the most successful and easily cultivated trees of the Southwest. It appears to be far better in accord with the artificial environment induced by cultivation than it is with its natural environment. The *Franklinia* of our gardens, a small tree first collected by John Bartram in 1765 on the banks of the Altamaha River in Georgia, is successful in cultivation, although as a wild plant it passed out of existence during the past century. It is far more successful in cultivation than the Loblolly bay, an allied species of the same genus which is now growing wild from Virginia to Florida. The Ginkgo, an Asiatic tree of ancient origin, grows remarkably well in cultivation, although at the present time it is not known to grow as a wild plant any where.

Modern plant types that have not yet reached the limits of their distribution and variation, as illustrated in many species of the Compositae, Rosaceae and Cactaceae, are so nicely adjusted to their natural environment that cultivation often tends to diminish their vitality rather than improve it.

It is not to be presumed that every variation in the structure of plant organs is a direct result of adaptations taken on by the plant to protect it from unfavorable factors in its environment. It is the natural, inherent tendency of plants to vary, and when the variation chances to be in a direction that fits it better to its environment, the variation is apt to persist in future generations. There is no apparent reason, however, why in many instances structures may not be present in the plant that are in no sense of direct aid. We should not expect to refer every variation in plant structures to variation in environment. We should, however, expect those species to do best that in their natural



FIG. 1. THE TUCSON PLAINS, SHOWING RANGE CATTLE IN THE DISTANCE FEEDING UPON THE FRUIT OF THE CHOLLA.

tendencies to vary become so modified as to fit them most perfectly to their surroundings.

Each plant organ must not only be adapted for the kind of work that it has to do, but it must be adapted for doing its best under the external influences which enable it to persist in any given form. The foliage leaf bears a definite relation to light and moisture: the leaves of one plant, however, may have quite different requirements as to light and moisture than the leaves of another. Every traveler in our arid southwest has noticed that the leaves of the trees and shrubs are small and thick, or, in some instances, entirely absent as foliage. The reason for this is very clear. It arises from the necessity of the desert plant to expose a comparatively small surface to the intense sunlight and the desiccating action of the dry atmosphere.

The various species of cacti illustrate this necessary correlation between plant structures and environment probably better than any other large group of plants. *Opuntia*, the most important genus, is abundantly represented in the flora of our arid southwest (Figs. 1 and 2) and reaches its maximum development on the Tucson plains in southern Arizona. No less than ninety-two species of *Opuntia* are growing wild in southwestern United States and northern Mexico, selecting for the most part situations that are so dry that few other plants persist where they thrive.

In this article I desire in particular to call attention to the cholla (*Opuntia fulgida* Engelm.) a cactus which grows to the size of a small tree and which reaches its maximum development on the Tucson plains.



FIG. 2. THE CHOLLA AND TUNA, GROWING TOGETHER IN SOUTHERN ARIZONA.

The cholla has probably not yet reached the limits of its variation and distribution, and is one of the most interesting and characteristic plants of the arid regions of the western continent. The organs of this plant are most wonderfully adapted for performing their various functions, to the best advantage of the plant, under what would be with most plants an extremely adverse environment.

The cholla is one of the largest of the cacti having numerous branches. It grows best where fully exposed to the intense glare and heat of the desert sun and where the annual rainfall averages from four to twelve inches. It grows on the driest upland, on open, porous, limy soil that for months at a time is as dry as powder.

Where it grows best the summer temperature often reaches a maximum of 115 degrees F. and the daily temperature for weeks at a time ex-

ceeds 100 degrees F. during the hottest part of the day. Often for several consecutive months there is no precipitation whatever and much of the rain that does fall only penetrates the soil to the depth of a few inches.

Not only is this cactus, as an individual plant, perfectly equipped by nature to withstand and thrive under this extremely hot and arid environment, but it is splendidly equipped for perpetuating itself by its successful distribution of offspring under conditions which enable them to succeed where on account of lack of moisture most plants would perish.

The roots of the cholla do not penetrate to great depths in the soil as one would at first thought suspect them to do. For the most part they spread out a few inches under the surface. It would be useless for this plant to send its roots to great depth into the soil, because only in rare instances is there any available moisture there. As most rains only penetrate the soil to the depth of a few inches the most moisture is found in the surface soil. These surface roots of the cholla have a different structure from that found in the deeper roots and in the roots of most plants. Their structure is splendidly adapted to enable them to take up water with great avidity when the soil is moist and to survive long periods of drought during which the surface soil is practically air dry.

It would be of no special value to the cholla to absorb large quantities of water when available, if there were no provision made by the plant for storing it, or if through transpiration it were readily given up to the surrounding atmosphere. This cactus is not only remarkably well equipped for storing water in large quantities, sufficient to carry it through months of continuous drought, but it is able to retain this water with wonderful tenacity, only giving it up to the hot and dry air a little each day and taking advantage of each rain to fill its storage tissue.

The structure of the young branches and stems of the cholla particularly adapts them for the storage of water in large quantities. At the height of the growing season or after a prolonged summer rain the stems of this cactus may contain as high as ninety-two per cent. of moisture. During a prolonged drought the percentage of moisture very perceptibly diminishes. The older stems and branches which give strength and support to the tree contain a much larger proportion of woody tissue and consequently serve to a less degree for the storage of water.

The ability of the plant to retain moisture results largely from the comparatively small surface exposed to the dry air and the remarkably thick epidermis and dense spine covering of the branches. The small

surface is chiefly a result of the elimination of the leaves as foliage and the contraction of the branches into thick, short stems as shown in Fig. 3. During the growing season the cholla exposes to the atmosphere less

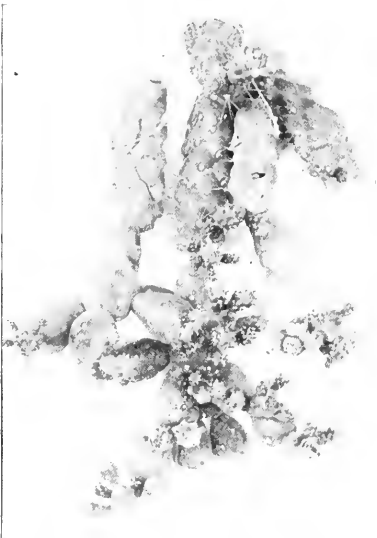


FIG. 3. THE SHORT, THICK, SUCULENT STEMS OF THE CHOLLA BEARING CLUSTERS OF FRUIT AND FLOWERS.

than one fiftieth of the surface which is exposed by the maple of equal weight here in the east.

Aside from this remarkable diminution of surface, the thick epidermis of the plant almost precludes transpiration at times when the water in the storage tissues begins to run low. The following illustrates how well the plant is adapted for conserving the moisture previously stored in its thick stems. I have cut a branch from the tree in the spring prior to the season of blooming, at a time when the storage tissue was well filled with moisture. I have placed these branches in a perfectly dry room out of contact with moisture. I have seen them continue in growth, and

ultimately blossom. I have placed branches of the previous season's growth in open boxes without soil and without access to moisture early in March, and in September have found the branches still succulent and in condition to root and grow when placed in the soil.

Several years ago I removed a large specimen, having a trunk diameter of eleven inches and a height of ten to twelve feet, from the open mesa where it was growing to my garden. The tree was moved in late May when in full bloom. Although the month was hot and dry, the roots were closely pruned and the top left unpruned. The flowers did not wilt as a result of this severe treatment and a full crop of fruit ripened in the fall. This tree, which is illustrated in Fig. 4, suffered no apparent harm in its removal, although probably fifty to one hundred years old.

As a summary it may well be said that the cholla is admirably adapted for absorbing water rapidly, storing large quantities of it, and even when exposed to a very dry atmosphere for a long time retaining it with wonderful tenacity. Provision is also made for undue loss of moisture at times of injury to the epidermis, and the consequent direct exposure of the storage tissue to the dry air. At such times a mucilaginous substance contained in the cells appears on the injured surface, quickly rendering it impervious to moisture.



It is probable that the thick covering of spines is of some value to the plant in protecting it from the full force of the intensely bright sunlight and also of some value in checking transpiration. These ever present and formidable, barbed spines are well illustrated in Fig. 5. They serve their greatest usefulness to the cholla in preventing its destruction by animals and in the important part which they play in the dissemination of the species. All the younger branches of the cholla are soft and succulent and, were it not for their efficient armor

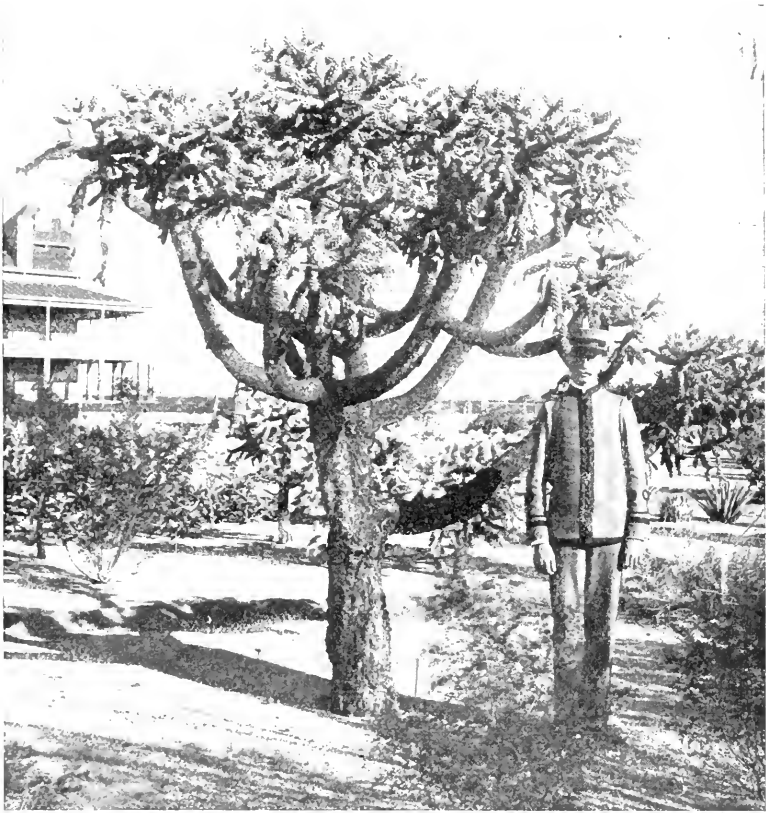


FIG. 4. A LARGE CHOLLA MOVED FROM THE MESA TO THE GARDEN.

of barbed spines, would be quickly destroyed by herbivorous animals. In acquiring a condensed and succulent plant body in order to fit itself to a desert environment the cholla would have courted its own ruin were it not that it acquired a full equipment of spines at the same time. From every standpoint it is, as an individual, admirably equipped for its desert home. It is, however, more than this; it is the best equipped of all desert plants for rapid and wide dissemination. It makes ample provision for its offspring.

The seeds of the cholla, like those of several allied species, rarely if ever germinate on the open mesa. In eight years of observation in its center of distribution I never found a seedling of this plant growing wild. It spreads almost entirely by vegetal dissemination, *i. e.*, by the ends of the branches becoming detached and transported often long distances from the mother plant.

The cholla is perfectly adapted not only for the easy detachment of the ends of the branches, but for their wide dissemination as well. The fruit which hangs from the tree in long, pendulous clusters as illustrated in Fig. 6 is within easy reach of cattle and other large animals.

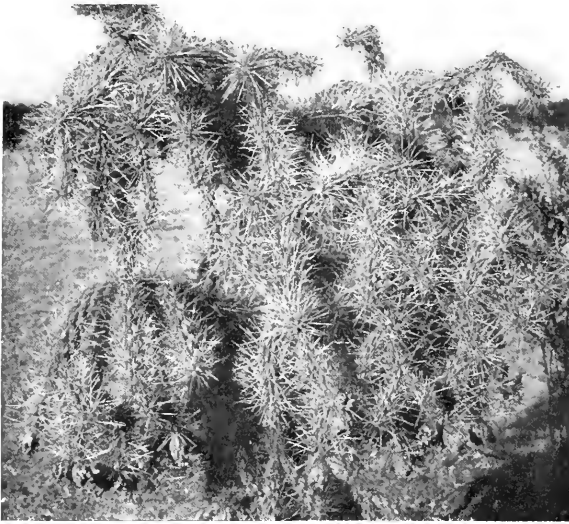


FIG. 5. WERE IT NOT FOR ITS FORMIDABLE ARMOR OF BARBED SPINES THE CHOLLA WOULD SOON BE DESTROYED BY ANIMALS.

These clusters of succulent fruits are without spines and are for the most part sterile. The fruit from the standpoint of seed production is of very little service to the plant in aiding in its perpetuation and dissemination. Its chief service appears to be to entice animals to the plant that the fragile ends of the branches which become detached at the slightest disturbance may adhere to them and become scattered far and wide.

In order that these fruits may best serve their purpose they are succulent, unarmed and as eagerly eaten by animals when green as when ripe. Moreover they often remain on the plant for two or more years if undisturbed. During periods of scanty forage in the region where the cholla grows it is not an uncommon sight to see the range cattle with their heads literally covered with these formidable cactus burs

which became attached to them in their effort to get the fruit. The spine arrangement of these end branches or burs is such that when they finally become detached from the animals transporting them and fall to the ground, the lower end comes in contact with the soil. As the roots start from this end of the branch the necessity for this provision is very evident. It results from the spines being very short or wanting on the lower end of the short, thick branches.

The special adaptation of the fruit to aid in vegetal dissemination is confined, so far as I am aware, to a few species of the *Opuntia* and reaches its highest development in the plant that I have described above.

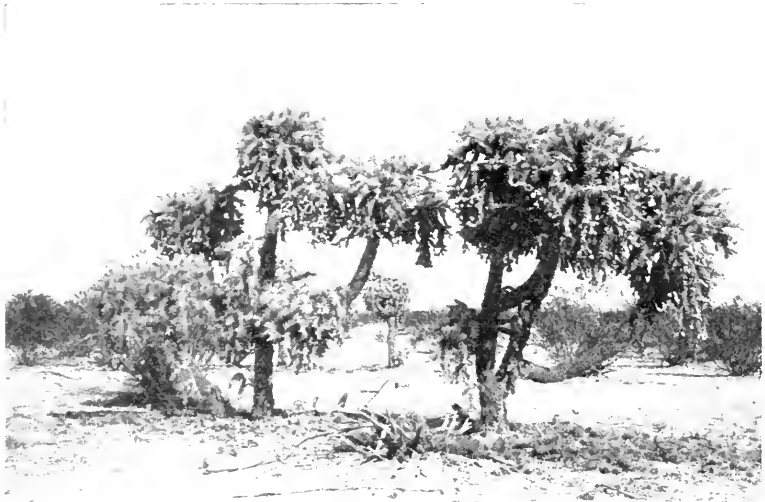


FIG. 6. A GROUP OF CHOLLAS, SHOWING THE LARGE CLUSTERS OF PENDULOUS, SPINELESS FRUIT. PHOTOGRAPHED BY W. T. SWINGLE.

The fruit of the cholla is probably changing from its original seed-bearing condition to a condition of sterility. The abundant clusters of fruit hang from the plant within easy reach of cattle and it is interesting to note that since the advent of stock into the arid southwest the cholla has become more widely distributed and more abundant than ever before. It is as well equipped by nature to care for itself and perpetuate itself on the hot, dry sands of the desert, as is the New England elm of the humid east which bursts into foliage under April showers.

## THE AMERICAN ORIGIN OF AGRICULTURE.

BY O. F. COOK,

U. S. DEPARTMENT OF AGRICULTURE.

AGRICULTURAL science so generally appears as a borrower from physics, chemistry, botany or zoology that it has not been expected to furnish facts of use in other lines of investigation. Thus, although it has been known since the sixteenth century that the same series of food plants extended throughout the tropics of both hemispheres, the significance of this is still unappreciated, and ethnologists are still doubtful regarding prehistoric communication across the Pacific. Stranded Japanese junks, Buddhist missionaries, Alaskan land connection and other possibilities of contact have been gravely and minutely discussed while unequivocal evidence of extensive early intercourse lay only too obviously at hand.

The history of agriculture shows a conservatism probably unequalled in any phase of human activity. Not only has no important food plant been domesticated in historic times, but even in the most enlightened communities changes in the culture and use of the food plants and products to which our physical constitutions and domestic customs have become adapted take place with extreme slowness except as they accompany movements of colonization. Remembering this strict self-limitation of man to traditional food materials, it becomes obvious that the possession of the same seedless plants, such as the yam, sweet potato, taro, sugar-cane and banana by the primitive peoples of the islands of the Pacific, as well as by those of the adjacent shores of Asia and America, indicates, with attendant facts, not only an older communication, but an intimate contact or community of origin of the agricultural civilizations of the lands adjacent to the Pacific and Indian Oceans.

*The Useful Plants of the Pacific Islands.*

Notwithstanding the immense distances by which the tropical islands of the Pacific are separated from the continents and from each other, European discoverers found them already occupied by an adventurous sea-faring people who knew enough astronomy to navigate their frail canoes in these vast expanses of ocean without the assistance of the mariner's compass. The agriculture of the Polynesians was, however, no less wonderful than their seamanship, and was certainly not less important to them, since the coral islands of the Pacific are not

only deficient in indigenous food plants and animals, but the natural conditions are distinctly unfavorable to agriculture.

The whole surface of these flat coral islands is like the clean white-sanded floor of an old English kitchen. The cocoanut tree springs up everywhere, but in the spots where yams and taros are grown the sand is hollowed out, and a pit formed, from one to two hundred yards long, and of varying width, into which decaying cocoanut leaves and refuse are thrown, till a rich soil is formed.\*

It is certain, however, that among the Polynesians the cocoanut is a cultivated plant no less than the yam, taro, sweet-potato, sugar-cane, banana, breadfruit and numerous other species found in use throughout the tropical islands of the Pacific. Moreover an especial interest attaches to the cocoanut in that there are adequate botanical reasons† for believing that it originated in America, the home of all related palms.

The agricultural achievements of the Polynesians become the more impressive when we reflect that so many of their cultivated species were not propagated from seeds, but from cuttings. To survive the long voyages in open canoes, these must have been carefully packed, kept moist with fresh water and protected against the salt spray. In the present state of botanical knowledge the number of species thus introduced and distributed by the Polynesians is necessarily uncertain. Many of the economic plants were native in some of the islands of the Pacific, though their constant presence among the peoples of widely separated archipelagos gives sufficient reason for including them in the list of twenty-four species, which Professor Hillebrand ‡ believes to have been brought to the Hawaiian Islands by the early Polynesians. This number, however, must be greatly increased, since there were many varieties of the sweet potato, taro, sugar-cane and banana. Moreover the Hawaiian group is scarcely more than subtropical in climate, and lacks numerous seedless sorts of the breadfruit, yam, taro and other plants of the equatorial belt of islands, so that a complete enumeration of the species and varieties carried by the Polynesians would include nearly a hundred.

A detailed study of the distribution, names, cultures and uses of these species and varieties of tropical economic plants would yield information of much value from the agricultural standpoint, but of even greater significance is its bearing upon the origins and migrations of

\* Moresby, 'Discoveries and Surveys in New Guinea,' p. 73, London, 1876. The volcanic islands of Polynesia have, of course, rich soil, but they shared the deficiency of native food-plants from which non-agricultural people could have secured a permanent food supply.

† 'The Origin and Distribution of the Cocoa Palm,' Contributions from the U. S. National Herbarium, Vol. VII., No. 2. Washington, 1901.

Bull. No. 95, Office of Experiment Stations, U. S. Dept. Agri., p. 33.

the ancient agricultural peoples of the Tropics.\* At present we have only incomplete and scattered data collected incidentally by missionaries, travelers and professional botanists who did not appreciate their opportunities from the agricultural point of view. But even these miscellaneous facts are often of unexpected interest. Thus, we know that in Central America the use of leguminous shade-trees in cacao plantations was adopted by the Spanish colonists from the natives who furnished even the name 'mother of cacao,' by which the species of *Erythrina* and other leguminous trees are still known in Spanish America. The Indians, of course, were not aware that the roots of the Leguminosæ develop tubercles for the accommodation of bacteria able to fix atmospheric nitrogen; they believed that the 'madre de cacao' supplied water for the roots of the cacao, a fanciful idea still credited by many planters of cacao and coffee. In the Pacific we encounter a similar fact with reference to the yam bean (*Pachyrhizus*), a leguminous vine with a fleshy edible root. The natives of the Tonga Islands no longer cultivate *Pachyrhizus* for food, but they nevertheless encourage its growth in their fallow clearings in the belief that it renders them the sooner capable of yielding large crops of yams. Such anticipations of the results of modern agricultural science are of extreme interest, but it is still uncertain whether similar knowledge exists in other archipelagos of the Pacific, or on the American continent where *Pachyrhizus* probably originated. The botanists report it as 'a common weed in cultivated grounds,' and we learn further that in the absence of better material, the people of Fiji use the fiber for fish-lines, and that the plant sometimes figures in an unexplained manner in their religious ceremonies.

Our knowledge is far from complete regarding even the present distribution of the principal tropical food plants, but the need of further investigation should not obscure the striking fact that several of the food plants with which the Spaniards became acquainted in the West Indies were also staple crops on the islands and shores of the Pacific and Indian Oceans, and even across tropical Africa.

Ethnologists who might have appreciated the bearing of this have passed it by because of the absence of maize or Indian corn among the Polynesians. But in addition to the unreason of accepting negative evidence as an offset for positive fact, two pertinent considerations have been overlooked, first, that most of the varieties of maize do not thrive in the humid climates of the equatorial islands, and, second, that maize was found by Captain Moresby in cultivation with yams, sweet

\* Even the cosmopolitan tropical weeds are worthy of careful study from this standpoint. After excluding aquatic, swamp-land and strand species, Seeman found 64 genuine weeds in Fiji, of which 48 were common to America, while only 16 were held to be Old World species.

potatoes and sugar-cane in eastern New Guinea and the adjacent islands, among Polynesian tribes who had never been visited by Europeans and who were ignorant of salt, iron and rice. Tobacco was also known among many primitive peoples of the Orient before they came in contact with Europeans, though these and many similar facts have remained obscure because the European discoveries of the East and the West Indies were practically simultaneous. Moreover, nearly a century elapsed between the discovery of America and the realization that it was indeed a new world and not merely an eastward prolongation of Asia, so that the community of food plants did not at first appear remarkable.

*The Agriculture of Ancient America.*

The most important food-plants of the Polynesians were seven in number, the taro, yam,\* sweet potato, sugar-cane, banana, breadfruit and cocoanut, of which six, or all except the breadfruit, existed in pre-Spanish America, and of these, five, or all except the cocoanut, were propagated only from cuttings.

From the botanical standpoint the breadfruit is as distinctly Asiatic as the cocoanut is American, but although many seedless varieties of the breadfruit were distributed among the eastern archipelagos of Polynesia, these did not reach America until introduced by Captain Bligh in 1793, while the cocoanut must have crossed the Pacific thousands of years before, in order to give time for the development of the numerous and very distinct varieties cultivated in the Malay region. Except with the banana, botany gives much evidence for and none against the new world origin of the food plants shared by ancient America with Polynesia and the tropics of the old world, though few of them are known under conditions which warrant a belief that they now exist anywhere in a truly wild state. The partial or complete seedlessness attained by several of the important species also indicates dependence upon human assistance in propagation for a very long period of time, and precludes all rational doubt that their wide dissemination was accomplished through the direct agency of primitive man.

Ethnologists will not deny that in the old world this distribution was the work of the ancestors of the Polynesians, who have been traced from Hawaii and Easter Island to Madagascar, and even across the African Continent.† We have not, however, been provided with any explanation of the existence of these food plants in America, for it is

\* Many species of true yams (*Dioscorea*) are cultivated, and the roots of numerous wild species are collected for food in various parts of the Tropics. The present reference is to *D. alata*, the most widely distributed of the domesticated species, and not known in the wild state.

† Frobenius, *Zeitsch. der Gesellsch. für Erdkunde zu Berlin*, Bd. 33, 1898. Report of the Smithsonian Institution for 1898, pp. 637-650.

now generally agreed that the tribes, languages and arts of the American Indians are of truly indigenous development, while it is held, on the other hand, that the Polynesians migrated eastward from Asia, but without reaching the shores of America. That these two suppositions can not both be true is apparent as soon as it is known that there has been a transfer of numerous cultivated plants between Polynesia and America, and other agricultural facts enable us to judge between the inconsistent theories. Since it is reasonable to suppose that the food plants which the Polynesians shared with the tropical peoples of both continents were carried by them across the Pacific, it is also reasonable to seek the origin of these widely distributed species on the continent which gives evidence of the oldest and most extensive agricultural activity, and to the question in this form there can be but one answer. The agriculture of the old world tropics is adequately explainable by the supposition that it was brought by the Polynesians, since the root-crops of the Polynesians were also staples of the old world tropics. This proposition would not apply to America, where, in addition to the sweet potato, yams, yam-bean (*Pachyrhizus*) and taro, which crossed the Pacific, the aborigines also domesticated a long series of root-crops—*Manihot* (cassava), *Maranta* (arrowroot), *Calathea* (Ileren), *Solanum* (Irish potato), *Xanthosoma* (several species), *Oxalis* (Oca), *Canna*, *Tropaeolum*, *Ullucus*, *Arracacia*, *Sechium* and *Helianthus* (artichoke), all of considerable local importance.

The simplest of cultural methods, propagation from cuttings, was applied to all these root-crops\* and has been in use for so long a period that several of them have become seedless. With equal uniformity the distinctively old world root-crops are grown from seed. American root-crops belong to at least twelve natural families, and the only important old world addition to the series is the mustard family, a distinctly temperate group, the cultivated members of which have not been greatly modified in domestication, and are still known in the wild state.

This apparent superfluity of American root-crops is explainable by the fact that different plants were independently domesticated in different localities, which means also that conditions favorable to the development of agriculture were very general among the natives of America. That most of these plants are not known in the wild state testifies also

\* *Sechium* is perhaps an exception, but the more varied and localized names of the root are an indication that this plant was first domesticated as a root-crop. It may also be noted that *Sechium* is peculiarly adapted for teaching the art of planting seeds, since the fruit does not decay, but remains alive and edible long after the contained seed has germinated and sent forth a new vine with its leaves and roots. (See 'The Chayote: A Tropical Vegetable,' Bulletin No. 28, Div. of Botany, U. S. Dept. of Agriculture.)



to the great antiquity of this agricultural tendency, while archeology gives equally vivid testimony to the same antiquity and diversity of the prehistoric civilizations of America. From the mounds of Ohio to the equally remarkable ruins of Patagonia, the American continents and islands are, as it were, dotted with remains of rudimentary civilizations which must have required centuries and millenniums to rise from surrounding savagery, culminate and perish. The constructive arts by which the existence of these vanished peoples is made known took the most diverse forms; some made mounds, some expended their energies upon huge carvings on high inaccessible rocks, some dug devious underground passages, some set up monoliths and carved statues, and some built massive pyramids, temples and tombs, while still others are known only from their pottery or their metal work. In civilization, as in agriculture, the tropics of America stand in striking contrast to those of the old world. Here men of the same race showed great diversity of plants and arts; there races are diverse, while arts and staple food-plants are relatively little varied. The early civilizations of the eastern world resembled some of the primitive cultures of America more than these resembled each other.

The American origin of agriculture is thus not doubtful, since not merely one, but several, agricultures originated in America. The same cannot be claimed for Asia and Africa, where only root-crops shared with America attained a wide distribution, an indication that they reached those continents before the uses of the similar indigenous plants had been discovered.

#### *Poisonous Root-Crops.*

The American habit of eating roots was not a simple and direct transition from the use of fruits, which are commonly supposed to have been the primitive food of man. The more important and the more ancient of the distinctively old world root-crops, onions, leeks, garlic, carrots, radishes and turnips, are eaten, or are at least edible, in the raw state, while in America there seems to be no indication that the natives used any of their root-crops in this way. Some of them, such as the sweet potato, the artichoke and the 'sweet cassava,' can be eaten raw, but throughout the tropics of America the Indians, like the Chinese, prefer everything cooked. This habit must have been adopted very far back to have made possible the obviously ancient domestication of *Manihot* (cassava), *Colocasia* (taro) and *Xanthosoma* (yautia), since the fleshy underground parts of these plants contain substances distinctly deleterious until disintegrated and rendered harmless by heat. The same may have been true of the sweet potato, since the fleshy roots of its uncultivated relatives are strongly purgative. Several of the yams, both wild and cultivated, are also poisonous in the raw state.

A culinary art which remained largely confined to the aborigines of tropical America and to the straight-haired races of the tropics of the old world is the making of starch or meal from roots which have been grated, soaked, washed or boiled with alkalies to destroy their poisonous properties. Separated from the sugars and other readily soluble substances which retain or absorb moisture, the starch of the taro, cassava, arrowroot, canna and other root-crops can be quickly and thoroughly dried, and will then keep indefinitely. In the absence of cereals this simple expedient might well be deemed an epoch-making discovery, since it rendered possible the accumulation of a permanent, readily transportable food supply, and thus protected man from the vicissitudes of the season and the chase. That the resulting economic difference appeared striking to the hunting tribes of Guiana is apparent in the name they gave to their agricultural neighbors, whom they called 'Arawacks' or 'eaters of meal.'

Cassava in the raw state carries a deadly charge of prussic acid and begins to decay in a few hours after being taken from the ground, but properly prepared it furnishes the starch which keeps best, and which in the form of tapioca our civilization is tardily learning to appreciate as a wholesome delicacy. In view of its unpromising qualities when raw, cassava would seem not to have been the first root-crop from which meal was made, and yet it is used by many South American tribes\* who plant nothing else except the so-called peach palm (*Guiljelma*), which gives suggestive evidence of a cultivation much older than that of the date palm, since it is generally seedless, and it is not known in the wild state. The farinaceous fruits are made into meal and baked into cakes in the same manner as the cassava, to which resource is necessary during the months in which the single harvest of palm fruits is exhausted.

Cassava is, indeed, so distinctively the best, as well as the most generously and continuously productive of the tropical root-crops, that it could hardly have been known in the regions in which the others were domesticated. Ever since the Spanish conquest put an end to the isolation of the native peoples of tropical America the use of cassava has been slowly extending at the expense of similar crops; it has also found a footing in the Malay region and other parts of the East, though from present indications it may be thousands of years before its value will be properly appreciated. The slow extension of so desirable a

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\* Some of these tribes are extremely primitive and in the absence of all domestic implements grate their cassava on the exposed spiny roots of another native palm (*Iriarteu exorhiza*). The Arawacks are similarly dependent upon still a third palm (*Mauritia*), from the pith of which they secure starch in a manner strongly suggestive of that used with the sago palm of the Malay region.

plant among the tropical peoples excludes also the suggestion of any recent introduction from Polynesia of the taro or other root-crops which the Pacific peoples shared with the American.

Indeed, it is not unreasonable to believe that the taro, like the closely similar aroids of the genus *Xanthosoma*, was domesticated somewhere about the shores of the Caribbean Sea, where it has a large variety of native names in contrast to the single designation applied to it by the Polynesians. In Porto Rico, where the highest aboriginal culture of the West Indies was attained,\* four aroids had the same generic name, *yautia*, which was adopted by the Spanish settlers. Strangely enough it is only with the taro, *yautia malanga*, that the native specific term has been preserved, three species of *Xanthosoma* having now only Spanish adjectives, *yautia blanca*, *yautia amarilla* and *yautia palma*. Botanists have never expressed a doubt that the species of *Xanthosoma*, some of which are known only in cultivation, originated in the West Indies and the adjacent parts of South America, and as these seem to be preferred to the taro, we must either look upon the latter as also indigenous in the West Indies or explain its presence by a movement from the mainland analogous to that which could have carried the same taro and numerous other American plants into the Pacific. Taro seems to have been the only cultivated aroid of the region of Panama whence some ethnologists have derived the sea-faring cannibals, the Caribs. To believe that the taro furnished the suggestion for the utilization of the *Xanthosomas* and also for that of *Alocasia*, *Amorphophallus*, *Cyrtosperma* and other aroids indigenous to the East Indies, seems far less irrational than to suppose that the strange habit of eating these painfully unpalatable plants originated independently in numerous primitive communities.

#### *From Root-Crops to Cereals.*

While it is, of course, not certain that the preparation of the starchy root-crops constituted the first regular application of fire to vegetable food, it is apparent that meal-eaters would be in a much better position than fruit-eaters or meat-eaters to attack the final problem of primitive agriculture, the use of cereals. Without the winter protection which primitive man could not supply, the culture of cassava and other trop-

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\* Botanists have found that the native names of plants are more numerous and are used with more precision in Porto Rico than elsewhere in the West Indies. The common opinion that the aborigines of this island were exterminated by the Spaniards is evidently quite erroneous. In the mountainous interior district there are thousands of people who have no negro admixture and who are accordingly enumerated in the census as whites, but who are Spaniards only in language and in the wearing of cotton prints. Their agriculture, architecture and domestic economy show little foreign influence, and there is no reason for believing that these natives differ seriously from their pre-Columbian ancestors.

ical root-crops is confined to strictly tropical climates, so that increase of latitude and altitude would bring to starch-eating peoples the necessity of a change of food plants. Indeed, altitude seems to have played a larger part than latitude in this transformation which brought about the adoption by primitive American peoples of Indian corn, 'Irish' potato, arracacha, oca and other crops of the temperate plateaus of South America. Without reasonable doubt, maize is the oldest of cereals, and the large soft kernels which distinguish it from all other food-grasses are exactly the character which would render it easily available to the meal-eating aborigines of America, though it is not to be supposed that the wild progenitor of the Indian corn had any very close similarity to our cultivated plant. Moreover, everywhere in tropical America maize is still prepared by methods adapted to root-crops instead of as a cereal. The rough stone slab (metate) against which they had rubbed their cassava or other starch-producing roots was well suited to making paste from maize, softened by soaking in water with lime or ashes, and throughout tropical America it has remained in use to the present day. Among the tribes of the arid temperate regions where the tropical root-crops were excluded the metate was deepened into the mortar in which seeds too small to be collected or handled singly are also bruised into meal.

It is also not impossible that maize was the first plant to be grown by man from seed, a cultural method permitting much easier and more rapid distribution than had been practicable with the root-crops grown from cuttings and tubers. Like other species cultivated in the highlands of tropical America most varieties of maize do not thrive in moist equatorial regions of low elevations, so that it did not seriously supplant the root-crops, though having a far wider distribution than any other plant cultivated by the aborigines in pre-Spanish America. Nor did the utilization of maize mark the limit of cereal cultures in America, though no other small foodseed of the new world compares in popularity with rice, wheat, barley, rye and oats. Even in Mexico, the supposed home of maize, the seeds of *Amaranthus* and *Salvia* (Chia) attained considerable economic importance. In addition to their use as food the latter were made to furnish a demulcent drink and an edible oil valued as an unguent and in applying pigments, a series of functions closely parallel to those of sesame, perhaps the most ancient of old world herbaceous seed-crops. Wild seeds of many kinds were collected by the Indians of the United States and Mexico, including wild rice (*Zizania*) and *Uniola*, another rice-like, aquatic grass of the shallow shore-water of the Gulf of California. In Chili there existed also several incipient cultures of small-seeded plants, such as *Madia*, while the people of the bleak plateaus of Peru and Bolivia had developed a unique

cereal crop from a pigweed (*Chenopodium quinoa*), another of many evidences of a very general tendency to agricultural civilization in ancient America.

As long recognized by historians and ethnologists, maize was the most important factor in the material progress of ancient America, and the American civilizations remained on a much more strictly agricultural basis than those of the old world, a fact not without practical significance to modern agriculture since it undoubtedly conduced to the more careful selection and improvement of the many valuable plants which we owe to the ancient peoples of America. Subordinate only to maize from the agricultural standpoint was the domestication of the beans, while the materials for a developed culinary art and a varied and wholesome diet were furnished by a variety of minor products like the Cayenne pepper, the tomato, the tree tomato (*Cyphomandra*), the pineapple, several species of the strawberry tomato (*Physalis*), the paw-paw (*Carica*), the granadilla (*Passiflora quadrangularis*), the gourd, the squash and the peanut. American fruit trees, such as the custard apple and related species of *Anona*, the alligator pear (*Persea*), the sapodilla, *Mammeas* and *Lucumas* afford refreshing acids, beverages, relishes or salads, but do not furnish substantial food like the banana. Contrary to the opinion of De Candolle there is every probability that the banana reached America from the west long before the arrival of the Spaniards, but it evidently did not come until after the agriculture and cultivated plants of America had spread into the Pacific.

#### *No Pastoral Period.*

The agricultural history of the Malays, Chinese, Japanese, and other Mongoloid peoples of the western shores of the Pacific, is exactly that of the American races, and differs fundamentally from that of the peoples of western Asia and the Mediterranean region in giving no indications of a primitive pastoral stage which so many writers have taken to be man's first step from savagery toward civilization. The straight-haired peoples made, however, early and vigorous use of a large number of Asiatic plants and showed skill in agriculture and irrigation equaled in prehistoric times only along the western coasts of America, among the congeries of primitive civilizations commonly not distinguished from the terminal members of the series, the Peruvians and Mexicans.

That the Aztec and Inca empires were comparatively recent organizations has caused many ethnological writers to forget that they incorporated much more ancient culture. For centuries still unnumbered the Andean region of South America supported crowded populations. On the western slopes of Peru every inch of irrigable land was cultivated,

houses and towns being relegated to waste places. The temperate food plants of Peru and China are all apparently indigenous to their respective continents. They testify to the independent development of the temperate agricultures of the two regions, but it seems certain that both were the successors of more tropical starch-eating populations, parts of which had been crowded back to the relatively inhospitable plateaus of Peru and Bolivia, and to the bleak plains of northern China, where the primitive tropical root-crops were, of necessity, replaced by more hardy indigenous species. The Chibcha people of the interior of Colombia attained a considerable degree of advancement without adopting a single domestic animal. The Peruvians and Chinese learned to use beasts of burden and animal fibers and skins, but their pastoral efforts were merely incidental to agriculture; they remained essentially vegetarians, eating little meat, and never taking up the use of milk.

#### *The Domestication of the Banana.*

In further support of the suggestion that the use of the starch-producing root-crops is a distinctively American development of primitive agriculture is the fact that the tropics of the old world contributed no important cultivated plant of this class, and none which gives evidence of long domestication. On the other hand, such regions as Madagascar and East Africa, where Polynesians are now supposed by ethnologists to have settled in 'remote prehistoric times,' continued the culture and differentiation of the varieties of the taro and the sweet potato, and were agriculturally mere outposts of the American tropics.

The presence of the banana might be thought to explain the relatively small importance of root-crops in the old world, since it furnishes with far less effort of cultivation and preparation a highly nutritious and palatable food. It appears, however, that the use of root-crops must have preceded the domestication of the banana, for although the seed-bearing wild bananas are utterly worthless as fruits and hence would not have been domesticated as such, nevertheless more species of them than of any other genus of food plants were brought into cultivation. The clue to this paradox is afforded by the fact that bananas are still cultivated as root crops in the old world tropics, particularly in New Caledonia and Abyssinia.\*

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\* The suggestion that the primitive culture race which domesticated the banana came from America also receives definite support from the fact that an American plant (*Heliconia bihai*), somewhat similar to the banana but without an edible fruit, reached the islands of the Pacific in prehistoric times. Though no longer cultivated by the Polynesians, it has become established in the mountains of Samoa and in many of the more western archipelagos. In New Caledonia the tough leaves are still woven into hats, but the *Pandanus*, native in the Malay region, affords a better material for general purposes and has dis-

That the varieties used for this purpose are as old or older than those grown for fruit is indicated by the fact that, like the sweet potato, taro and sugar-cane, they seldom produce flowers. Furthermore, among all savage tribes the varieties valued by civilized peoples as fruits are relatively little used, far greater popularity being enjoyed by the so-called 'plantains,' not edible in the raw state, even when ripe, though nearly always cooked and eaten while still immature, or before the starch has changed to sugar. They are also in many countries dried and made into a meal or flour often compared to arrowroot.

In dietary and culinary senses the breadfruit also is as much a vegetable as the taro or the sweet potato; as a fruit it would be no more likely to be domesticated than its distant relative the Osage orange. The farinaceous character of the breadfruit also probably explains its relatively greater importance among the Polynesians than in its original Malayan home, as shown by the propagation of numerous seedless varieties. The popularity of the breadfruit among the Polynesians was further extended by the discovery that the fruits could be stored in covered pits, the prototypes of the modern silo.

If the domestication of the banana is to be ascribed to cultivators of root-crops, the same reasoning applies with even greater propriety to cereals. Tribes accustomed to subsist upon mangoes, dates, figs or similar fruits which require no grating, grinding or cooking, and are eaten alone and not with meat, would not develop the food habits and culinary arts necessary to equip primitive man for utilizing the cereals.

Wild bananas and their botanical relatives are natives of the rocky slopes of mountainous regions of the moist tropics where shrubs and trees prevent the growth of ordinary herbaceous vegetation. The commencement of the culture of cereals by fruit-eating natives of such forest-covered regions is obviously improbable, but such an undertaking would be a comparatively easy transition for the meal-eating cultivators of root-crops, since the grasses and other plants domesticated for their seeds are exactly those which flourish in cleared ground and are prompt to take advantage of the cultural efforts intended for other crops. Thus, the Japanese have by selection secured a useful cereal from the common barnyard-grass (*Panicum crus-galli*) just as they have made a root-crop of the burdock. Accordingly, we should look to some taro-growing tribe of southeastern Asia as the probable domesticators of rice, and to other cultivators of root-crops for similar services in taking up the somewhat less tropical cereals, sesame and Guinea corn. That root-crops preceded cereals in America was inferred above partly from the

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placed *Heliconia* in cultivation among the Polynesians. In the time of Oviedo the natives of the West Indies made hats, mats, baskets and thatch from the leaves of *Heliconia*, and the starchy rootstocks were eaten.

fact that root-crops were not there grown from seeds; and there is a corresponding indication that the knowledge of cereals preceded the domestication of the seed-grown temperate root-crops of the old world, since none of these is anywhere dried, made into starch, or otherwise prepared for storage as the basis of a permanent food-supply of primitive tribes.

That the fruit-eating aborigines of the old world were not equipped for undertaking the use of cereals is further shown by the fact that those who left the moist tropics for the subtropical and temperate regions of Western Asia, North Africa and Europe did not resort, as in America, to the culture of more hardy root crops and cereals, but became pastoral nomads, dependent upon the milk and flesh of their herds, supplemented by such honey, wild fruits and other edible plants as they might encounter in searching for pasture. Dates, figs and other fruit trees might receive some attention from such wanderers, but the more successful they might become as shepherds the less likely they would be to take up the planting of cereals or of other herbaceous crops, which in the absence of fences would be appropriated by their animals before the owners could make even an initial experiment. It is accordingly significant that the origin of the agricultures and civilizations of the valleys of the Nile and Euphrates is no longer sought by ethnologists with Semitic shepherds or more northern peoples, but with a seafaring race which has been traced to southern Arabia, and whose language has been found to have analogies with the ancient Polynesian tongue of Madagascar.

#### *Summary.*

With the exception of the banana, the cultivated plants which were shared with America by the natives of the islands of the Pacific and of the old world tropics appear to be of American origin, and the wide distribution of these plants in the east and the relatively recent domestication of the old world root crops and cereals accord with the suggestion that the agricultural skill and compact social organization of a primitive American culture race were transferred to southern Asia during the movements of conquest and colonization which spread the Malayo-Polynesian linguistic stock from Hawaii and Easter Island to Madagascar and southern Arabia, but long anterior to existing peoples or languages. The cocoanut which affords so direct an intimation of American origin has already explained the failure of those who have attempted to demonstrate identity of languages, customs and arts on the two sides of the Pacific, but also condemns the equally erroneous attitude of others who refuse, in the absence of such identity, to accept the countless trans-Pacific similarities as indications of affinity or common origin.



The distribution and uses of the tropical cultivated plants support the belief of ethnologists in the truly indigenous character of the peoples, agricultures and civilizations of the new world, but they also testify to a very early colonization of the islands of the Pacific and Indian oceans from tropical America. The comparative deficiency of the western continent in fruits and animals suitable for food was compensated by numerous starchy root-crops. The primitive culture peoples of the tropical regions of ancient America were accustomed to the cooking, grinding, and storing of vegetable food, and were thus prepared to appreciate and utilize the cereals by agricultural experience lacking among the fruit-eating aborigines of the old world, who developed instead the arts of the chase, the domestication of animals, and the use of milk. But fruit, meat and milk do not complete the agricultural series, and do not include its essential members, since civilizations have nowhere developed without the assistance of the farinaceous root-crops and cereals, the use and cultivation of which are habits acquired by primitive man in America and carried in remote times westward across the Pacific, together with the social organization and constructive arts which appear only in settled communities supported by the tillage of the soil.

By means of agricultural facts it is possible thus to choose between the rival theories of the ethnologists, and in addition to gain a suggestion of the history of agriculture among primitive peoples. If we may not know where man first began to encourage the growth of the plants which furnished his food, we are not without numerous indications that agriculture proper, together with the agricultural organization of human society which lay behind modern civilization, originated in America and has now completed the circuit of the globe.

## MENTAL AND MORAL HEREDITY IN ROYALTY. III.

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*Evidence from the Romanhofs in Russia Down to Peter III.*

From Feodor Romanhof (1550-1633), to Peter III. (1728-62), includes six generations and twenty-one persons in the direct family. These twenty-one show the most remarkable variation in character and abilities.

The first one to be considered, Feodor, was the greatest man in Russia in his day, and it was owing to *his* abilities and virtues that his son, Michael, was placed on the throne. Michael was prudent, mild and virtuous, married a peasant woman of the same character and was the father of Alexis, who in his time was very much like his parents. Alexis married twice, both queens being beautiful peasant girls. The czars at this time chose their wives from a large number of their subjects. All the charming peasant girls were brought to the court for their sovereign's inspection, the most beautiful being chosen and made legal queen.

From both of these unions came epileptic children. It seems impossible to trace the origin of this famous neurosis in the Romanhofs since it probably arose in the obscure stock back of Alexis. From Alexis' first marriage were produced Feodor, imbecile; Sophia, extraordinary force of will, ambition and high abilities; and Ivan, imbecile and epileptic. From the second marriage came Peter the Great, extraordinary will and capacity, but violent and epileptic; and several other children in no way remarkable. The genius of Peter the Great and Sophia may have been a reversion to Feodor, their great-grandparent, or it may have been a manifestation of the neurosis as Lombroso would say. On account of the very same ability already in the family as well as the evident neurosis, it does not seem necessary to consider them evidences of the insanity of genius, since the genius may have struck them from one source and the insanity from another. Those who consider the tyranny of the Russian czars a result of absolutism of the rulers should remember that just prior to the appearance of the neurosis there were four sovereigns who were in every way wise, mild and virtuous. Also the 'Age of Absolutism' in Denmark produced mild and good-natured rulers.

Now from this time on we find among the remaining eighteen who appear in the next three generations, six who have extremely bad char-

acters; three of these are children, two are grandchildren and one is a great-grandchild of Peter the Great. Thus in this arrangement we see the principle of heredity which calls for a closer resemblance among those more closely related in kin.

Of Ivan's children, Catharine was as good as the Empress Anne was inconsistent, vindictive, cruel, passionate and sentimental. Catharine married average stock, but her daughter, Anne, was passionate, indolent, capricious and weak. Anne married the excellent but mediocre Anton Ulric, of Brunswick, which family we have already seen to be full of virtue and literary tastes, so that the next generation brings one parent and three grandparents free from the taint.

We now get just what we might expect, in spite of the fact that the five children were all taken when infants and for political reasons imprisoned for thirty-six years. Ivan the eldest was almost an imbecile and showed occasional symptoms of insanity.\* This imbecility might be attributed to the imprisonment, which was extremely severe, but the other four children help us out. The following is taken from Coxe, a very accurate historian:

Elizabeth, the youngest sister, was a woman of high spirit and elegant manners. On being released she wrote a letter of thanks to the empress so well expressed as to excite admiration how she could have obtained sufficient instruction during her long confinement.

The other children were mediocre and in no way peculiar. "They amuse themselves with reading, playing billiards and cards, riding and walking. They walk much about the town and in the environs, and drive out in carriages; the princes frequently ride and particularly Alexis, who is very fond of that exercise, and said to be an expert. They not infrequently pay visits in the country and dine with the neighboring families."†

Thus among five children exposed to a very unusual environment from infancy we find a result showing little influence other than should be expected from heredity. Three were mediocre representing the majority of the strain, one was an imbecile, corresponding to the combined influence of his mother and great-grandfather, Ivan, and one was spirited and cultivated in spite of it all, and rose very nearly as high as any of the immediate ancestors. Of course such remarkable circumstances must have modified the characters of the four normal ones, at least to some noteworthy extent, such as raising one of the sons above the absolute mediocrity in which we find them; but I do contend that even these deviate very little from what is to be expected from the principles of heredity as we usually expect them to act.

Alexis, Peter the Great's son by his first wife, Eudoria Lapookin, was a very poor specimen.

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\* Coxe, 'Travels,' III., p. 51.

† Coxe, 'Travels,' V., p. 19.

Never was the birth of any prince more unfortunate to himself, to his parents and to his country. All persons however join in condemning the imprudence and obstinacy of Alexis which seems to have warped his judgment and at times to have transported him to a degree of insanity. Alexis was extremely dissolute and preferred the company of the lower classes. When twenty-six, worn out by continual drunkenness, he demanded permission to retire to a convent, but changed his mind and escaped to Vienna.

He was retaken and tried. He died soon after, probably murdered by his father's orders, though some historians contend he died, as Peter claimed he did, by an apoplectic fit.

By Peter's second marriage with Catharine he had two daughters, Elizabeth and Anne. They were as different as possible. Elizabeth, the notorious empress, was very inconsistent, being indolent, dissolute, cruel and pious.\* Anne, on the contrary, was serious-minded, cultivated and virtuous.† The latter married Charles Frederick, Duke of Holstein, an inferior sort of man of undistinguished parentage, and the only son, Peter III., was as bad as the worst of them, being weak, dissolute, violent and headstrong. Alexis, the imbecile son of Peter the Great, married Charlotte, an 'angelic' daughter of the good House of Brunswick already referred to, and by this marriage we see two children, one good and one bad. Natalia, the daughter, was sweet tempered, remarkably bright and energetic, while Peter, the son, who became Peter II., in spite of the best education, gave up all study and political work and confined himself to hunting and shooting. He had a 'somewhat unstable mind,' but his character showed none of the cruelty and degeneracy of some of the others of the family. Peter III. married Catherine of Anhalt-Zerbst, who became the notorious empress Catherine II. As we do not know who was the father of Paul, owing to the licentiousness of Catherine, the remaining division of the so-called Romanhofs down to the present day had best be studied as another group.

The great variation in the characters of the early Romanhofs is better explained by the presence of the neurosis than by any other cause, since this has been shown to account for it.

If we consider the rudeness of the times to be the cause we can not see just why the first three of the Czars, Feodor, Michel and Alexis, were so prudent, mild and virtuous, or why the subsequent neurosis appears more frequently in those closely related to the height of its manifestation in the generation of Peter the Great. In modern Spain a condition similar from the heredity standpoint can be studied under several different environments in no way like that of early Russia, yet the variation in character in the royalty of modern Spain is quite

\* Lippincott and Coxe, 'Travels,' II., pp. 302-306.

† Bruce's 'Memoirs,' pp. 100-197.

as remarkable as that just considered. In Spain it is related to an inherited mental unbalance in just the same way as in Russia.

*Evidence from the House of Montmorency.*

Since the family of Nassau Orange perpetuated itself by aid of the House of Coligny and since the Collignys, Condés and Montmorencys intermarried freely, these three families may be considered next and treated as one group under the three separate headings.

The pages of Betham's 'Genealogy of the Sovereigns of the World' (London, 1795) contain from Eberhard Montmorency contemporary with Hugh Capet to Anne, Duke of Montmorency, the great Constable of France (1493-1567), 107 names covering a period of eighteen generations. During the later sixteen of these generations, the family held exceedingly high social position and were lords of Montmorency, Laval, Montfort, etc. There were among this 107 a considerable number of persons of local influence, constables and marshals of France, but the names of two alone of this large number, the product of eighteen generations, have come down to us as distinguished historical characters.

These are Mathew I., Constable, died in 1151, and Mathew II., called 'The Great,' died 1230. They were grandfather and grandson. The next great Montmorency was Anne, Constable of France (1493-1567) (8). "He was a brave but ferocious warrior, was totally illiterate, and yet through his natural talent and the experience of a long life, he was an able statesman and counsellor." None of the immediate ancestry of Anne appears to have been famous, as the two Mathews are many generations back; therefore the inherited talents of Anne must be considered a new variation.

Now comes another little region of great names: Anne's second son, Henry I., Duke of Montmorency, was a distinguished legislator (8), being the only one of seven mature children to reach high fame; the general average of the fraternity shows the reversion to the mean.

Henry II., the representative of the next generation, was rather more distinguished than his father. He was the only son to reach maturity. His sister, Charlotte, who married Henry II., Prince of Condé, and was the mother of the Great Condé, has remained famous all these years, but rather for her extreme beauty and strength of character than for purely intellectual qualities. There were two other sisters not distinguished. Henry left no children, so the male line ends here.

Not only is this house, as is well known, an instance of heredity, but its closer analysis strengthens this view even more, and the six most famous ones fall in two little groups far removed from each other; and comparing the percentages of geniuses with the sizes of

the family, we see that it does not prove too much. The first eighteen generations show a perfectly natural result from the influences of heredity. The last three generations giving four big names among eighteen are also in line with the expected, since both Anne and his most distinguished son, Henry, had large families, these great ones being a select few out of many. It will be seen later that the great descendants of the Montmorencys, who bore the name of Condé, traced their lineage from the great names among the Montmorencys, not from the mediocre.

*Condé.*

This high wave of Montmorency had probably a great deal to do with making the name of Condé so well known, since its greatest personages were the children of both families. The male line of Condé is traced through the lines of Marche and Vendome back to Robert, Count of Clermont, Lord of Bourbon (died 1317) and son of Louis IX., prince of France. From Robert to Louis I. Prince of Condé (died 1569), includes in the direct line forty-four adult names, covers a period of two and a half centuries and includes nine generations. During the first of these generations not a single one, as Count of Vendome, Duke of Bourbon, or the possessor of any other high title ever distinguish himself sufficiently to be even mentioned by 'Lippincott's Dictionary.' During all this time one also notices no illustrious name on the maternal side, so this is all to be expected.

Now in the ninth generation appears Louis, the first distinguished Condé, the eighth of ten mature brothers and sisters. His oldest brother, Anthony de Bourbon, King of Navarre, is famous, but ranks far from the great. He was a weak and irresolute prince, who died in 1562 'detested by the protestants whom he had deserted and little regretted by the catholics.'\* The second brother, Charles, was one of the chiefs of the catholic league and receives a few lines in 'Lippincott.' The other children were not heard from.

It does not appear clear where Louis's talents arose since none of his immediate ancestors were remarkable, nor was his marriage calculated to perpetuate any greatness he might have inherited, since his wife, Eleonora, was a daughter of Charles, Count of Ponce, a family of no distinction. He had three sons, one of whom was Henry I., Prince of Condé. He was 'liberal, gracious and eloquent and promised to be as great a captain as his father.'† Only two of the eight other children reached maturity. These two held high titles and presumably had equal opportunities, but left no great names behind them. Now supposing Henry I. to have inherited all the talents of his father, and

\* Rose, 'Biographical Dictionary.'

† Brantome, 'Vies des hommes illustres.'

that he was the only one to so inherit them, the next generation would have just as much chance to receive the birthright of the Condé's as his own generation had. There were but two children, and it is not asking too much from heredity if we believe that one of these two again shows the family strength by the same cause, since a father, grandfather and great grandfather are worth about 33 per cent., and we add to this one distinguished ancestor on the maternal side, since the mother of the children of the next generation was a granddaughter of Anne, the great Constable Montmorency, referred to above as the beginning of the second celebrity of the Montmorency family. This one to follow in the footsteps of his father was Henry II. of Condé, whose record, however, was not so illustrious as that of some of those who had gone before.

We now come to one of the greatest 'fraternities' in point of average to be found in all modern royalty, at least among those fraternities that contain as many as three children. Here we find two out of three in about the highest intellectual rank. Louis II., the 'Great Condé' and his sister Anne, Duchess de Longeville, certainly belong in 10. The third was Armand, Prince of Condé, famous but not praised either for character or intellect.\* Can we account for these strictly by heredity? If these three children had arrived without any other influence than the House of Condé, it would be evidence against heredity, since before the fourth generation reversion to the mean would be called for; but it certainly is significant to note that this most brilliant fraternity of all is also backed by about the most brilliant pedigree of all royalty since Henry II. of Condé married Charlotte, daughter of Henry I. of Montmorency. She was noted for her beauty, strength of character and fascinating qualities. Henry I. was the center of the Montmorency genius. Thus the greatest of the Condés occur where we should most expect them, just at the junction of the two great streams.

The subsequent history of Condé is one of decline. Is there any infusion of bad blood sufficient to account for it aside from the external circumstances in which they lived? Louis II., the Great Condé, married Clemence, a daughter of Urban de Maillé de Brézé and a niece of Cardinal Richelieu. Maillé de Brézé was marshal of France, so it might seem at first sight as if this would be a case where we might expect a perpetuation of genius. But in looking more carefully we get the following idea of the character of the marshal, which throws no optimistic light on the rest of the members of the family. Maillé de Brézé was made Marshal of France in 1632, and left his command in Holland in anger saying that he *n'était point bête du compagne*. In 1636 he was given the government of Anjou, where he showed himself '*bizarre* and tyrannical.' He gave but little proof of military talent.

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\* 'Encyclopædia Britannica.'

Lenet said that he was under the possession of a woman (la Dervois), the widow of one of his valets, ugly but of quick and forceful mind, who governed his entire fortunes up to the last breath of his life. Cardinal de Retz pictured him as extravagant, but sufficiently to the taste of the king for him to permit the marshals' tirades against the greatest personages of the court. So much for the father; the mother, Nicole, was insane, and the daughter, Clementia, was woman '*energetique vaillante et même cruelle*.\*'

The Great Condé had but one child. If he had been the father of several, we might expect some to have been very brilliant and perhaps escape the taint. This one son was Henri Jules. Eight lines are devoted to him in 'Lippincott's' and read as follows:

Condé de Henri (Jules de Bourbon), Prince, the only son of the Great Condé, was born in 1643. He distinguished himself at the siege of Tournay in 1665, and in 1674 took part in the battle of Seneffe, where he is said to have saved his father's life. Saint-Simon gives a just but most favorable view of his character. Towards the end of his life he became insane and fancied himself a dead man. Died in 1709.

Brilliance, bad character and congenital insanity was then united with mediocrity, since the mother of the next generation was from an undistinguished branch of the Palatine House and mother's family, Nevers, is also 'obscure' at this point.

Of the four adult children of Henri Jules, Anne Louisa, Duchess of Maine, alone has left a fame that has come down to us.

She had more than an ordinary share of the pride of birth by which that branch of the Bourbons was distinguished. She was highly educated and a great patroness of literature and art. Most of her life was spent in her beautiful mansion at Seaux, surrounded by men most eminent for genius and learning. It was she who first patronized the muse of Voltaire.†

The intellectual qualities being the interesting thing to trace in the family of Condé, nothing further need be said save that the remaining nine showed no marked genius. The five in the next generation exhibited two instances of *extreme cruelty*. These were Louis IV., Prince of Condé, and his brother Charles, Count de Charlais.

Bad as the Duke de Bourbon was his brother the Count de Charlais was infinitely worse. He excited public execration by acts of such ferocious atrocity that they seem to belong to the worst tyrants of antiquity. Like all the nobles who had been educated under the regency he had abandoned himself to the wildest and most profligate debauchery which however did not satisfy him unless it was accompanied by the most savage cruelty. He murdered one of his servants whose wife, fondly attached to her husband, refused to receive his addresses. He fired at the slaters employed on the tops of houses and when he brought down one of his human game he hastened to gratify himself by watching his last agonies.‡

\* Jacobi, 'Selection chez les aristocrates,' p. 414.

† Taylor, 'Mémoires Orléans,' I., p. 211.

‡ Taylor, 'Mémoires Orléans,' I., p. 383.



We notice that the writer refers to his having been educated like the other youths of the day in the debauching school of the regency, but does not make mention of the fact that he was a grandson of the mad Henri Jules.

The remaining generations had but one, two, and one children respectively. Since Louis IV., Prince of Condé, was of little account, and the remaining pedigrees contain Hesse, Rheinfels, Soubises and Orleans without bringing in intellectual distinction, as far as I know, there appears to be nothing against heredity in the closing chapter of the house. In fact the neurosis appears to have been eliminated through the principle of regression, and we find the last members of the house rather fine heroic types, though not like their Condé ancestors, capable of grappling with difficult conditions. The last of the line, Louis Anthony Henri, Duke d' Enghien, was executed in March, 1804, an act that is commonly regarded as one of the worst stains on the character of Napoleon.

THE COMPETITION OF THE UNITED STATES WITH  
THE UNITED KINGDOM.BY JOHN WADDELL, D.Sc., Ph.D.,  
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IN the *Allgemeine Zeitung* of Munich, Dr. Alex. von Peez says, 'Slowly has England grown commercially, more rapidly has Germany risen after gaining political unity and establishing the protective system, but like a storm is the forward movement of the United States.'

In the ten years before 1897 the exports of manufactured articles averaged \$163,000,000 annually; in 1898 the value was, according to the statistical abstract, \$290,697,354; in 1899 it was \$339,592,146, and in 1900 \$433,851,756. This, be it noted, is the value of the *manufactured* articles, and does not include grain and agricultural products. The total sales of the United States to foreign countries amounted in 1900 to the tremendous total of nearly \$1,500,000,000. In 1901 the exports in manufactures had decreased a little, being only \$412,155,066, or about five per cent. less than in the preceding year; but this decrease is due apparently to a depressed state of trade in Europe during the last year—the general exports from Britain were also less in 1901 than in 1900.

The immense growth in the export of manufactures during late years is partly due perhaps to greater prosperity throughout the world, but since other nations, England, Germany and France, are not increasing to anything like the same amount, American competition is evidently becoming more prominent and distinct. The United States has a far greater share of the world's trade than she had ten years ago.

America's competition with the world is not confined to exports; the competition is also within her own borders and does not show in international trade. The United States now manufactures for her own consumption many things that formerly she imported from abroad. In many departments she has hitherto just been able to keep up with her own growth in consumption, having little left over for export. But in these departments she now threatens to invade the world.

Coal is an essential for a manufacturing nation. In 1896 the United States produced one hundred and sixty-seven million tons of coal, in 1900 she produced two hundred and sixty-eight millions. In that time the importation of coal increased nearly half a million tons, but the export increased four million tons. The total export of bituminous

and anthracite coal is now almost eight million tons, and, though this is small as compared with the home consumption, yet the export is likely to increase more rapidly, and a leading ironmaster in Germany predicts that in ten or fifteen years America will supply all the Mediterranean coast with coal and iron. He says that cheap production and transport will be the chief factors and will more than counterbalance the nearness of Britain. A few years ago Britain led as a coal producer, but now the United Kingdom is surpassed by the United States. In 1900 Britain produced two hundred and twenty-five million tons of coal, in 1901 she produced two hundred and nineteen million tons only. This difference of six million tons is almost exactly equal to the excess of exports over imports of coal in the United States.

An industry of very rapid growth in the United States is that of cement. There are two large and important classes of cements, called natural cement and Portland cement. In the United States natural cements are still produced in greatest amount, but the growth in output of Portland cement has been very rapid, and Portland cement bids fair soon to surpass natural cement in quantity. Not many years ago nearly all the Portland cement was brought from England, American Portland cement being considered inferior; but now by the introduction of rotary kilns and other improvements it is claimed that American Portland cement is made at least equal to and probably better than English cement.

The production of natural and Portland cement was in 1896, 9,510,355 barrels; in 1900 it was 20,486,274 barrels. This tremendous growth is due to the greatly extended use of cement in buildings and pavements and in structural works of many kinds in which stone was formerly used. This growth in consumption has not been accompanied by a growth in importation. On the contrary, the imports have declined to a slight extent, being in 1896 3,558,166 barrels, and in 1900 3,182,245 barrels. The export is small, but there is an increase from 87,910 barrels in 1896 to 186,586 barrels in 1900. This means that the cement factories have been able to keep up with the growth in the demand at home and have had a slight surplus.

The soda industry is one of the most important chemical industries, and in it England was for a long time supreme and America imported largely from her. Now, however, the importation is small, America providing her own soda to a great extent. In 1896 the soda imported was 86,991 tons, in 1900 it was 33,482. Common salt is the starting point for the manufacture of soda, and it is used for many other purposes as well. The world's consumption of salt has grown during the last twenty years, but Britain's output has fallen off. This appears to be largely due to American competition. In 1880 the United Kingdom produced nearly 2,700,000 tons of salt and the United States 800,000

tons. In 1889 the United Kingdom produced 1,950,000 tons and the United States 2,400,000 tons, which amount was increased in 1900 to 2,650,000 tons, so that now the United States occupies the position held by Britain in 1880.

The growth of the iron and steel industry in the United States is phenomenal. In 1901 the production of pig iron was 13,789,242 metric tons, as opposed to 13,620,703 metric tons in 1900. The metric ton is about a tenth larger than the ordinary ton, so that over fifteen million tons of two thousand pounds each was the output of pig iron in the United States. In 1882 the production was only 4,144,254 tons, of which approximately 0.15 per cent., was exported; of the 13,789,242 tons produced in 1901, the export amounted to 255,253 tons, or nearly two per cent. On the other hand, the import in 1882 was 496,045 tons, which was 10.65 per cent. of the total consumed, while the import in 1901 was only 39,325 tons, or 0.29 per cent. of the total consumption. In England, however, the importation of pig iron has increased from 1896 when it was 108,152 tons, to 1900 when it was 184,049 tons. The increase during the same time in steel imported into Britain is even more noticeable; the import of unwrought steel growing from 17,771 tons to 182,210 tons. The total exports of Britain in iron and steel are of course enormous, although the United Kingdom does not produce so much as the United States. There is not so much local consumption, and a large quantity is exported, the amount being in 1900 3,602,083 tons, a trifle less than the 3,607,204 tons exported in 1896. Britain's output of Bessemer steel was greatest in 1882, when it amounted to 1,125,785 tons; the present output of the United States is more than double that figure. It may be noted that Bessemer steel is largely used for rails, and the growth of railroads is now much greater in this country than in Britain.

Perhaps in nothing has the competition of the United States with the United Kingdom been more conspicuous than in tin plate. The use of tin plate has grown tremendously, owing to the growth of the canning industry, canned meats, canned fish, canned fruits and canned vegetables being now common where formerly they were rare.

The imports of tin plate from England were in 1869 over one hundred and eighty-one million pounds, and from 1884 to 1894 the yearly average was about five hundred millions, with the exception of 1891, when the remarkable figure of 1,036 million pounds was reached. But in 1901 the imports were one hundred and eighteen million pounds, a figure considerably less than in 1869. The value has decreased even more than the quantity, for in 1869 the value was \$8,767,381, and in 1901 it was \$3,770,062. To this extent has Britain lost in her trade in tin plate with this country. As against the decline in importation is the growth in production in the United States. In 1892 the produc-

tion in America was fourteen million pounds, in 1900 it was six hundred and seventy-eight million pounds, or in eight years the increase in output has grown more than forty-eight times. Tin plate has actually been landed in considerable quantity at Cardiff, the original home of the industry.

The figures given above for iron and steel refer to the unmanufactured product; in machinery and other articles manufactured from iron, the United States competes keenly with the United Kingdom. In connection with iron and steel may be mentioned the competition which America has offered in bridge building and similar work. England has till very lately had a practical monopoly of railway building in most of the British colonies. But the Atbara bridge in the Soudan was constructed by America, the lowest British tender being £15, 15s. (or \$76.50) a ton, whereas the American tender was £10, 13s. 6d. (or \$51.60) a ton. The British contract was for twenty-six weeks, the American for only fourteen. Afterwards came the construction of the Gokteik Viaduct in Burma, which was completed by an American firm in twelve months, and is the wonder of British engineers. The American tender was for fifteen pounds a ton, the lowest British tender was for twenty-six pounds ten shillings a ton, and the time required was three years. The Uganda Viaduct is another instance in which the American tender was twenty per cent. lower than the British, and the time required slightly more than one third.

In rolling stock for railroads, American competition is likewise felt. New Zealand has taken locomotives from America, so has Cape Colony, which not long since placed a million pounds worth of orders including twenty-nine locomotives, in this country. Even the Midland Railway Company in England in 1898 ordered twenty locomotives from America. The Sanyo Company in Japan has been using American locomotives for six years and has lately ordered more from America, but not from Britain. They have already thirty-three American and twenty-four English engines. They say that the American engines are more quickly provided and cost only two thirds as much. It is said that the American design is the better, though it is admitted that the British workmanship is superior. The English boilers are more carefully riveted and are less liable to leak. The American wheels are, however, said to have better tires and to last longer.

As an example of how American machinery is being introduced into England, the experience of the firm of Messrs. Charles Churchill & Co. in London may be cited. Thirty-five years ago they commenced to introduce American machinery into Britain and met with many discouragements, but during the last five years they have sold four million dollars' worth of machinery. The business of the past year has been

the largest they have had, and it promises to be still better during the coming year.

The competition of the United States has not been confined to iron goods, to locomotives, bridges and heavy machinery, but has extended to many departments. America has taken away a large part of Britain's colonial trade in boots and shoes; she has a practical monopoly of the boot and shoe trade of West Australia and Africa. The boots have a better appearance and a better fit than English boots, and they wear as well. A good deal of the leather is identical in kind in the two countries, but the Americans tan better than the British. A very considerable quantity of the leather used in Britain is imported from the United States and costs less than it does at home, but though wages are smaller in Britain, American boots can be sold in the British market.

"Americans have a practical control of the match making industry in Britain, also of the tobacco industry; half of the English newspapers are printed on American presses or upon presses built on American models in English shops that are branches of American manufactories, and the paper of most of the newspapers is American." So says Mr. Frank Vanderlip, formerly assistant secretary of the Treasury.

It appears that British shipping even is to be invaded by America. In the days of wooden vessels the United States led the world in shipping, but since iron and steel have been used in shipbuilding Britain has been without a rival. At the present time, however, quite apart from the American ownership of foreign-built vessels, the tonnage of vessels built in the United States has reached a very respectable figure, being in 1901 as much as 483,489, while in February of this year it is stated that there were on the stocks twenty-two ships, averaging ten thousand tons each.

The causes that account for the position of the United States as a competitor of the United Kingdom may be grouped under two heads—the nature of the two countries and the characteristics of the two peoples. America is a large country, with immense resources and a population nearly double that of Britain. Hence, the home market is larger, and a larger home market permits of a cheaper production for the foreign market. The accessibility and abundance of some raw materials, such as coal and iron ore, gives America a great advantage. Britain can never hope again to reach America in the output of iron. Iron ore is much more easily obtained in this country, occurring in some places in large quantity of so soft a nature that it can be scooped out with steam shovels; and since it is on the surface it is possible to load it directly on cars, ready to be transported to the furnace. In Britain the ore must be mined, usually from great depths, or must be imported from other countries.

The cost of mining coal has increased in Britain as in other European countries, whereas it has decreased in America. In 1885 the average price of European coal at the mine was \$1.62, and in the United States \$1.58; in 1899 the European price was \$1.96, while that in the United States had fallen to \$1.10. The average depth of the seams in America is much less and their width is considerably greater. It is remarkable that though the output of the mines of the United Kingdom was less in 1901 than in 1900, the number of employees was 24,661 greater. This increase was, I believe, entirely in the coal mines, in which the decrease of output was over six million tons.

Of course the character of the two peoples counts for much. The power of the initiative of the American, his shrewdness and his energy give him an advantage and contrast with the Englishman's inertness, self-complacency and policy of *laissez faire*. A case was cited in the *London Mining Journal* of a firm in Australasia that sent to a British firm for a catalogue of prices. Instead of sending the catalogue, the British firm wrote for evidence of the *bona fides* of the presumable customer. The latter thereupon sent to the United States and received three large and well illustrated catalogues, and so became a customer of the American firm. It is safe to say that the majority of colonial merchants would prefer to deal with Britain if they could obtain the goods they require at the same cost and with the same ease and quickness, but sentiment must not be too much strained.

Not only is the British merchant slow to adapt himself to the wants of his customers, but the British manufacturer is slow to change old processes and to adopt new machinery. Workmen are seldom encouraged to suggest improvements in methods and machinery as they are in the United States. It is fair to say that British workmen are not very ready to make suggestions for the improvement of machinery since they have a prejudice against machinery, though any that come to America, where they find it an advantage to exercise their ingenuity, show that they can compete in inventiveness with their fellow-workmen in the United States. In Britain, however, workmen, as a rule, look upon machinery as a disadvantage. They consider that an improved machine means less hand work, and that the machine takes the bread out of the mouth of the honest laborer.

In 1901 there were in Britain no more than 311 coal cutting machines in use, while in Pennsylvania alone there were 3,125, or ten times as many. In the United States there was an output of 493 tons per man employed, in Britain only 318 tons.

The English workmen will not use machines at their full capacity, even when the machines are provided. Most of the British match factories, being under American control, use American machinery; but

in a particular case where the same company had two factories, one in Britain and one in the United States, seven hundred employees in the former turned out fewer matches than four hundred employees in the latter. The trades unions object to a man looking after more than one machine, where it might be possible for him to look after two or three, or possibly half a dozen. The trades unionists go on the assumption that there is only so much work to be done and if one man does the work of two he throws some one out of a job, forgetting that a small output at a large cost to the capitalist precludes him from competing with outside employers in the same department, and lessens the amount of work he can give to his men.

Tenders were asked for a bridge in an English colony. Several English firms and one American tendered. The lowest English tender was by a firm employing six hundred men for whom there was barely sufficient work. The English tender allowed for only five per cent. margin for profit and contingencies, but the tender was not sufficiently low, and the contract went to an American company. Within a month the English firm was obliged to dismiss one hundred men. If the employees had realized the state of the case and had been willing to work to their full capacity the contract might have been secured by the English firm, the hundred men might have still been employed and possibly others added.

Though American boots and shoes are invading Britain, two hundred riveters and finishers lately went out on strike against shoe-lasting machines. In America a hundred machines are used in the making of one boot. In England labor-saving machines have been invented, but very few have been suggested by operatives, and they are grudgingly used.

America has the advantage that the factories turn out large numbers of articles all upon the same pattern. For instance, the locomotive makers build a particular style of locomotive, and will not make any other style, except at a very great advance in cost. In England specifications are drawn up by some engineer, and these specifications must be followed. It is complained that there is a colony of consulting engineers in Westminster that have supervision of the contracts for bridges, permanent way and railway stock. It is contended that these engineers put restrictions upon English firms tendering for contracts to which American firms are not subjected. It is said, for instance, that when the Midland Railway ordered American locomotives these would not comply with the restrictions to which home made engines would be subject. When an American firm is asked to tender according to specification, the usual reply is that such a locomotive can be made, but it will cost a half more than one of the regular style that will be quite as



good. The British tender to specification is usually lower than the American. Locomotive works in England are usually smaller than in America, since most of the large railways have their own shops, and the outside constituency is small. In America few of the railroad companies make their own locomotives; they buy them from the large factories.

The case with bridges is much the same as with locomotives. The bridge companies build a number of bridges upon the same plan, hence can supply the parts for any particular contract at a rapid rate and may indeed have them on hand.

The cost of transportation in the United States is very much less than in the United Kingdom. The American cars are much larger, carrying fifty tons, whereas the English cars carry eight tons, and the American locomotives are enormous as compared with the English engines. The average charge for freight per ton mile in America is less than 0.75 cents, in Great Britain it is 2.4 cents, or more than three times as much. Of course, the short journeys in Britain increase the cost, because the terminal charges are the same whether the run has been long or short. The complaint is made in Britain that the freight on foreign goods is cheaper than on home productions, and that there is thus a discrimination against the English producer.

The United States has an advantage over the United Kingdom in the technical training afforded. In this respect Germany leads the world, but America far surpasses Britain. The total number of day students over fifteen years of age taking a technical course of twenty hours or more a week is in the whole United Kingdom only 3,873. In the Massachusetts Institute of Technology alone the number of students over eighteen years of age is about 1,200. It will be noticed that the age in the American institution is higher than that in Britain, which doubtless implies that a more advanced course of study is pursued.

The question naturally presents itself, How is Britain meeting the American competition? In some things it probably can not be met, the advantage of natural resources can not be overcome. But the English are awaking to the necessity of technical education and the importance of making the best use of their conditions. More than eleven years ago parliament placed at the disposal of the local authorities certain excise grants, commonly called 'liquor money.' Well-equipped technical schools have been started all over Britain. Two are being built in Ireland—one at Dublin, the other at Belfast—each to cost \$500,000. The new Manchester Institute of Technology has just been opened. A school is being built in Glasgow to cost \$750,000 for building alone. In Birmingham over two million dollars has been subscribed for a new technical training school. These expenditures are

small as compared with those of the United States, but they indicate a sense of the need of technical education.

The starting of the National Physical Laboratory for the purpose of testing and standardizing and for research on physical constants promises to be of great value. The simple standardizing of screws and nuts will be a great assistance to manufacturers. It is important that these should be made to an exact size, so that in replacing them there may be no misfits. For this it is necessary that the manufacturers' standards should be kept exact.

Trade and technical papers in Britain are awake and are sounding the alarm, which, though it falls on many deaf ears, especially in the case of those who had grown old while Britain was supreme in nearly all departments of manufacture and trade, is yet arousing some response from the younger and more active men who are beginning to learn that the world does move.

American methods are being introduced, and in some cases American energy is being imitated. The Westinghouse Company is building a five million dollar electric plant in Manchester. English bricklayers are accustomed to lay not more than four hundred bricks a day, and they started at this rate, but, under American contractors, were induced to work up to eight hundred a day. A few American bricklayers were imported and set the example of laying nearly two thousand bricks a day, whereupon the English bricklayers in their desire to show that they could equal the Yankees, followed the example set; and buildings that the English master builders said would require five years have been erected in twelve months. It is said that when the plant is installed seven thousand hands will be employed, and that it is the design of the Westinghouse Company to give a lesson to the English engineers as they have to English builders.

Though the United States is so rich in inventions, the United Kingdom is responsible for many of the pioneer inventions, and it seems that she can still make a good showing. The Bessemer process and the Thomas Gilchrist basic steel process are English inventions, and lately the Parson's Steam Turbine has gained prominence and bids fair to start a new era for steam engines. It is thought that in a few years it will be in use on all stationary engines and on steamboats.

In shipbuilding Britain still leads, the cost of building being considerably less there than in the United States. The cost of a ship of about ten thousand tons is approximately \$160,000 in the United States and \$130,000 in Britain.

Sir Christopher Furness, who has lately been in America, thinks that in the iron and steel trade Britain need not despair. Mr. Schwab says that the United States will be able to compete with the world in

rails, girders and heavy products, but that England will be ahead in steel products requiring special and delicate manipulation.

Probably the greatest hindrance to advance in Britain is trades unionism; but the fallacy of their doctrine may soon be realized by the workmen, and any just cause for complaint against the capitalist may be adjusted in an amicable and reasonable manner. An association called the National Industrial Association has been formed or is in the process of forming with this as one of its aims. The object is 'to create and cement a feeling of common interest between employer and employee.' The Association appeals to every engineering firm in the United Kingdom because by bringing employers and employees to see their mutual interest there will be an increase in the output of their works without additional cost. With better and cheaper work the manufacturer will be more able to combat foreign competition. Strikes and lockouts will be far less frequent, and so great loss and misery will be prevented. In this Association employers and employees meet upon the same plane, and they hope to provide machinery for conciliation which shall be available in case of any threatened dispute between employers and their men. The Association has in view the carrying on of inquiries regarding matters affecting British trade and commerce, with the object of holding their own in the markets of the world.

It will be to the interest not only of Britain, but of America as well, if British manufactures increase and if Britain grows commercially. America sells most to the richest nation—Britain is her best customer. There is no doubt that the United States will continue to develop her resources and will be able to sell to nations that can afford to buy. The standard of living is higher now than it was even a few years ago. What were luxuries to our fathers are necessities to us. There is room for all the growth possible in both Britain and America, and it is to be hoped that civilization may be advanced and the world benefited by the competition of the United States with the United Kingdom.

## SCIENTIFIC READING IN A PUBLIC LIBRARY.

BY ARTHUR E. BOSTWICK,

CHIEF OF CIRCULATING DEPARTMENT, NEW YORK PUBLIC LIBRARY.

PUBLIC libraries usually divide their circulation into ten or a dozen broad classes and so report it. This division is interesting, but a subdivision of each class would be still more so. For instance the scientific man is interested to know that a given library circulates four per cent. of science, but he would be still more interested to know exactly what is included in 'science' and how much of the circulation is to be credited to each subclass. Those libraries that use the decimal classification of Melvil Dewey, which has been so generally adopted in this country, often report together as 'science' the classes 300 (sociology), 400 (philology) and 500 (natural science) and they exclude the applications of the last-named sciences, which are placed under useful arts. It is evident that in order to mean anything, a report of circulation should be more closely subdivided. This is true of many other classes, of course, as well as of science.

## PERCENTAGE OF SCIENTIFIC BOOKS CIRCULATED BY VARIOUS PUBLIC LIBRARIES.

Brooklyn .....	4.0	New York*.....	9.0
Buffalo .....	5.3	Philadelphia .....	5.9
Chicago (including Arts).....	5.3	Pittsburgh .....	5.9
Cleveland .....	8.4	Providence .....	7.6
Los Angeles.....	11.5	Salem, Mass.....	3.3
Newark .....	3.4	San Francisco.....	7.1

And yet a public library cannot systematically classify its circulation more closely than it does. To do so would involve a great amount of labor which would be more profitably expended in other directions. It is quite possible, however, to do this extra work for a short period and in a single class of literature and the result, even if partial and perhaps not typical, can not fail to interest those whose studies and work lie in the particular line of literature that is under investigation. Such a classification of the scientific circulation was made for this purpose in all of the circulating branches of the New York Public Library (11 in number at that time) during the month of May, 1901, with the result shown in the accompanying table. For purposes of comparison the circulation is accompanied by figures showing the number of volumes in each subclass, in each branch library.

\* Percentage for the entire year. That given in the larger table is for one month only.

During this month the total home circulation of these branch libraries was 131,700, and that of the sciences was 8,553, or 6.5 per cent. The first thing that strikes one is that this is a very small percentage. It is not so as compared with other libraries, as the smaller table shows; and of course it is impossible to say *a priori* what amount of scientific literature a public library ought to circulate; but taken in connection with other facts in the writer's experience as a librarian, it is believed that these figures show a general lack of public interest in science—the same lack of interest that has been brought out of late by several writers who note the general want of consideration for science and scientific men in this country as compared with those of Europe. But while this smallness of our scientific reading is doubtless symptomatic of something deeper, it is probable that interest in science might be stimulated in the library itself. The librarian has numerous effective ways of increasing the reading in a particular class of literature, but none of them appears to have been generally used in this case. Lists and bibliographies, in history, for instance, are very much more numerous than in science, probably for the reason that public librarians and also the teachers with whom they come most in contact are generally more interested in the former subject than in the latter.

Scientific men themselves could doubtless do much to better matters, and I am sure that those in charge of public libraries would welcome suggestions from them regarding the character of their scientific books and plans for making those books attractive to the public and stimulating interest in them. Men like Mr. Hodges, of Cincinnati, who is both a librarian and a scientific man, are doing much toward putting science on a better footing in our public circulating libraries, as his paper read at the recent conference of the American Library Association shows. A glance at the numerical table shows that the public interest in science is not even as great as the total figure would seem to indicate. The largest circulation by far in any one of the thirty subclasses represented is in 420—English philology. But in this are included many volumes of elementary language lessons, etc., which are used in connection with school work, and these doubtless account for the size of this figure. Next comes 370—education, and although it is interesting to see that books on this subject are so popular, their popularity has little to do with a general appreciation of the importance of scientific literature.

The next largest circulation is in 590—zoology. Here at last we have a natural science. But among works on zoology are classed a large number of popular animal stories, which probably make up a considerable number of the 778 books in this subject read during the month.

Science Circulation (N. Y. Public Library), May, 1901.	Bond.		Otten- dorfer.		Bruce.		Jackson Square.		Harlem.		Muhlen- berg.		Bloom- ingdale.		River- side.		Yorkville.		34th St		Chatham.		Totals.	
	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in Lib.	Circulation.	Vols. in 11 Branches.	Circulation.
300 Sociology.....	66	17	45	15	55	15	41	6	32	14	22	12	33	16	23	28	16	13	6	23	9	381	126	
310 Statistics.....	26	3	23	1	21	1	1	1	2	1	9	3	3	3	5	2	3	2	6	6	6	77	12	
320 Political Science.....	121	17	56	21	68	18	53	20	41	16	31	13	35	13	26	33	18	15	39	8	521	161		
330 " Economy.....	175	52	95	19	111	27	92	26	62	23	35	12	42	19	45	69	37	26	6	47	15	799	257	
340 Law.....	75	41	52	27	34	8	39	11	35	18	16	5	17	9	10	23	11	15	2	43	8	338	142	
350 Administration.....	92	84	55	26	68	23	61	20	44	21	29	10	39	15	25	58	30	20	7	39	33	530	278	
360 Assns and Inst'ns.....	22	2	11	1	15	1	13	2	9	2	5	2	2	2	8	1	6	1	2	1	1	94	13	
370 Education.....	136	66	146	142	167	70	122	41	128	105	55	24	92	73	40	23	109	98	36	21	137	242	1168	905
380 Commerce, etc.....	4	4	10	1	14	3	8	2	8	4	4	2	6	2	4	1	3	4	2	1	1	63	16	
390 Customs, Folk-lore.....	98	69	85	70	113	61	88	57	71	57	48	39	63	38	43	27	77	85	29	27	57	772	601	
400 Philology.....	5	2	7	4	5	3	1	1	3	1	2	1	1	1	1	4	2	1	1	1	1	26	11	
410 Comparative.....	3	3	2	1	5	1	5	1	3	1	3	1	3	3	1	2	2	1	1	1	1	26	3	
420 English.....	143	197	131	204	95	37	73	52	36	57	39	4	63	71	57	83	124	136	64	73	257	829	1082	1683
430 German.....	41	47	60	41	43	5	13	6	25	18	13	6	13	6	1	1	25	19	4	1	38	19	276	169
440 French.....	36	34	29	26	58	9	15	11	15	7	17	3	9	4	9	2	25	9	9	4	35	24	257	133
450 Italian.....	13	5	2	1	8	2	2	1	1	1	1	1	1	1	1	2	2	5	9	4	7	5	37	16
460 Spanish.....	13	10	26	6	10	3	9	2	7	5	3	2	5	5	5	6	6	6	1	2	2	3	82	42
470 Latin.....	22	7	13	7	11	4	13	3	4	6	8	1	7	4	6	12	8	3	3	3	18	4	117	47
480 Greek.....	10	1	3	1	5	1	4	1	3	3	6	1	1	1	1	7	11	4	3	10	54	18	54	18
490 Minor Languages.....	1	1	3	1	2	1	4	1	1	1	1	1	1	1	1	7	11	4	3	10	54	18	54	18
500 Natural Science.....	82	46	121	46	140	45	74	26	39	26	30	11	76	47	20	71	66	33	17	154	300	830	631	
510 Mathematics.....	99	121	102	97	61	41	60	45	54	50	31	23	39	31	19	1	58	77	22	13	137	174	682	673
520 Astronomy.....	52	15	44	14	55	15	41	19	37	14	14	6	27	14	21	13	31	17	19	6	27	80	368	213
530 Physics.....	136	122	156	90	155	47	115	60	108	78	58	33	65	47	52	17	81	63	42	20	61	28	1029	605
540 Chemistry.....	44	37	51	36	42	14	36	18	24	6	12	3	16	13	9	2	18	14	7	9	20	16	279	168
550 Geology.....	78	39	72	34	80	13	63	17	55	12	19	5	34	12	32	5	36	23	21	12	33	19	523	191
560 Paleontology.....	5	1	5	1	4	1	3	1	4	1	4	1	1	1	2	1	3	2	1	2	3	4	24	4
570 Biology.....	59	24	60	21	72	23	61	15	45	18	18	12	36	23	23	16	34	18	23	8	18	8	449	186
580 Botany.....	64	33	66	59	70	29	61	8	59	25	27	19	36	36	31	21	69	38	33	13	111	180	607	461
590 Zoology.....	155	68	150	130	205	73	160	52	101	53	54	28	100	82	56	33	121	84	38	16	113	159	1263	778
Totals.....	1876	1160	1658	1139	1794	593	1328	522	1053	636	696	277	862	589	670	230	1123	890	477	282	1415	2235	12762	8553

Mathematics has a relatively large circulation, but we must not suppose that in May, 1901, 673 citizens of New York devoted themselves to the theory of functions or the calculus of probabilities. Further analysis would reveal the fact that a very large proportion of the books taken out were text-books on arithmetic and algebra.

An examination of the records of the separate libraries reveals some points of interest. For instance the circulation in political science and political economy at Bond Street was twice as great as at Bloomingdale—five miles above. The proportion of Hebrews among the users of the two branches must be in nearly the same ratio—a fact that speaks for itself. On the other hand the circulation in education was larger at Bloomingdale. In English philology, the Chatham Square Branch circulated nearly as many books as all the other branches together, which is noteworthy when we remember that this is in a foreign section, where there are news-stands on which not a single English newspaper is exposed for sale. The same proportion holds good at this branch for general works on natural science (class 500). Some things about the table are inexplicable. Why, for instance, should the Ottendorfer Branch have circulated twice as much zoology as Bond Street, only a half mile distant? Doubtless this was owing to some temporary demand, which another month's record might reverse.

Comparison of the circulation in each class with the number of books in that class shows, as might have been expected, that the larger the stock the larger the circulation. There is a mutual reaction between these two numbers. On the one hand, if the demand for a particular class of books is not great, in any branch library, that library naturally does not call for books on that subject; on the other hand, if a library is meagerly supplied in any subject, so that users who wish to read in that subject can not get what they want, the circulation is apt to remain small. In such cases the circulation may be raised by replenishing the stock. The ratio does not always hold good, however, and there are some notable exceptions.

Evidently these are but a very few of the considerations suggested by a study of the table. Different parts of it will naturally interest different readers, and each will be able to find many things in it that can not be brought out here. Of course the record for a whole year would be still more valuable, but, as has been said, the amount of daily labor necessary to subdivide the report is so great that its continuance beyond a month would hardly be justified. So far as I know this is the first attempt made in any library to subdivide so closely in any subject and to present the results in a form suitable for observation and study.

## AN ASCENT OF MT. ORIZABA.\*

BY PROFESSOR ALJA ROBINSON CROOK,  
NORTHWESTERN UNIVERSITY.

ORIZABA is the highest mountain in North America whose summit has been reached by mountain climbers. It lies one hundred and fifty miles southeast of Mexico City and less than sixty miles from the Gulf of Mexico and is a most attractive peak for mountaineers.

I determined to climb it, and after a week spent in Mexico City in the vain attempt to find companions for the journey took the train for San Andres, the railroad station nearest to the village of Chalchicomula, from which the ascent is most favorably begun. A broken axle delayed the train five hours. The passengers wagging their heads said the accident was to be expected, the day was the thirteenth of the month. It was evening when San Andres was reached. The station agent knew of two men in Chalchicomula who could speak English. Fortunately one of them was at home, and we were soon upon a friendly footing. He offered to find guides and horses for me, but proved to be not a very aggressive agent. A native of Florida, crowded out of his country by competition, he was teaching the Mexicans English and receiving for his work eight cents an hour. He was so doubled with rheumatism as to be scarce able to walk. After much encouragement on my part and an hour's talking on his, he engaged two guides. A horse was to be procured. It was eight o'clock at night; the rain was descending in torrents; I had eaten nothing since morning. We called at several places where horses were reported for hire and where it took the polite proprietors many minutes to explain that they did not have horses. We were making such slow progress that I finally picked my interpreter up in my arms and carried him from place to place through the rain till we had visited half a dozen polite gentlemen and finally obtained the promise of a horse for the morrow. Even the preparation for mountain climbing in that village was uphill work. That night, lying in bed, nursing a toothache, listening to the driving rain outside, remembering the remarks of the villagers that rain and snow storms and avalanches would make the ascent impossible, it seemed the extreme of foolhardiness to attempt such a thing.

In the morning the guides were late, and the horse proved to be too weak to carry a man, so I contented myself with putting blanket roll and

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\* Photographs by the author.



provisions on the horse and walking with the guides. There was some compensation in this, as it gave opportunity of measuring my walking ability. The guides had the advantage of being accustomed to an altitude of eight thousand feet and of living a life requiring constant walking. But before the close of the first day one of them complained of the difficulty of breathing and on the day of final ascent begged to return before the climb was completed. After three years of mountaineering with European university students, I am of the opinion that the American college man of average athletic habits can walk with the men of any nation. Good ancestry, good food, good habits of life, produce good muscle. In the same class with the American come the



FIG. 1. MOUNT ORIZABA, FROM CHALCHICOMULA.

English and the Russian student, while the German and French are in a second class, and the Latin races in a third largely because of their habits of life.

By eight o'clock we had started for the mountain. The little burro, buried under food, bedding, ax and shovel, led the procession. A guide followed to encourage the burro and lead the *caballo*. The second guide came next to encourage the horse. I followed. The preceding evening I had searched the lexicon to learn to say 'whoa.' Unnecessary labor! The only expression needed was 'Get up!'—and that in the universal language of the birch stick.

A short climb soon brought us above the town and showed the flat-roofed plaster houses thickly crowded together without door-yards or pavements in the narrow streets. Several churches rising above the

general mass of buildings gave picturesqueness to the scene. Before us not more than a dozen miles away, and seemingly less, was Orizaba. Usually the traveler in mountain regions is disappointed in the peaks he would visit, because they are dwarfed by the neighboring hills and mountain spurs surrounding them, and seem flat and tame. But on that August morning Orizaba was the most majestic mountain that could be conceived. It was the very picture of just such a mountain as a plainsman would draw. Its sharp summit pierced the sky with such favorable perspective that the great height could be really appreciated. Snow came far down upon its sides. The treeless tract below the snow line stood out plainly and ended with thick forests which covered the



FIG. 2. CHALCHICOMULA. AND OUTFIT FOR THE ASCENT OF MOUNT ORIZABA.

hills rounded and piled up over the mountain's base. A well-marked trail led through the fields, some filled with black stalked corn, some bristling with thousands of that valuable cactus, called *maguay* in Mexico and century plant in the United States, and some entirely barren. A horseback rider with a revolver at his belt came dashing through the thicket and asked a drink of the guides. Though they were going on a three days' trip and had but a quart of wine between them they handed the man their bottle, how unwillingly I do not know. Possibly the beggar was the proprietor of the hacienda through which we were passing and took that means to levy toll. After two hours' walking we reached the forest belt and spent the remainder of the day within it. As in all mountain regions here the most common and stately trees are pines and spruce. The pines flourish from nine thousand feet

up to the tree limit—between thirteen and fourteen thousand feet. Spruce trees thrive best above the ten-thousand-foot line. There is very little undergrowth and the country is park-like. The absence of animal life is noticeable. Ants, flies, mosquitos, birds and mammals that are so abundant in most parts of the world are rare here. The only reptiles that I saw were occasional salamanders. The slopes are easy and regular, so that little energy is wasted by the necessity of descending from heights once reached.

During the day shifting clouds revealed one beauty after another by blotting out one portion of the heavens or mountains and calling attention to others. Occasionally the splendid summit of Orizaba would appear, then the top of a neighboring mountain, as if nature were try-

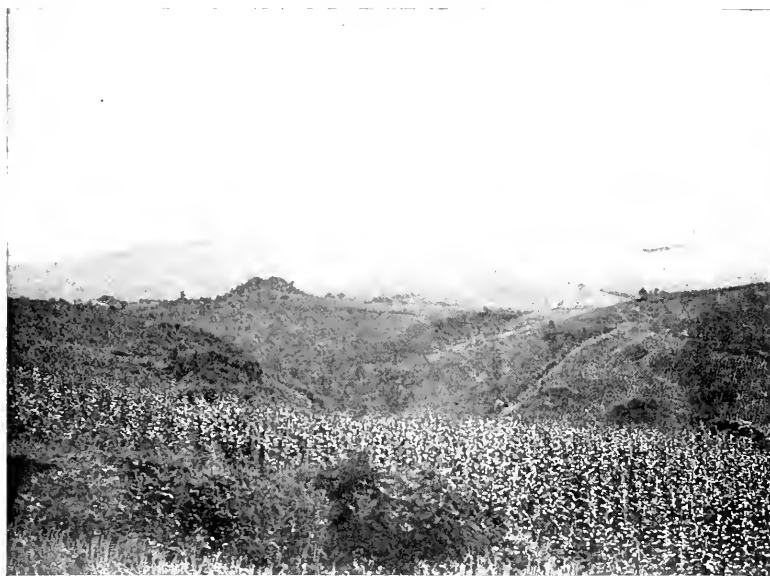


FIG. 3. MOUNT ORIZABA FROM ELEVATION OF ABOUT 8,500 FT., ABOUT 12 MILES AWAY.

ing the effect of draperies. Sometimes the clouds would envelop us with their cold folds and shut out from view all but the nearest trees.

At four in the afternoon, though much too early according to my judgment, we halted and prepared a camp under the shelter of a cliff, whose base is hollowed out in the form of a shallow cave. It affords poor protection. The rain coming from one direction is shut off, but water drips from the rocks. Just after darkness had begun to settle down we heard a far-away shout as if from some one in distress. We answered and soon found that it was simply a shepherd calling his flock. It was a cold night and sleeping out of doors at that altitude is not a luxury. In the morning my rubber blanket was stiff with a sheet of ice.

This 'cave' was probably the place where Baron Müller, who climbed the mountain in 1856, stopped, and where nearly all the mountaineers who have attempted the ascent since have passed the night. Müller speaks of the 'granite' walls of the cave and other tourists use the same term. But there is no granite here nor elsewhere in the region. The rock masses forming the mountain are singularly uniform. They are eruptive rocks of prevailing dark grayish or brownish color composed of crystals of augite and plagioclase in a fine ground mass and are called andesite. In places glassy masses of obsidian appear, and in others volcanic tuffs and ashes, but in no place is there granite or gneiss.



FIG. 4. FOREST ON MOUNT ORIZABA IN THE DISTANCE—100 MILES AWAY—POPOCATEPETL AND IZTACCIHAUTL.

The following morning at six o'clock, after a hurried breakfast, one guide and I started for the summit. In a few minutes we were above the timber line. Two hours of walking brought us to the snow line, that day at about fifteen thousand feet.

At the lower levels the snow is finely crystalline, very compact and of the variety known as 'firn' or 'névé.' It affords excellent footing to the properly shod climber. Toward the top of the mountain it is softer, though the individual flakes are never large, and the feet sink in to the shoe tops. The beauty of the snow furnishes one of the great rewards to the tourist. The spike of an alpine stock leaves after each thrust a hole of wondrous green in the glittering white mass. The snow fills the chasms of the mountain, smoothes out its ridges, softens

its outline, gives it a dazzling splendor—a crown of glory worn only by the kings among mountains.

For five hours we plodded upward through the snow. With woolen socks pulled partly over the shoes so as to leave the rubber heels exposed, I found it easy to walk up the steep smooth slopes which held the feet almost like sandpaper. But my guide's wide sandals could not hold to the snow, consequently he had to cut steps. When he became exhausted I took his place, and thus we alternated. Exertion at that altitude is difficult. At the cave to roll over on a blanket and pull it over the shoulder almost makes one pant. 'And to pull the blanket over both shoulders would make a pair of pants, I suppose,' said my hostess at a dinner party a few months later, when the story was being related.

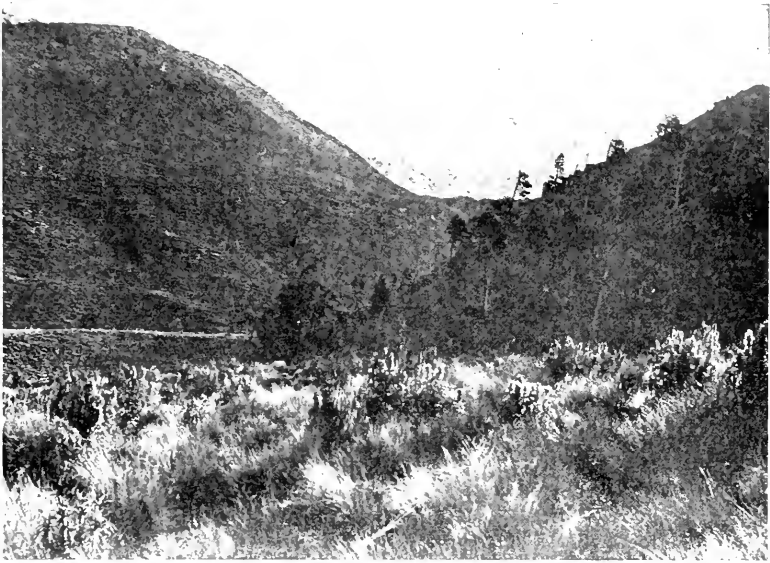


FIG. 5. MOUNT ORIZABA FROM 12,000 FT. ELEVATION. SNOW EXTENDING DOWN TO THE 15,000 FT. LINE.

During the ascent of mountains up to fourteen thousand feet in height heretofore mountain sickness has not caused me much annoyance. But for the last three thousand feet of the ascent of Orizaba, headache, pain at the top of the spinal cord, rapid beating of the heart, shortness of breath, inability to eat even a cracker or chocolate, general discomfort nearly destroyed all pleasure. I have never noticed the popularly reported tendency to bleeding at the nose and ears. Olives and lemon juice were the only things I could swallow. This *mal de montagne* was less severe when clouds obscured the sun than when the glare was brightest, and less noticeable when we were in hollows than when we

were on *arêtes*. When exhausted from climbing and shoveling the only thing to do was to lie down and often to sleep for a few minutes. While resting we needed only to start boulders rolling down the snow fields to behold a thrilling sight. The black masses would begin with small leaps, leaving behind indentations like an unwinding white ribbon in the dazzling snow. Increasing in speed, the boulders would finally dash with cannon-ball velocity and mighty springs out of view thousands of feet below. An obstacle at the beginning so slight as to be unnoticed would often change the path of the boulders started from the same spot so that their lower lines would be a mile apart—one making a path down a gully to the south perchance and another down an eastern gully. Form, color and motion combined to give an astonishing effect. Of the many mountain slopes that I have seen this is the most favorable for such a sight.

The weather had been propitious all morning. Though threatening, the clouds shifted constantly and disclosed one extensive view after another—any one of them a complete compensation for the effort of the ascent. Finally, after we had been climbing seven hours and were within probably three hundred feet of the rim of the crater, a vigorous snow storm swept around the mountain. We continued the ascent for an hour. The cold and wind increased. It was impossible to see fifty yards. There was nothing to do but begin the descent. We had not seen the crater nor had we had a view from the summit. But our rewards had been enjoyed all the way up and the wisdom of not postponing the return afterwards appeared since the snow storm continued the remainder of the day. So after waiting half an hour and finding the storm becoming worse, we tobogganed down the snow slope, and in fifteen minutes passed over the distance which had required three hours to climb.

We reached the cave camp in two hours, and I spent the night in bathing eyes to take out inflammation caused by the excessive light experienced on the snow.

The next morning we returned to Chalehicomula, and the tram which runs eight miles without animal, steam, or electrical traction simply with the force of gravity, carried me to San Andres, and in a few hours I was taking photographs of banana groves and coffee plantations in the city of Orizaba, having passed from frigid to tropical regions in one day.

Orizaba, 'the Star Mountain,' is the most favorable mountain in the world for an American who wishes to climb higher than eighteen thousand feet. Elbruz, the culminating point of Europe, is less accessible to Europeans than Orizaba to Americans.

The starting point for the ascent of Orizaba is high, the slopes ridable up to fourteen thousand feet, and easy the entire distance to the

summit. Ice work is unnecessary. The guides are of obliging disposition and moderate in charges. They wear sandals and for ice work wrap their feet in strips of cloth. They provide the same primitive and clumsy footgear for the tourist. Knickerbockers, woolen stockings, canvas leggings or puttees, and shoes protected with rubber are the most satisfactory clothing. The guides greatly admired my golf stockings which were hanging before the fire at the cave. They would feel them repeatedly exclaiming '*Magnifico, magnifico.*'

The earliest recorded ascent of Orizaba is that made by some United States army officers in 1848. But no one in the country credited their report. Three years later eighteen young men of different nationalities formed a party and started for the summit. One man after another dropped out of the company till finally only a Frenchman by the name of Doignon was left. He persevered and after great hardships reached the summit. Upon his return to Chalchicomula the villagers ridiculed the claim. Consequently the following week he repeated the ascent and planted a flag upon the ridge of the crater, where it could be plainly seen by the doubting inhabitants. He was received with honor when he descended. Since Baron Müller's ascent in 1856 more than a dozen climbers have reached the summit and made many measurements of altitude.\* Miss Anna Peck, of New York City, who is an experienced mountain climber, displayed great courage and endurance in her ascent of Orizaba. She is the only woman who has ever succeeded in reaching its summit so far as I am aware.

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\* Reports upon the altitude of Orizaba:

North American Engineers		
in 1848.....	17,879	
Ferran .....	17,885	
Müller .....	18,133	
Doignon .....	18,178	(Determined by boiling point of water.)
Scovill and Bunsen.....	18,174	“ by aneroid barometer.
Heilprin .....	18,205	“ “ “ “
Kaska .....	18,270	“ “ mercurial “
Scovill and Bunsen.....	18,314	“ “ triangulation.

## ORIGIN OF THE FINS OF FISHES.

BY PRESIDENT DAVID STARR JORDAN,  
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ONE of the most interesting problems in vertebrate morphology, and one of the most important from its wide-reaching relations, is that of the derivation of the fins of fishes. This resolves itself at once into two problems, the origin of the median fins, which appear in the lancelets, at the very bottom of the fish-like series, and the origin of the paired fins or limbs, which are much more complex, and which first appear with the primitive sharks.

In this study the problem is to ascertain not what theoretically should happen, but what, as a matter of fact, has happened in the early history of the fish-like groups. That these structures, with the others in the fish body, have sprung from simple origins, growing more complex with the demands of varied conditions, and then at times again simple, through degeneration, there can be no doubt. It is also certain that each structure must have had some element of usefulness in all its stages. In such studies we have, as Haeckel has expressed it, 'three ancestral documents, paleontology, morphology and ontogeny,'—the actual history as shown by fossil remains, the side-light derived from comparison of structures, and the evidence of the hereditary influences shown in the development of the individual. As to the first of these ancestral documents, the evidence of paleontology is conclusive where it is complete. But in very few cases are we sure of any series of details. The records of geology are like a book with half its leaves torn out, the other half confused, displaced and blotted.

The evidence of comparative anatomy is most completely secured, but it is often indecisive as to relative age and primitiveness of origin among structures. As to ontogeny, it is, of course, true that through heredity, 'the life history of the individual is an epitome of the life history of the race.' 'Ontogeny repeats phylogeny,' and phylogeny, or line of descent of organisms and structures, is what we are seeking. But here the repetition is never perfect, never so perfect in fact as Haeckel and his followers expected to find it. The demands of natural selection may lead to the lengthening, shortening, or distortion of phases of growth, just as they may modify adult conditions. The conditions of the individual development may, therefore, furnish evidence in favor of certain theories of origins, but they cannot alone furnish the absolute proof.



*Origin of the Median or Vertical Fins.*

In the process of development the median or vertical fins are doubtless older than the paired fins or limbs, whatever be the origin of the latter. They arise in a dermal keel which is developed in a web fitting and accentuating the undulatory motion of the body. In the embryo of the fish the continuous vertical fin from the head along the back and around the tail precedes any trace of the paired fins.

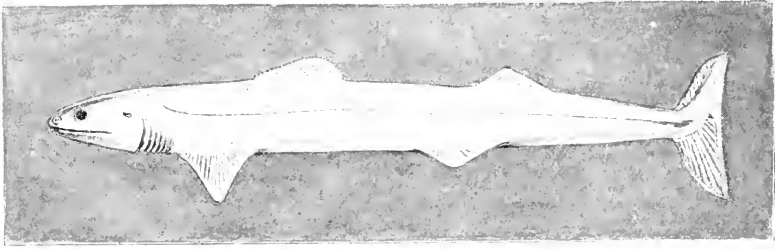
In this elementary fin-fold slender supports, the rudiments of fin-rays, tend to appear at intervals. These are called by Ryder ray-hairs or actinotrichia. They are the prototype of fin-rays in the embryo fish, and doubtless similarly preceded the latter in geological time. In the development of fishes, the caudal fin becomes more and more the seat of propulsion. The fin-rays are strengthened, and their basal supports are more and more specialized.

That the vertical fins, dorsal, anal and caudal, have their origin in a median fold of the skin admits of no very serious question. In the lowest forms which bear fins these structures are dermal folds, being supported by very feeble rays. Doubtless, at first the vertical fins formed a continuous fold, extending around the tail, this fold ultimately broken by atrophy into distinct dorsal, anal and caudal fins. In the lower fishes, as in the earlier sharks, there is an approach to this condition of primitive continuity, and in the embryos of almost all fishes the same condition occurs. Dr. John A. Ryder points out the fact that there are certain unexplained exceptions to this rule. The sea-horse, pipe-fish and other highly modified forms do not show this unbroken fold, and it is wanting in the embryo of the top-minnow, *Gambusia affinis*. Nevertheless, the existence of a continuous vertical fold in the embryo is the rule, almost universal. The codfish with three dorsals, the Spanish mackerel with dorsal and anal finlets, the herring with one dorsal, the stickleback with a highly modified one, all show this character and we may well regard it as a certain trait of the primitive fish. This fold springs from the ectoblast or external series of cells in the embryo. The fin-rays and bony supports of the fins spring from the mesoblast or middle series of cells, being thrust upward from the skeleton as supports for the fin-fold.

*Origin of the Paired Fins.*

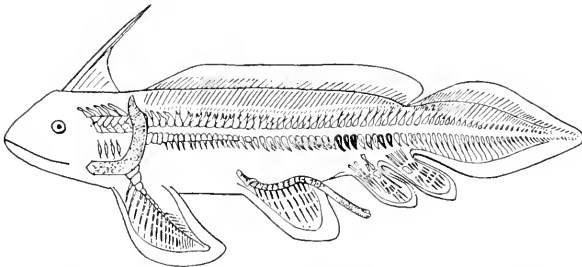
The question of the origin of the paired fins is much more difficult and is still far from settled, although the majority of recent writers have favored the theory that these are parts of a once continuous lateral fold of skin, corresponding to the vertical fold which forms the dorsal, anal and caudal. In this view the lateral fold is soon atrophied in the middle, while at either end it is highly specialized, at first into an organ

of direction, then into fan-shaped and later paddle-shaped organs of locomotion. Finally, from the jointed paddle, which Gegenbaur has called the archipterygium, there has developed, on the one hand, the rayed pectoral and ventral fins of ordinary fishes, and on the other, in land-creeping animals, jointed legs and arms. As to this the evidence of paleontology is conflicting. An early shark of the Devonian, *Cladose-*



CLADOSELAÏCHE FYLERI. AFTER DEAN.

*lache*, has fan-shaped paired fins so formed and placed. Another shark almost as old, *Pleuracanthus*, of the Carboniferous, has fins which fit best a totally different theory of origin. Its jointed or archipterygial fin has no resemblance to a fold of skin, but accords better with Gegenbaur's theory that the pectoral limb was at first a modified septum or gill arch. Sharks still older than either (*Heterodontidæ*) in the Silurian, so far as we can judge by their teeth, are closely related to forms bearing the more specialized type of fin found in the typical



PLEUROCANTHUS DECHENI RESTORED. AFTER BROGNIART. THE ANTERIOR ANAL VERY HYPOTHETICAL.

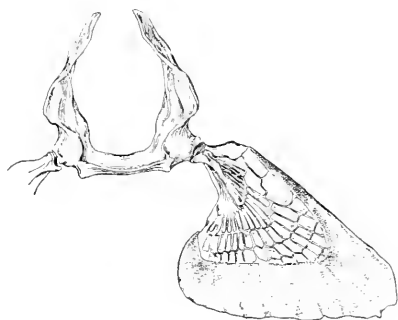
sharks of to-day. Evidently none of these three, as seen in the rocks, represents the real beginning of paired fins in the life of the past. As we shall see, the evidence of comparative anatomy may be consistent with either of these theories, while that of ontogeny or embryology is apparently inconclusive, and that of paleontology seems contradictory.

#### *Development of the Paired Fins in the Embryo.*

According to Dr. John A. Ryder ('Embryography of Osseous Fishes,' 1882) "the paired fins in Teleostei, like the limbs of the higher

vertebrates, arise locally, not, however, as blunt processes but as short longitudinal folds, with perhaps a few exceptions. The pectorals of *Lepisosteus* originate in the same way. Of the paired fins, the pectoral or anterior pair seems to be the first to be developed, the ventral or pelvic pair often making its appearance until after the absorption of the yolk-sac has been completed, in other cases, before that event as in *Salmo* and in *Gambusia*. The ventral undergoes less alteration of position during its evolution than the posterior pair."

In the codfish (*Gadus callarius*) the pectoral fin-fold "appears as a slight longitudinal elevation of the skin on either side of the body of the embryo a little way behind the auditory vesicles, and shortly after the tail of the embryo begins to bud out. At the very first, it appears to be merely a dermal fold, and in some forms, a layer of cells extends out underneath it from the sides of the body but does not ascend into it. It begins to develop as a very low fold, hardly noticeable, and as growth proceeds, its base does not expand antero-posteriorly but tends rather to become narrowed, so that it has a pedunculated form. With the progress of this process the margin of the fin-fold also becomes thinner at its distal border, and at the basal part mesodermal cells make their appearance more noticeably within the inner contour line. In some species I am quite assured that there is a mesodermal tract or plate of cells developed just behind the auditory vesicles, just outside the source of the mesodermal cells which are carried up into the pectoral fin-fold. This is developed at about the time of



PECTORAL FIN OF HEPTERODONTUS PHILIPPI.  
FROM NATURE.

the closure of the blastoderm and these lateral mesodermal folds of tissue may be called the pectoral plates. The free border of the fin-fold grows out laterally and longitudinally, expanding the portion outside of the inner contour line of the fin into fan-shape. This distal thinner portion is at first without any evidence of rays; further than that there is a manifest tendency to a radial disposition of the histological elements of the fin."

The next point of interest is found in the change of position of the pectoral fin by a rotation on its base. This is associated with changes in the development of the fish itself. The ventral fin is also, in most fishes, a short horizontal fold and just above the preanal part of the median vertical fold which becomes anal, caudal and dorsal. But in the top-minnow (*Gambusia*), of the order Haplomi, the ventral first

appears as 'a little papilla and not as a fold, where the body walls join the hinder upper portion of the yolk-sac, a very little way in front of the vent.' 'These two modes of origin,' observes Dr. Ryder, 'are therefore in striking contrast and well calculated to impress us with the protean character of the means at the disposal of Nature to achieve one and the same end.'

#### *Current Theories.*

There are three chief theories as to the morphology and origin of the paired fins:

The earliest is that of Gegenbaur, supported by numerous others, that these fins are derived from modified gill-arches or septa between the gill-openings. According to this theory, the skeletal arrangements of the vertebrate limb are derived from modifications of one primitive form, a structure made up of successive joints, with a series of fin-rays on each side of it. To this structure, Gegenbaur gives the name of archipterygium. It is found in the shark, *Pleuracanthus*, and in all the Dipnoan and Crossopterygian fishes, its primitive form being still retained in the Australian genus of Dipnoans, *Neoceratodus*. This biserial archipterygium with its limb girdle is derived from a series of gill rays attached to a branchial arch.

Professor J. Graham Kerr observes:

"The Gegenbaur theory of the morphology of vertebrate limbs thus consists of two very distinct portions. The first, that the archipterygium is the ground-form from which all other forms of presently existing fin skeletons are derived, concerns us only indirectly as we are dealing here only with the *origin* of the limbs, *i. e.*, their origin from other structures that were not limbs.

"It is the second part of the view that we have to do with, that deriving the archipterygium, the skeleton of the primitive paired fin, from a series of gill-rays and involving the idea that the limb itself is derived from the septum between two gill clefts.

"This view is based on the skeletal structures within the fin. It rests upon: (1) The assumption that the archipterygium is the primitive type of fin, and (2) the fact that amongst the Selachians is found a tendency for one branchial ray to become larger than the others, and when this has happened, for the base of attachment of neighboring rays to show a tendency to migrate from the branchial arch on to the base of the larger or, as we may call it, primary ray; a condition coming about which, were the process to continue rather further than it is known to do in actual fact, would obviously result in a structure practically identical with the archipterygium. Gegenbaur suggests that the archipterygium actually has arisen in this way in phylogeny.

The theory of Balfour, adopted by Dohrn, Wiedersheim, Thacher,

Mivart, Ryder, Dean, Boulenger and others, and now generally accepted by most morphologists as plausible, is this: that "The paired limbs are persisting and exaggerated portions of a fin-fold once continuous, which stretched along each side of the body and to which they bear an exactly similar phylogenetic relation as do the separate dorsal and anal fins to the once continuous median fin-fold."

"This view, in its modern form, was based by Balfour on his observation that in the embryos of certain Elasmobranchs the rudiments of the pectoral and pelvic fins are at a very early period connected together by a longitudinal ridge of thickened epiblast—of which indeed they are but exaggerations. In Balfour's own words referring to these observations: 'If the account just given of the development of the limb is an accurate record of what really takes place, it is not possible to deny that some light is thrown by it upon the first origin of the vertebrate limbs. The facts can only bear one interpretation, viz., that the limbs are the remnants of continuous lateral fins.'

"A similar view to that of Balfour was enunciated almost synchronously by Thacher and a little later by Mivart—in each case based on anatomical investigation of Selachians—mainly relating to the remarkable similarity of the skeletal arrangements in the paired and unpaired fins."

A third theory is suggested by Mr. J. Grabam Kerr (*Cambridge Philos. Trans.*, 1899), who has given us the best recent summary of the theories on this subject. Mr. Kerr agrees with Gegenbaur as to the primitive nature of the archipterygium, but believes that it is derived, not from the gill-septum but from an external gill. Such a gill is well developed in the young of all the living sharks, Dipnoans and Crossopterygians, and in the latter types of fishes it has a form strikingly similar to that of the archipterygium, although without bony or cartilaginous axis.

We may now take up the evidence in regard to each of the different theories, using largely the language of Kerr, the paragraphs in quotation marks being taken from his paper. We may first consider Balfour's theory of the lateral fold.

#### *Balfour's Theory of the Lateral Fold.*

"The evidence in regard to this view may be classed under three heads, as Ontogenetic, Comparative Anatomical, and Paleontological. The ultimate fact on which it was founded was Balfour's discovery that in certain Elasmobranch embryos, but especially in *Torpedo (parcoatis)*, the fin rudiments were, at an early stage, connected by a ridge of epiblast. I am not able to make out what were the other forms in which Balfour found this ridge, but subsequent research, in particular by

Mollier, a supporter of the lateral-fold view, is to the effect that it does not occur in such ordinary sharks as *Pristiurus* and *Mustelus*, while it is to be gathered from Balfour himself that it does not occur in *Scyllium* (*Scylliorhinus*).

“It appears to me that the knowledge we have now that the longitudinal ridge is confined to the rays and absent in the less highly specialized sharks, greatly diminishes its security as a basis on which to rest a theory. In the rays, in correlation with their peculiar mode of life, the paired fins have undergone (in secondary development) enormous extension along the sides of the body, and their continuity in the embryo may well be a mere foreshadowing of this.

“An apparently powerful support from the side of embryology came in Dohrn and Rabl’s discoveries that in *Pristiurus* all the interpterygial myotomes produce muscle buds. This, however, was explained away by the Gegenbaur school as being merely evidence of the backward migration of the hind limb—successive myotomes being taken up and left behind again as the limb moved further back. As either explanation seems an adequate one, I do not think we can lay stress upon this body of facts as supporting either one view or the other. The facts of the development of the skeleton can not be said to support the fold view; according to it we should expect to find a series of metameric supporting rays produced which later on become fused at their bases. Instead of this we find a *longitudinal* bar of cartilage developing quite continuously, the rays forming as projections from its outer side.

“The most important evidence for the fold view from the side of comparative anatomy is afforded by: (1) The fact that the limb derives its nerve supply from a large number of spinal nerves, and (2) the extraordinary resemblance met with between the skeletal arrangements of paired and unpaired fins. The believers in the branchial-arch hypothesis have disposed of the first of these in the same way as they did the occurrence of interpterygial myotomes, by looking on the nerves received from regions of the spinal cord anterior to the attachment of the limb as forming a kind of trail marking the backward migration of the limb.

“The similarity in the skeleton is indeed most striking, though its weight as evidence has been recently greatly diminished by the knowledge that the apparently metameric segmentation of the skeletal and muscular tissues of the paired fins is quite secondary and does not at all agree with the metamery of the trunk. What resemblance there is may well be of a homoplastic character when we take into account the similarity in function of the median and unpaired fins, especially in such forms as *Raja* where the anatomical resemblances are especially striking. There is a surprising dearth of paleontological evidence in favor of this view.”

*Objections to the Theory of the Lateral Fold.*

The objection to the first view is its precarious foundation. Such lateral folds are found only in certain rays, in which they may be developed as a secondary modification in connection with the peculiar form of these fishes. Professor Kerr observes that this theory must be looked upon and judged:

“Just as any other view at the present time regarding the nature of the vertebrate limb, rather as a speculation, brilliant and suggestive though it be, than as a logically constructed theory of the now known facts. It is, I think, on this account allowable to apply to it a test of a character which is admittedly very apt to mislead, that of ‘common sense.’

“If there is any soundness in zoological speculation at all I think it must be admitted that the more primitive vertebrates were creatures possessing a notochordal axial skeleton near the dorsal side, with the main nervous axis above it, the main viscera below it, and the great mass of muscle lying in myotomes along its sides. Now such a creature is well adapted to movements of the character of lateral flexure, and not at all for movements in the sagittal plane—which would be not only difficult to achieve but would tend to alternately compress and extend its spinal cord and its viscera. Such a creature would swim through the water as does a Cyclostome, or a Lepidosiren, or any other elongated vertebrate without special swimming organs. Swimming like this, specialization for more and more rapid movement, would mean flattening of the tail region and its extension into an at first not separately mobile median tail fold. It is extremely difficult to my mind to suppose that a new purely *swimming* arrangement should have arisen involving up and down movement, and which, at its first beginnings, while useless as a swimming organ itself, must greatly detract from the efficiency of that which already existed.”

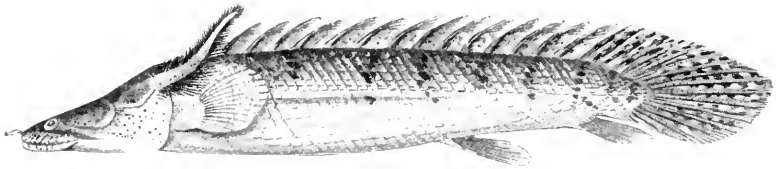
*Objections to Gegenbaur's Theory.*

We now return to the Gegenbaur view—that the limb is a modified gill septum.

“Resting on Gegenbaur's discovery already mentioned that the gill-rays in certain cases assume an arrangement showing great similarity to that of the skeletal elements of the archipterygium, it has, so far as I am aware, up to the present time received *no* direct support whatever of a nature comparable with that found for the rival view in the fact that, in certain forms at all events, the limbs actually do arise in the individual in the way that the theory holds they did in phylogeny. No one has produced either a form in which a gill septum becomes the limb during ontogeny, or the fossil remains of any form which shows an intermediate condition.

“The portion of Gegenbaur’s view which asserts that the biserial archipterygial fin is of an extremely primitive character is supported by a large body of anatomical facts, and is rendered further probable by the great frequency with which fins apparently of this character occur amongst the oldest known fishes. On the lateral fold view we should have to regard these as independently evolved, which would imply that fins of this type are of a very perfect character, and in that case we may be indeed surprised at their so complete disappearance in the more highly developed forms, which followed later on.”

As to Gegenbaur’s theory it is urged that no form is known in which a gill septum develops into a limb during the growth of the individual. The main thesis, according to Professor Kerr, “that the archipterygium was derived from gill-rays, is supported only by evidence of an indirect character. Gegenbaur in his very first suggestion of his theory pointed out, as a great difficulty in the way of its acceptance, the position of the



POLYPTERUS CONGICUS, A CROSSOPTERYGIAN FISH FROM CONGO RIVER; YOUNG WITH EXTERNAL GILLS. AFTER BOULENGER

limbs, especially of the pelvic limbs, in a position far removed from that of the branchial arches. This difficulty has been entirely removed by the brilliant work of Gegenbaur’s followers, who have shown from the facts of comparative anatomy and embryology that the limbs, and the hind limbs especially, actually have undergone, and in ontogeny do undergo, an extensive backward migration. In some cases Braus has been able to find traces of this migration as far forward as a point just behind the branchial arches. Now, when we consider the numbers, the enthusiasm, and the ability of Gegenbaur’s disciples, we cannot help being struck by the fact that the *only* evidence in favor of this derivation of the limbs has been that which tends to show that a migration of the limbs backwards has taken place from a region somewhere near the last branchial arch, and that they have failed utterly to discover any intermediate steps between gill-rays and archipterygial fin. And if for a moment we apply the test of common sense we cannot but be impressed by the improbability of the evolution of a gill septum, which in all the lower forms of fishes is fixed firmly in the body wall, and beneath its surface, into an organ of locomotion.

“May I express the hope that what I have said is sufficient to show in what a state of uncertainty our views are regarding the morphological



nature of the paired fins, and upon what an exceedingly slender basis rest both of the two views which at present hold the field?"

*Kerr's Theory of Modified External Gills.*

"It is because I feel that in the present state of our knowledge neither of the two views I have mentioned has a claim to any higher rank than that of extremely suggestive speculations that I venture to say a few words for the third view, which is avowedly a mere speculation.

"Before proceeding with it I should say that I assume the serial homology of fore- and hind-limbs to be beyond dispute. The great and deep-seated resemblances between them are such as to my mind seem not to be adequately explicable except on this assumption.

"In the Urodela (salamanders) the external gills are well-known structures—serially arranged projections from the body wall near the upper ends of certain of the branchial arches. When one considers the ontogenetic development of these organs, from knob-like outgrowth from the outer face of the branchial arch, covered with ectoderm and possessing a mesoblastic core, and which frequently if not always appear before the branchial clefts are open, one cannot but conclude that they are morphologically projections of the outer skin and that they have nothing whatever to do with the gill pouches of the gut wall. Amongst the Urodela one such gill projects from each of the first three branchial arches. In *Lepidosiren* there is one on each of branchial arches I.—IV. In *Polypterus* and *Calamoichthys* (*Erpetoichthys*) there is one on the hyoid arch. Finally, in many Urodelan larvæ we have present at the same time as the external gills a pair of curious structures called balancers. At an early stage of my work on *Lepidosiren*, while looking over other vertebrate embryos and larvæ for purposes of comparison, my attention was arrested by these structures, and further examinations by section and otherwise, convinced me that they were serial homologues of the external gills, situated on the mandibular arch. On then looking up the literature, I found that I was by no means first in this view. Rusconi had long ago noticed the resemblance, and in more recent times both Orr and Maurer had been led to the same conclusion as I had been. Three different observers having been independently led to exactly the same conclusions, we may, I think, fairly enough regard the view I have mentioned of the morphological nature of the balancers as probably a correct one.

"Here then, we have a series of homologous structures projecting from each of the series of visceral arches. They crop up on the Cross-opterygii, the Dipnoi and the Urodela, *i. e.*, in three of the most archaic of the groups of Gnathatomata. But we may put it in another way. The groups in which they do *not* occur are those whose young possess a

very large yolk-sac (or which are admittedly derived from such forms). Now wherever we have a large yolk-sac we have developed on its surface a rich network of blood vessels for purposes of nutrition. But such a network *must necessarily* act as an extraordinarily efficient organ of respiration, and did we not know the facts we might venture to prophesy that in forms possessing it any other small skin organ of respiration would tend to disappear.

“No doubt these external gills are absent also in a few of the admittedly primitive forms such as, *e. g.*, (neo-) *Ceratodus*. But I would ask that in this connection one should bear in mind one of the marked characteristics of external gills—their great regenerative power. This involves their being extremely liable to injury and consequently a source of danger to their possessor. Their absence, therefore, in certain cases may well have been due to natural selection. On the other hand, the *presence* in so many lowly forms of these organs, the general close similarity in structure that runs through them in different forms and the exact correspondence in their position and relations to the body can, it seems to me, *only* be adequately explained by looking on them as being homologous structures inherited from a common ancestor and consequently of great antiquity in the vertebrate stem.”

As to the third theory, Professor Kerr suggests tentatively that the external gill, as developed in salamanders and in the young *Lepidosiren*, may be the structure modified to form the paired limbs. Of the homology of fore and hind limbs and consequently of their like origin there can be no doubt.

The general gill structures have, according to Kerr, “the primary function of respiration. They are also, however, provided with an elaborate muscular apparatus comprising elevators, depressors and adductors, and larvæ possessing them may be seen every now and then to give them a sharp backward twitch. They are thus *potentially* motor organs. In such a Urodele as *Amblystoma* their homologues on the mandibular arch are used as supporting structures against a solid substratum exactly as are the limbs of the young *Lepidosiren*.

“I have, therefore, to suggest that the more ancient Gnathostomata possessed a series of potentially motor, potentially supporting structures projecting from their visceral arches; it was inherently extremely probable that these should be made use of when actual supporting and motor appendages had to be developed in connection with clambering about a solid substratum. If this had been so we should look upon the limb as a modified external gill; the limb girdle, with Gegenbaur, as a modified branchial arch.

“This theory of the vertebrate paired limb seems to me, I confess, to be a more plausible one on the face of it than either of the two which

at present hold the field. If untrue it is so dangerously plausible as to surely deserve more consideration than it appears to have had. One of the main differences between it and the other two hypotheses is that, instead of deriving the swimming fin from the walking and supporting limb, it goes the other way about. That this is the safer line to take seems to me to be shown by the consideration that a very small and rudimentary limb could *only* be of use if provided with a fixed *point d'appui*. Also on this view, the pentadactyle limb and the swimming fin would probably be evolved independently from a simple form of limb. This would evade the great difficulties which have beset those who have endeavored to establish the homologies of the elements of the pentadactyle limb with those of any type of fully-formed fin."

#### *Uncertain Conclusions.*

In conclusion, we may say that the evidence of embryology in this matter is inadequate, that of morphology is inconclusive and perhaps the final answer may be given by paleontology. If the records of the rocks were complete they would be decisive. At present we have to decide which is the more primitive of two forms of pectoral fin actually known among fossils. That of *Cladoselache* is a low, horizontal fold of skin, with feeble rays, called by Cope *ptychopterygium*. That of *Pleuracanthus* is a jointed paddle-shaped appendage with a fringe of rays on either side. In the theory of Gegenbaur and Kerr *Pleuracanthus* must be, so far as the limbs are concerned, the form nearest the primitive limb-bearing vertebrate. In Balfour's theory *Cladoselache* is nearest the primitive type from which the other and with it the archipterygium of later forms may be derived.

Boulenger and others question even this, believing that the archipterygium in *Pleuracanthus* and that in *Neo-Ceratodus* and its Dipnoan and Crossopterygian allies have been derived independently from the archipterygium in the primitive sharks. In the one theory, the type of *Pleuracanthus* would be ancestral to the other sharks, on the one hand, and to Crossopterygians and all higher vertebrates on the other. With the theory of the origin of the pectoral from a lateral fold, *Pleuracanthus* would be merely a curious specialized offshoot from the primitive sharks, without descendants and without special significance in phylogeny.

As elements bearing on this decision we may note that the tapering unspecialized diphycecal tail of *Pleuracanthus* seems very primitive in comparison with the short heterocercal tail of *Cladoselache*. This evidence, perhaps deceptive, is balanced by the presence on the head of *Pleuracanthus* of a highly specialized serrated spine, evidence of a far from primitive structure.

## DOMESTIC AND INTERCOLLEGIATE ATHLETICS.\*

BY PROFESSOR CALVIN M. WOODWARD,  
WASHINGTON UNIVERSITY.

I NEED no statistics to prove that engineering schools and engineering departments as a rule take no active part in intercollegiate athletics. There may be exceptions, but we never hear of the Massachusetts Institute of Technology, or Troy, or Worcester, or Stevens, on the gridiron or on the diamond or in regattas. How the teams are made up at Harvard and Yale, Cornell, Wisconsin, Michigan and Pennsylvania, I do not know, but I suspect that student engineers are generally 'too busy' to find time, and too interested in their work to feel an overmastering craving for athletics, so the athletic spirit which occasionally bursts into flame is gradually quenched by the steady stream of 'lectures' and 'laboratory calls.'

Doubtless we have all been somewhat to blame in this matter. We have seen so much that the student engineer ought to get and to do, and so much that the future engineer ought to know and to be, that we have pre-empted the students' hours of play and recreation as well as their hours of study, and have overlooked the plain duty of attending to the physical natures and appetites of the young men in our charge.

It is my conviction that we have made a serious mistake. To a certain degree we have defeated ourselves. Faculties and boards of control have great responsibilities in the direction of athletics, which responsibilities in a vast majority of cases they fail to meet properly. Sometimes they grossly mismanage matters, but more often they neglect them and try to ignore them. They let things drift. They admit in a half-hearted way that physical culture is a good thing, but they discourage every development of athletics under student management, while they inaugurate no adequate management of their own. In many cases athletic managers, supported as they are by strong popular favor, are a sort of terror to tutors and professors; they compel them to assist or at least to wink at deception and dishonesty.

It is useless to expect clean athletics when the members of the faculty participate in or condone fraud and unfairness. I do not willingly admit the shortcomings of college officers, but their own confessions can not be gainsaid. I know of no more corrupting influ-

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\* Read before the Society for the Promotion of Engineering Education, Pittsburgh meeting, July, 1902.

ence upon students than a dishonest faculty. You would be astonished and mortified if you knew the extent to which professors in reputable institutions make false returns of the standing of players supposed to be indispensable to the success of a college team. The excuses they offer are that they must make allowance for different standards, and hence some 'diplomacy' is necessary to secure a fair game; and secondly that the demand for leniency is so strong that it becomes a duty to the institution they represent to exercise a discreet indulgence. It is extremely discouraging, it is said, to make a poor showing in what are popularly held to be manly sports, through the maintenance of high standards of scholarship. In one institution a student is held to be disqualified by dropping below an average grading of sixty or seventy per cent.; in another he is allowed to 'pass' on an average of thirty or forty per cent. Similarly the phrases 'college grade' and 'post-graduate' mean little or much according to usage. It is clear that the temptations to place new and unwonted meanings to the word 'conditioned' are very strong.

Has not the time arrived for a general conference of representatives from all institutions for higher education, whether literary or technical, for the purpose of formulating rules and adopting uniform standards in so far as they bear upon the question of eligibility to athletic teams? All admit that high standards are necessary in determining a man's worthiness to be proclaimed an attorney, an architect, an engineer or a physician; while a more moderate standard may be admissible in the general studies which are regarded as in no way professional. A university may require a passing grade of forty per cent. in its college of letters, but insist upon sixty or seventy per cent. in its schools of engineering, law and medicine. Evidently there should be no such discrepancy in determining athletic eligibility for intercollegiate games.

Local conferences have already been held, but I suggest an effort to bring together all institutions east, west, north and south, and if possible to adopt standards and rules that all can faithfully observe. My object to-day is to lay before you some considerations in favor of the systematic management of both domestic and intercollegiate athletics in every school or college of engineering, and to submit some practical suggestions in regard to the latter feature.

I have recently given some thought to manly sports, and I venture a few words in regard to their value in every scheme of all-round education.

*The General Value of Systematic Athletics.*

The modern development of athletics has resulted from a combination of causes. The physical asceticism of the middle ages has

passed away. Muscular Christianity is now the rule and not the exception. A weak, stunted and famished body is no longer regarded as a sure abode, not even as a promise, of a purified, robust spirit. The Roman motto of a sound mind only in a sound body is in universal favor.

Again, a continually diminishing proportion of the people are engaged in reducing the wilderness, in raising the crops and in rearing the stock which are needed for food; and as for the rest of us, we are walled up in great cities, roofed in from the sunlight and pure air, and then given a maximum of brain work with as little as possible of physical exercise. This state of things can not long endure without serious injury to our manhood. Close observers of the American people state that nervous diseases and all complaints arising from excessive brain work, combined with a lack of physical health and vigor, are steadily increasing, and if we would avert the threatened physical degeneracy of our nation we must consciously introduce physical culture and athletic games which shall strengthen our bodies and invigorate our minds.

The army and navy draw but a very small fraction of our youth to the fascinations of military or marine life, and even the cadets must have their sports and games in addition to the routine of drill.

Perhaps we can leave mere fun to the children, but contests which tax one's strength and skill have perpetual charm for young men who are at an age to be delightfully conscious of their strength, and increasingly ambitious to exhibit their skill. Now, more than ever in history, opportunities for exhibiting strength and skill in competition must be manufactured. In primitive days the young farmer, the builder, the hunter, the soldier, found abundant opportunity to exhibit his prowess without modern athletics. The marked development of athletics during the last four years is due to no change in the mental, moral and physical tastes and appetites of young men, but to a social development which renders necessary special provision for the gratification of those normal tastes and appetites.

#### *Manly Sports vs. Gymnastics.*

I find it necessary to make a distinction between manly sports and gymnastics. They agree generally in affording athletic culture, but they differ in the order of importance they attach to exercise and to sport. Gymnastic training makes the exercise the main thing, while the pleasure and passion for competition and victory are secondary. It is just the other way with athletic games; with them the game is foremost, while the physical and moral benefits are incidental.

'Athletics begin where gymnastics leave off.' There is no antag-

onism between them; the one supplements the other. Every participator in field sports should bring to his games a body well developed by judicious gymnastic training. On the other hand the trained gymnast is entitled to the peculiar delights and rewards of athletic games.

*The Relation of Physical to Mental Vigor.*

There is in the minds of many people a natural and reasonable fear that an enthusiasm for athletics involves a loss of interest in scholarship, in the high ideals of the spirit and in the details of a chosen course of study. It is feared that even when one does not lose his interest in study in consequence of his interest in athletics, he must suffer a loss of the time which athletics require. I doubt if any of these fears are well grounded. There is great economy of time in spending a proper amount of it in healthful, invigorating exercise; and again there is a great waste of time in lingering and poring long over one's books. On this point I can speak from considerable experience and observation. Again and again I have felt it my duty to order students to close their books and go out for exercise or for a game. The physical ills that students suffer from as a rule arise from too little exercise, not from too much.

Says Dr. Mitchell, of Philadelphia, in a little book labeled 'Wear and Tear': 'A proper alternation of physical and mental labor is fitted to insure a lifetime of wholesome and vigorous intellectual exertion.'

Again he says: 'Eat regularly and exercise freely, and there is scarce a limit to the work you may get out of the thinking organs.' Mental action is a distinctly physical process. Without the free circulation of blood in the brain there can be neither thought nor sensation, emotion nor ideas, and the quality of the mental action is largely dependent upon the quality of this supply of blood. Here then seems to lie the solution of this vitally important problem. We succeed best not by diminishing the amount of brain work, but by so regulating the manner of our lives as to make that amount of work harmless. The time we spend in judicious and absorbing exercise is not lost.

Will you pardon me for drawing upon my personal experience? I am old enough to draw some safe conclusions as to the immediate and permanent value of moderate athletics.

When I entered Harvard there was no gymnasium, no baseball, no Rugby football, no athletics of any kind except rowing, and that was too expensive for me. So I got on a while without any exercise. I had always been accustomed to an active life on a farm, and I was soon in a bad way. Fortunately my people became alarmed and insisted upon my joining a boat club; so I joined a club near the end of my

Freshman year. I enjoyed the sport, became a 'good oar,' and rapidly recovered my strength and vigor. From that time I joined regularly in the sports of the seasons as they came round. I have a set of heavy Indian clubs which I have used for forty-five years.

During my Senior year in college a vacancy occurred in the university crew and it seemed to be necessary for me to pull an oar in the 'Harvard.' There were special reasons for hard study in a particular direction on my part, and I was very unwilling to abridge or interfere with my hours for work. Moreover, I was a member of a cricket club which had been challenged to play by a lower class, and I could not refuse to meet with the club during practice hours.

Meanwhile, I had, of course, my daily lessons and exercises to prepare, and the regular recitations and lectures to attend. With reason, I said that my hands were already full; and yet the case was so urgent, and I loved rowing so much, that I concluded to try the experiment and see if, with more regular habits of eating and sleeping, and a steady, hard pull of eight miles per day, I could not do as much work in the time that remained as I had been accustomed to. I drank neither tea nor coffee, used no tobacco, and indulged in neither wine nor beer; I ate neither puddings nor pies, strawberries nor ice cream. My diet was chiefly beef, mutton, potatoes, oatmeal, bread and milk. I went to bed at ten o'clock. To my surprise, I found I could do about two hours' steady work in one, my head was as clear as a bell, I was as strong as an ox, and I had never felt so gloriously in my life. I should add that I have never had any reason to regret the decision I then made.

My own experience thus confirms the statement of Dr. Mitchell, and I have no doubt that your experience and observation point in the same direction. One conclusion then seems to be reached: To be able to perform our intellectual labor successfully, we must alternate it with active exercise which is intense enough to absorb the attention without taxing those areas of the brain that need rest. Such active exercise as a general thing is found in the manly sports. Therefore, our intellectual well-being demands as a general thing that we participate in them rationally and regularly.

#### *The Moral Influence.*

But there is more in athletics than mere physical and mental health. There is a moral training which is of equal if not of greater value. One acquires from successful athletics as from gymnastics a mental dexterity which is of infinite worth. In an emergency, one must not lose his head or forget his hands. Be it a shipwreck, a midnight fire, a school panic, a summer camp—the man of brain and brawn is a saving help.



The moral and mental value of high-class athletics is well pointed out by the late President Francis A. Walker:

It must be said that the favorite athletics of to-day are, in great measure, such as call for more than mere strength and swiftness. They demand, also, steadiness of nerve, quickness of apprehension, coolness, resourcefulness, self-knowledge, self-reliance; further still, they often demand of the contestants the ability to work with others, power of combination, readiness to subordinate individual impulses, selfish desires, and even personal credit, to a common end. These are all qualities useful in any profession; in some professions they are of the highest value. So genuine does this advantage appear to me that were I Superintendent of the Academy at West Point, I should encourage the game of football among the cadets as a military exercise of no mean importance. It is the opinion of most educated Englishmen that the cultivation of this sport has had not a little to do with the courage, address, and energy with which the graduates of Rugby, Eton, and Harrow, have made their way through dangers and over difficulties in all quarters of the globe.

Rugby football has taken a strong hold upon popular favor and no outdoor entertainment can command so large an attendance of respectable people as a game of football between two teams of college boys. Of course there is mixed with a love of the game pure and simple a great deal of college spirit and college pride.

But there is something more. There is a moral force that is mighty and strong, and which only a player truly knows. The player alone feels the wild joy of the charge, the struggle, the tackle and the gauntlet. None but the player feels the absolute necessity of obeying orders, of cooperation, of vigilance, of instant decision and prompt action. A novice at the game subordinates the care of the ball to the care of himself; he can not help this; he feels that his person is worth any number of points in the game, and he risks a defeat to avoid a bruise or a sprain; but when he is trained and can fall safely without thinking of himself, he subordinates himself to the requirements of the game and puts his whole soul as well as his body into the play.

Experienced players can see great moral gain in all this, and in the sense of obligation to cherish the body so that it may always be at its best. Men who have made athletics a business have taught us that certain things weaken and enervate a man and make him less noble and less manly; so the football player must avoid them, not only while he plays, but as long as he wishes to be noble and manly.

#### *President Thwing's Views.*

In a recent number of the *North American Review*, President Thwing of the Western Reserve University elaborates 'The Ethical Functions of Football.' His points are summarized as follows: (1) Football represents the inexorable. It embraces things that must be done at specific times, places and in specific ways. (2) Football

illustrates the value of the positive. It teaches one to do. It is action, not inaction. It bucks, it punches, it breaks, it runs, it goes, it goes through the line, it goes round the ends, but it goes. (3) Football represents the value of a compelling interest. There are other interests, good and bad, but certain temperaments need something like football to arouse them. Speaking of a lazy boy, Emerson said: 'Set a dog on him, send him West, do something to him.' Football serves such a purpose. (4) Football embodies the process of self-discovery. Every football game is a crisis. It not only creates power and develops power; it also discovers the possession or the lack of power. (5) Football develops self-restraint. Self-restraint, or more broadly, self-control, is one of the primary signs of the gentleman. Football demands self-restraint for it teems with temptations to do mean and nasty things. It thus helps to make the finest type of a gentleman.

Few college men would claim all the above, but if we grant the half, football is amply justified, and deserves general support.

It is interesting to note the favor with which athletics are received by educational leaders on all sides. I quote a paragraph from Supt. Thomas M. Balliet, one of the ablest of Massachusetts educators:

The need of systematic physical training as a part of the legitimate work of the public schools is to-day not questioned by anyone who is informed on the subject. The health and care of the body is as much the concern of the school as the training of the mind, and this fact is coming to be very widely recognized by school committees. . . . The best authorities on physical training place much less emphasis at present than formerly on formal gymnastics, and far more on free, spontaneous outdoor play as a means of physical culture.

#### *Unmanly Interference.*

In the interest of fairness and good breeding General Walker protests vigorously against a style of systematic cheering or yelling, which directly or indirectly tends to disconcert and impede opposing players. In this protest I cordially join. Good play should be generously recognized no matter who makes it, and neither the side lines nor the grand stand should say or do anything to embarrass or confuse visiting players. It ceases to be a manly sport when ungentlemanly tricks are resorted to. Fair play means the golden rule; treat others as you would wish to be treated in a similar situation. I do not say, as you would *expect* to be treated, but as you would *wish* to be treated. I regret that in many a community visiting clubs are treated by the spectators in such a disgraceful way that one is forced to infer that they do not know what fair play and good breeding mean.

Last spring I witnessed some athletic contests between the representatives of different educational institutions in a neighboring park. One

institution was represented by a big-mouthed man who sat on a front seat, and made rude and insulting remarks in a loud voice just when men whom he wished to disconcert were on the point of a jump or a vault or a throw. I had no interest in any particular player, but I was intensely disgusted at that man's behavior, and I felt deeply humiliated to find myself in such company. Had I been clothed with the proper authority, I would have had that boor promptly expelled from the park. I have witnessed other exhibitions of unfairness and bad manners on the part of the spectators, and I have felt ashamed for my city and State, but nothing quite as bad as that I saw last spring. I hope no such unfairness will ever be seen on your campus or on mine. We must train our audiences 'to be as virtuous and as impartial as the Greek chorus, to the end that the game may be played by the players and not by the spectators'. We

Must set the cause above renown,  
And love the game beyond the prize.

Professionalism has been the curse of intercollegiate contests in many of the younger and smaller institutions of the west. Even in the east, eligibility rules have been agreed to with difficulty, and then readily evaded or ignored. It has been rare to find a college team where every member was a *bona fide* student playing without compensation in some shape or form, such as remittance of fees and dues, payment of personal expenses, or excuse from lectures and examinations; while veteran players, almost gray in athletic service, are received under the ample cloak of 'post-graduates.'

I close with some practical suggestions based upon my experience as chairman of an athletic board, and upon a study of the conditions which obtain elsewhere.

The following rules and definitions are respectfully submitted:

#### *Eligibility.*

1. To be eligible to membership in a team representing the institution one must be a *bona fide* student, doing full work as a 'regular' or a 'special.'

2. His average scholastic standing must not be less than sixty per cent. and in no single branch or study shall his record for the last quarter be less than fifty per cent.

3. If a 'dropped' student, or a 'not-promoted' student, he shall not be eligible till after one year, either in the same department or in a different department. (For example, a student not-promoted in a school of engineering can not secure eligibility by withdrawing and entering the college of letters or the law school.)

4. He must not have been a representative college athlete for four years either in one, or more than one, institution. The four years begin with the date of his first appearance on a representative team; no allowance is to be made for not playing, except in the case of exclusion under Rule 3.

5. He must hold a certificate of actual physical soundness, and a muscular development sufficient to justify his taking part in a proposed athletic contest; this should be signed by the gymnastic director if a physician, or by the highest medical authority connected with the institution.

6. He must be able to swim if he proposes to row in a college boat either for practice or in a regatta.

7. He must not be in arrears to the local athletic association.

8. He must not be receiving and must never have received compensation for playing or teaching others to play athletics. Compensation is here held to include not only salary, but rebates and remission of fees, ordinary personal expenses, a share in the gate money, or financial aid in any other direct or indirect form.

9. He must be free or acquitted of all charges of improper and ungentlemanly conduct in his athletic record.

All the above rules shall hold as well for substitutes and ranking candidates for positions on a college team.

#### *Miscellaneous Rules.*

1. An athletic committee appointed by the president or elected by the faculty shall represent the faculty and board of control in all athletic matters. The chairman shall certify to the eligibility of every man on the team, and whenever asked for it he shall furnish a certified copy of the athletic record of any man on the team.

2. The athletic committee shall pass upon the time, place and conditions of a proposed intercollegiate contest, and shall determine the amount of absence from college exercises a member of the team may have during a season.

3. The athletic committee shall at all times be free to examine and audit the accounts of the treasurer of the athletic association.

4. Contracts for coaches, trainers, grounds, etc., shall not be valid until approved by the athletic committee.

5. Except for practice and informally, *i. e.*, not for public exhibition, a university team shall not play with teams from preparatory schools nor with teams from non-educational institutions.

6. No university team shall play formally or informally with a professional team or with a team containing professional players.

7. A university team shall not play with the team of another college or university unless every member of the opposing team be eligible under rules substantially the same as above.

8. No personal expenses for travel, clothing, training or medical attendance shall be paid for students not enrolled as members of teams and substitutes.

9. If a member of a team becomes ineligible for any reason, he shall at once be dropped from the team and a promotion shall be made from the waiting list.

10. If a player be dropped from a team on account of delinquency or dishonorable conduct, he shall at once cease to wear athletic honors in the way of numerals or letters.

11. Members of a university team shall not have played on a team of similar character during the preceding summer vacation.

12. Managers of teams shall be elected by the athletic association.

13. Each team of actual players shall at the end of a season elect the captain for the succeeding season.

14. Managers in consultation with the athletic committee shall make up the schedule of games for the season.

15. Captains with the approval of the athletic committee shall make up their teams from the eligible lists.

The object of all athletic organizations shall be understood to be chiefly the following, arranged in the order of importance, the most important first:

(a) Physical culture, with the mental alertness and moral stability which follows in its train; consequently the greater the number and variety of athletic games and teams the better.

(b) To meet the normal and healthy demand of young men for manly sports, for recreation and relaxation, and to relieve the tedium of much study.

(c) To foster to a reasonable extent local pride and emulation, to create an *esprit de corps*, and to promote harmony and good-fellowship between students and faculty and between different departments.

(d) To advertise a college or university by arousing an interest among preparatory students and others who otherwise might never be attracted to the advantage and enjoyments of higher education.

To secure these objects every student should be encouraged on entrance to immediately submit himself to a physical examination, and with the advice of the physical director or the athletic committee not only begin regular gymnastic practice, but join a branch of the association devoted to systematic practice in some athletic game.

Every program of hours in a school of engineering as well as in a college of letters should recognize the demands of rational athletics.

RECENT ADVANCES IN SCIENCE, AND THEIR BEARING ON  
MEDICINE AND SURGERY.\*

BY PROFESSOR RUDOLF VIRCHOW.

THE honor of being invited to deliver the second Huxley lecture has deeply moved me. How beautiful are these days of remembrance which have become a national custom of the English people! How touching is this act of gratitude when the celebration is held at the very place wherein the genius of the man whom it commemorates was first guided toward its scientific development! We are filled not alone with admiration for the hero, but at the same time with grateful recognition of the institution which planted the seed of high achievement in the soul of the youthful student. That you, gentlemen, should have entrusted to a stranger the task of giving these feelings expression seemed to me an act of such kindly sentiment, implying such perfect confidence, that I at first hesitated to accept it. How am I to find in a strange tongue words which shall perfectly express my feelings? How shall I, in the presence of a circle of men who are personally unknown to me, but of whom many knew him who has passed away and had seen him at work, always find the right expression for that which I wish to say as well as a member of that circle itself could? I dare not believe that I shall throughout succeed in this. But if, in spite of all, I repress my scruples it is because I know how indulgently my English colleagues will judge my often incomplete statements, and how fully they are inclined to pardon deficiency in diction if they are convinced of the good intentions of the lecturer.

*Professor Huxley's Work.*

I may assume that such a task would not have been allotted to me had not those who imposed it known how deeply the feeling of admiration for Huxley is rooted within me, had they not seen how fully I recognized the achievements of the dead master from his first epoch-making publications, and how greatly I prized the personal friendship which he extended toward me. In truth, the lessons that I received from him in his laboratory—a very modest one according to present conditions—and the introduction to his work which I owe to him form

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\* The second Huxley lecture, delivered at the opening of the winter session of Charing Cross Hospital Medical School, on October 3, 1898. Originally printed in the *London Times*.

one of the pleasantest and most lasting recollections of my visit to Kensington. The most competent witness of Huxley's earliest period of development, Professor Foster, presented in the first of these lectures a picture of the rapidly increasing extension of the biological knowledge which must have excited not only our admiration but also the emulation of all who study medicine. Upon me the duty is incumbent of incorporating with this presentment the newer strides of knowledge and of stating their influence upon the art of healing. So great a task is this that it would be presumptuous even to dare to attempt its accomplishment in a single lecture. I have decided, therefore, that I must confine myself to merely sketching the influence of biological discoveries upon medicine. In this way, also, will the example of Huxley be most intelligible to us. I must here make a confession. When I tried to ascertain how much time would be required to deliver my lecture as I had prepared it, I found, to my regret, that its delivery would occupy nearly double the time assigned to me. I had therefore to reduce it to about half of its original dimensions. This could only be done by means of very heroic cuts, seriously damaging in more than one place my chain of ideas.

*The Beginnings of Biology.*

Huxley himself, though trained in the practical school of Charing Cross Hospital, won his special title to fame in the dominion of biology. As a matter of fact, at that time even the name of biology had not come into general use. It was only recently that the idea of life itself obtained its full significance. Even in the late Middle Ages it had not sufficient strength to struggle through the veil of dogmatism into the light. I am glad to be able to-day for the second time to credit the English nation with the service of having made the first attempts to define the nature and character of life. It was Francis Glisson who, following expressly in the footsteps of Paracelsus, investigated the *principium vite*. If he could not elucidate the nature of life, he at least recognized its main characteristic. This is what he was the first to describe as "irritability," the property on which the energy of living matter depends. How great was the step from Paracelsus to Glisson and, we may continue, from Glisson to Hunter! According to Paracelsus life was the work of the special *spiritus*, which set material substance in action, like a machine; for Glisson, matter itself was the *principium energeticum*. Unfortunately, he did not confine this dictum to living substances only, but applied it to substance in general, to all matter. It was Hunter who first announced the specific nature of living matter as contrasted with nonliving, and he was led to place a *materia vite diffusa* at the head of his physiological and pathological views. According to the teaching of Hewson and Hunter, the blood

supplied the plastic materials of physiology as well as the plastic exudates of pathology. Such was the basis of the new biological method, if one can apply such an expression to a still incomplete doctrine, in 1842, when Huxley was beginning his medical studies at Charing Cross Hospital. It would lead too far afield were I to recount in this place how it happened that I myself, like Huxley, was early weaned from the pernicious doctrines of humoral pathology.

*The Development of Biology.*

When Huxley himself left Charing Cross Hospital, in 1846, he had enjoyed a rich measure of instruction in anatomy and physiology. Thus trained, he took the post of naval surgeon, and by the time that he returned, four years later, he had become a perfect zoologist and a keen-sighted ethnologist. How this was possible anyone will readily understand who knows from his own experience how great the value of personal observation is for the development of independent and unprejudiced thought. For a young man who, besides collecting a rich treasure of positive knowledge, has practiced dissection and the exercise of a critical judgment, a long sea voyage and a peaceful sojourn among entirely new surroundings afford an invaluable opportunity for original work and deep reflection. Freed from the formalism of the schools, thrown upon the use of his own intellect, compelled to test each single object as regards properties and history, he soon forgets the dogmas of the prevailing system and becomes first a skeptic and then an investigator. This change, which did not fail to affect Huxley, and through which arose that Huxley whom we commemorate to-day, is no unknown occurrence to one who is acquainted with the history not only of knowledge, but also of scholars. We need only to point to John Hunter and Darwin as closely allied examples. The path on which these men have achieved their triumphs is that which biology in general has trodden with ever-widening strides since the end of last century—it is the path of genetic investigation. We Germans point with pride to our countryman who opened up this road with full conviction of its importance, and who directed toward it the eyes of the world—our poet-prince Goethe. What he accomplished in particular from plants others of our fellow-countrymen achieved from animals—Wolf, Meckel, and our whole embryological school. As Harvey, Haller, and Hunter had once done, so these men began also with the study of the ‘ovulum,’ but this very soon showed that the egg was itself organized, and that from it arose the whole series of organic developments. When Huxley, after his return, came to publish his fundamental observations, he found the history of the progressive transformations of the contents of the egg already verified, for it was by now known that the egg was a cell, and that from it fresh cells and



from them organs arose. The second of his three famous papers—that on the relationship between man and the animals next beneath him—limned in exemplary fashion the parallelism in the earliest development of all animal beings. But beyond this it stepped boldly across the border line which tradition and dogma had drawn between man and beast. Huxley had no hesitation in filling the gaps which Darwin had left in his argument, and in explaining that “in respect of substance and structure man and the lower animals are one.” Whatever opinion one may hold as to the origin of mankind, the conviction as to the fundamental correspondence of human organization with that of animals is at present universally accepted.

*Omnis Cellula e Cellula.*

The greatest difficulty in the advance of biology has been the natural tendency of its disciples to set the search after the unity of life in the forefront of their inquiries. Hence arose the doctrine of vital force, an assumption now discarded, but still revealing its influence from time to time in isolated errors. No satisfactory progress could be made till the idea of highly organized living things as units had been set aside; till it was recognized that they were in reality organisms, each constituent part of which had its special life. Ultimate analysis of higher animals and plants brings us alike to the cell, and it is these single parts, the cells, which are to be regarded as the factors of existence. The discovery of the development of complete beings from the ova of animals and the germ-cells of plants has bridged the gap between isolated living cells and complete organisms, and has enabled the study of the former to be employed in elucidating the life of the latter. In a medical school where the teaching is almost exclusively concerned with human beings this sentence should be writ large: “The organism is not an individual, but a social mechanism.” Two corollaries must also be stated—(1) that every living organism, like every organ and tissue, contains cells; (2) that the cells are composed of organic chemical substances, which are not themselves alive. The progress of truth in these matters was much retarded by that portion of Schwann’s cell theory, which sought to establish the existence of free cell formation, which really implied the revival of the old doctrine of spontaneous generation. This belief was gradually driven out of the domain of zoology, but in connection with the formation of plastic exudates found a sanctuary in that of pathology. I myself was taught the discontinuity of pathological growths—a view which would logically lead back to the origin of living from nonliving matter. But enlightenment in this matter came to me. At the end of my academical career I was acting as clinical assistant in the eye department of the Berlin Hospital, and

I was struck by the fact that keratitis and corneal wounds healed without the appearance of plastic exudation, and I was thus led to study the process of inflammation in other nonvascular structures, such as articular cartilages and the intima of the larger vessels. In no one of these cases was plastic exudation found, but in all of them were changes in the tissue cells. Turning next to vascular organs, and in particular those which are the common seats of exudation processes, I succeeded in demonstrating that the presence of cells in inflammatory exudates was not the result of exudation, but of multiplication of preexisting cells. Extending this to the growth in thickness of the long bones—which was ascribed by Duhamel to organization of a nutritious juice exuded by the periosteal vessels—I was thus eventually able to extend the biological doctrine of *omnis cellula e cellula* to pathological processes as well; every new formation presupposing a matrix from which its cells arise and the stamp of which they bear.

#### *Heredity.*

Herein also lies the key to the mystery of heredity. The humoral theory attributed this to the blood, and based the most fantastic ideas upon this hypothesis. We know now that the cells are the factors of the inherited properties, the sources of the germs of new tissues and the motive power of vital action. It must not, however, be supposed that all the problems of heredity have thus been solved. Thus, for instance, a general explanation of theromorphism, or the appearance of variations recalling the lower animals, is still to be found. Each case must be studied on its merit, and an endeavor made to discover whether it arose by atavism or by hereditary transmission of an acquired condition. As to the occurrence of the latter mode of origin, I can express myself positively. Equally difficult is the question of hereditary diseases; this is now generally assumed to depend on the transmission of a predisposition which is present, though not recognizable, in the earliest cells, being derived from the parental or maternal tissues. But the most elaborately constructed doctrines as to the hereditariness of a given disorder may break down before the discovery of an actual *causa viva*. A notable example of this is found in the case of leprosy, the transmission of which by inheritance was at one time so firmly believed in that thirty years ago a law was nearly passed in Norway forbidding the marriage of members of leprosy families. I myself, however, found that a certain number of cases at any rate did not arise in this way, and my results were confirmed by the discovery of the leprosy bacillus by Armauer Hansen. In a moment the hereditary theory of the disease was overthrown and the old view of its acquirement by contagion restored. Precisely the same happened a few decades earlier with regard to favus and scabies. Another instructive

condition is that known as Heterotopia, in which fragments of tissues or organs are found dwelling in a situation other than that which is normal to them. This is particularly the case with certain glands, such as the thyroid and suprarenal, but is also known with cartilage, teeth, and the various constituents of dermoids. It no doubt occurs by process of transplantation, the misplaced tissues developing no new properties, but merely preserving their normal powers of growth. The attempt to generalize from this fact and to attribute all tumor formations to this cause carries the idea beyond its proper scientific limits.

#### *Parasitism and Infection.*

With regard to the subject of parasitism, the progress of scientific observation was retarded for centuries by the prevalence of the assumption made by Paracelsus that disease in general was to be regarded as a parasite. Pushed to its logical conclusion, this view would imply that each independent living part of the organism would act as a parasite relatively to the others. The true conception of a parasite implies its harmfulness to its host. The larger animal parasites have been longest known, but it is not so many years since their life history has been completely ascertained and the nature of their cysts explained, while an alternation of generations has been discovered in those which are apparently sexless. Very much more recent is the detection of the parasitic protozoa, by which the occurrence of the tropical fevers may be explained. As yet we have not complete knowledge as to their life history, but we hold the end of the chain by which this knowledge can be attained. The élite of the infectious diseases are, however, the work of the minutest kind of parasitic plants, bacteria, the scientific study of which may be said to date from Pasteur's immortal researches upon putrefaction and fermentation. The observation of microbes under exact experimental conditions, and the chemical investigation of their products opened up the modern field of bacteriology, a science among the early triumphs of which were the discoveries of the bacilli of tubercle and Asiatic cholera by Robert Koch. In connection with this subject three important landmarks require comment. One is the necessity for distinguishing between the cause and the essential nature of infectious diseases, the latter of which is determined by the reaction of the tissues and organs to microbes. Secondly, there is the relation between the smaller parasites and the diseases determined by them. This may be summed up in the general word [introduced by Professor Virehow himself] "infection." But to assume that all infections result from the action of bacteria is to go beyond the domain of present knowledge, and probably to retard further progress. The third point is the question as to the mode of action of infection. It is only the larger parasites

whose main effect is the devouring of parts of their hosts; the smaller act mainly by the secretion of virulent poisons. The recognition of this latter fact has led to the brilliant work of Lister on the one hand and to the introduction of serum therapeutics on the other.

#### *Antiseptic Surgery.*

It would be carrying coals to Newcastle were I to sketch in London the beneficial effects which the application of methods of cleanliness has exercised upon surgical practice. In the city wherein the man still lives and works who, by devising this treatment has introduced the greatest and most beneficent reform that the practical branches of medical science have ever known, everyone is aware that Lord Lister, on the strength of his original reasoning, arrived at practical results which the new theory of fermentative and septic processes fully confirmed. Before anyone had succeeded in demonstrating by exact methods the microbes which are active in different diseases, Lister had learned, in a truly prophetic revelation, the means by which protection against the action of putrefactive organisms can be attained. The opening up of further regions of clinical medicine to the knife of the surgeon and a perfect revolution in the basis of therapeutics have been the consequence. Lord Lister, whom I am proud to be able to greet as an old friend, is already and always will be reckoned among the greatest benefactors of the human race. May he long be spared to remain at the head of the movement which he called into existence.

#### *Artificial Immunization.*

It remains for me to say a word concerning the other great problem, the solution of which the whole world is awaiting with anxious impatience. I refer to the problem of immunity and its practical corollary, artificial immunization. It has already happened once that an Englishman has succeeded in applying this to the definite destruction of at least one of the most deadly infectious diseases. Jenner's noble discovery has stood its trial as successfully, except in popular fancy, as he hoped. Vaccine is in all hands; vaccination is, with the aid of governments, spreading continually. Pasteur also labored with determination; others have followed him, and the new doctrine of antitoxines is continually acquiring more adherents. But it has not yet emerged from the conflict of opinions, and still less is the secret of immunity itself revealed. We must become well accustomed to the thought that only the next century can bring light and certainty on this point.

## DISCUSSION AND CORRESPONDENCE.

ARE FELLOWSHIPS ALMSGIVING  
OR INVESTMENTS?

TO THE EDITOR: In the *POPULAR SCIENCE MONTHLY* for September, page 472, Mrs. W. A. Kellerman asks, 'Are Fellowships Almsgiving or Investments?'

As ordinarily granted in American universities, they may be either. Still more often they are rather advertisements, and they may in any case partake of the nature of all three of these.

The great gifts to education have been for the purpose not of feeding men but of furnishing means of study and investigation beyond the reach of individual effort. This is 'investment put to the credit of the country's future.' The ordinary fellowship furnishes not special facilities, but board and lodging for individuals, matters quite within the range of individual effort on the part of almost any student worth educating. It does not increase scholarship but multiplies the number of those who scramble for its rewards. The same amounts expended in better teachers and in better facilities for work would do more for American scholarship than the fellowships now accomplish.

It is understood that the Carnegie gift is to be devoted solely to the promotion of research, not to the encouragement of men who show mere promise of ability. It is to be used to complete the equipment of investigators who have already done all within their power as individuals, and whose lives will be devoted to research whether helped or not. To aid in making their work effective is not almsgiving. If any part of the fund is used to hire men to undertake research, it will be

wasted, and the trustees of the fund will have to resist many temptations to do this.

The fellowship is now largely used as a means of university advertisement, to the real injury of higher education. To induce any man to go where he does not wish to go or to study what he would not otherwise have cared for is to cheapen higher education.

Real scholars will work out their own salvation, so far as the cost of education is concerned. Real universities are built up by real investigators. To furnish these and their students with books, implements and materials will bring students worthy of the opportunity. To give students that which they need in their work and can not buy for themselves is to draw the line between 'investment' and 'almsgiving.'

Certainly the whole American 'system of fellowships for advanced students is now on trial with most of the evidence against it.'

DAVID S. JORDAN.

## COLLEGE PROFESSORS.

TO THE EDITOR: I have read with interest Professor Stevenson's article in the September number of the *MONTHLY*. It is sane and well considered. Two of his generalizations are however not based on a sufficient number of data. In speaking of the college professors of a generation ago he says, 'The hours of teaching were short.' In so far as this was the case I believe it was the exception rather than the rule. Not long ago a professor who began to teach in the fifties remarked to me incidentally in a conversation, 'For many years I taught all the time and so did my colleagues.'

Several instances almost similar are within my knowledge. It has been said of a prominent college not fifty miles from Philadelphia that its trustees had for many years a regulation threatening with dismissal any professor who published a book. They wished to have it understood that professors were expected to devote all their time to teaching and that the writing of books was equivalent to depriving their students of what clearly belonged to them. Perhaps it would not be easy to find a board at this time that takes such a view, but individual members are not rare. That man is most acceptable who can, or thinks he can, teach the largest number of subjects. Again, there may be many high schools that do the excellent work Professor Stevenson had in mind; I have no desire to belittle it or them. On the other hand I am sure there is a far larger number, taking the country as a whole, in which, for various reasons, the instruction is very inferior and the graduates of which could not be admitted into any reputable college unconditioned. Furthermore, I believe the three following propositions can be sustained: (1) The average ability of college professors is not higher than that of the legal or medical profession, if we include among the latter only those members who have had collegiate training in addition to their professional education. That they are generally men of wider information most people will admit. (2) That speaking by and large those college professors who have had adequate preparation can find time for original work, if they desire. Of the professors in the college from which I graduated, about a dozen in all, two were constantly carrying on original investigations; yet they had no more time but rather less than their colleagues. Very often the college professor makes deliberate choice between two courses open to him: either he will employ his spare time in keeping

abreast of the advances in his own department and in preparing to present this fresh knowledge most effectively to his classes, or in original researches. Few men can do both. (3) College professors on the average get as much satisfaction out of life as any other class. It may be assumed that the young man who enters deliberately upon the profession of teaching does so in response to a 'call,' that is, because it represents the work he feels best fitted to perform. Of the men who engage in the quest for money the large majority is disappointed. The pleasure of the pursuit is conditioned upon possession; but when they fail in securing possession their labor and self-denial have been in vain. Not so with him who is engaged in seeking and imparting knowledge. Few persons have a large preponderance of the good things of this life. He who dwarfs his mind by bending all his energies to the acquisition of wealth effectually closes it to esthetic enjoyment. If all men were permitted to fix the pecuniary compensation for their services we should see some curious estimates. Few are satisfied with what they get. Our frequent strikes are evidence that labor is as discontented as teaching. Most persons who give their services for pay get all they can; it is the philosophically inclined who grumble least over the amount. College professors above all others need to take to heart the injunction of the poet,

"With a heart for any fate  
Still achieving, still pursuing,  
Learn to labor and to wait."

He who in the course of a life-time has succeeded in making a few of his students better, wiser, nobler, has not lived to little purpose. He is something more than a 'link in being's endless chain.'

C. W. SUPER.

OHIO UNIVERSITY,  
ATHENS, O.

## THE PROGRESS OF SCIENCE.

## RUDOLF VIRCHOW.

THE world has lost one of its great men in the death of Professor Rudolf Virchow. Born on October 13, 1821, the son of a small shopkeeper and farmer in an obscure village of Pomerania, he died on September 5, known everywhere as one of the greatest if not the greatest of contemporary scientific men, having at the same time performed in his long life public services such as do not ordinarily fall to the lot of the man of science. It is not possible to recount in this place the numerous events of Virchow's career nor to describe his great contributions to science. His 'Cellular Pathology' was published in 1858; his theories and experiments having been in part printed in earlier volumes of the *Archives für pathologische Anatomie und Physiologie*, established by him and Reinhart in 1848. Virchow's main thesis was that the cells of the animal body propagate themselves, and that outside forces acting on the cells produce in them mechanical or chemical changes which are disease. The facts of bacteriology since discovered harmonize with this theory and do not conflict with it as has sometimes been assumed. Virchow more than any other one man established the science of pathology and made it possible for medicine to become an applied science. Only second in importance to his contributions to pathology was his work in anthropology which covered all branches of the science—physical measurements, racial differences, ethnology and even archeology. He did not oppose evolution, having indeed advocated the transmutation of species before Darwin, but he was critical in his attitude toward natural selection.

Virchow's scientific work was singularly complete. He made numerous and exact observations and experiments; he deduced from them wide-reaching theories; he conducted an important journal for more than fifty years; he wrote text-books, summaries of scientific advance and books popularizing science; he established a school to which students came from all parts of the world, while at the same time taking part in the education of the people; he founded a great museum and took a leading part in scientific societies; he applied science directly to human welfare.

It is almost incredible that among these multifarious scientific activities Virchow should have been one of the leading statesmen of his country. Here too his work was wide and long continued. He was a member of the municipal council of Berlin for more than forty years, and through him the hygienic conditions of the capital were revolutionized. He had been a member of the Prussian chamber since 1862 and was for twenty-five years chairman of the committee on finance. He was leader of the radical party in the Reichstag. In his public career he opposed centralization, autocracy and war, and advocated all measures for the welfare of the people. He was at one time compelled to leave the University of Berlin owing to his political activity, but his personality and eminence were such that he was recalled to a professorship in 1856, and he was thereafter the preeminent representative of academic freedom.

In this number of the MONTHLY will be found the Huxley lecture on 'Recent Advances in Science and their Bearing on Medicine and Surgery.'

given three years ago by Virchow in London. The issues for July and August of last year contain a paper by him on the 'Peopling of the Philippines,' translated from the *Proceedings* of the Prussian Academy of Sciences. A recent portrait of Virchow is given above as a frontispiece. An earlier portrait and an account of his life will be found in the number of THE POPULAR SCIENCE MONTHLY for October, 1882.

#### SCIENTIFIC EMINENCE.

THE death of Virchow, following the deaths of Pasteur, Helmholtz and Darwin, seems to leave the world without men of science as great as those it has lost. Great Britain, in the establishment of its new order of merit, has selected Lord Kelvin, Lord Lister, Lord Rayleigh and Sir William Huggins as the four students of science to be honored. In addition to Mr. Herbert Spencer, whose claims for recognition are somewhat different, Sir Joseph Hooker and Sir William Stokes may be placed in this group. When, on the occasion of Virchow's eightieth birthday last year, Lord Lister brought greetings from Great Britain, he was the only man whose work could be placed beside Virchow's; but while his method of antiseptic treatment in surgery has been one of the greatest advances in medicine, it is in some respects an isolated discovery, and can scarcely claim equality with the immense work accomplished by Virchow and Pasteur. Lord Kelvin is the only living physicist who might be ranked with Helmholtz. Darwin has no peer.

Although Germany has a larger number of scientific workers than Great Britain, it is not certain that it now has more men of exceptional eminence. Professor Haeckel has a world-wide reputation, but would perhaps be ranked less highly by the expert than by the general public. Professor Röntgen's name is known everywhere for one striking discovery, as are also Pro-

fessor Weismann's for a theory around which much discussion has collected, and Dr. Koch's, less for his real work than for sensational expectations. But it may be doubted whether the leading German men of science are known to the general public or even to those in other departments of science. They would include Klein in mathematics, Struve in astronomy, Boltzmann in physics, Ostwald in chemistry, Suess in geology, Koelliker and Gegenbaur in anatomy, Pflüger in physiology, Strasburger in botany and Wundt in psychology. These, and others who might be named with equal justice, form an important group, and several of them are still in the prime of life. It is doubtful, however, whether any of them will attain the eminence of Helmholtz and Virchow.

A similar list for France would include the names of Hermite and Poincaré in mathematics, Loewy in astronomy, Cornu in physics, Berthelot and Moissan in chemistry, Gaudry in geology and van Tieghem in botany. No other European nation ranks with Great Britain, Germany and France. Russia has Mendeléef in chemistry, Kovalevskij in zoology and Karpinskij in geology; Italy has Cremona in mathematics, Rigbi in physics and Mosso in physiology; and there are of course many other notable men in these and in other countries.

It is obviously difficult to compare our own eminent men with those of other nations. Among those who have an international reputation are Newcomb, Hall and Hill in astronomy, Willard Gibbs in theoretical physics, Michelson in experimental physics, Wolcott Gibbs in chemistry, Gilbert in geology, Agassiz in zoology, Farlow in botany, Welch in pathology and James in psychology.

Eminence is relative, and as scientific work becomes more widespread and special it may be that men of equal ability will no longer become as eminent as might have been the case



had they lived earlier. The complexity of knowledge and of civilization has increased more rapidly within the past four hundred years than the capacity of the mind. A century ago it might have been almost possible to be personally acquainted with the men of the world who were doing work of importance; now it is not possible to remember their names.

#### THE NEW BRITISH ORDER AND ACADEMY.

IN connection with the order of merit established by King Edward on the occasion of his coronation it is of some interest to note that four men of science—whose names are given above—have been placed among the twelve original members. There are in addition three generals, two admirals, two men of letters and one artist. It would thus appear that one third of the recognition for services rendered to the nation fall to science, twice as much as to letters and humanities and four times as much as to art. The creation of the British order of merit and the selection of its recipients have apparently met with general approval, but its usefulness is not quite obvious. The Prussian order 'Pour le Mérite,' established by Frederick the Great in 1740, was fitted to its age and environment, but it seems somewhat late to found an English imitation. An eminent German resident in America has recently maintained that productive scholarship here suffers because we have no honorary recognitions such as flourish in Germany. It must be admitted that men of science like such honors. Even a man as great as Huxley was obviously pleased at being made a privy councilor and being granted an audience with the Queen. Sir William Thomson was willing to give up the name of his father, himself a professor of mathematics, to become Lord Kelvin, even though he has no heir. It is said that he and Professor Lister were made first baronets

and then barons because they had no heirs, a certain amount of property, more likely to be possessed by brewers than by scientific men, being required before a hereditary title is granted. But while men of science may like to be Hofrats, Geheimrats, vons, sirs, lords and LL.D.'s, it is not certain that their work is thereby improved or that these honorary distinctions will survive the twentieth century.

Much the same may be said in regard to the British Academy for the promotion of historical, philosophical and philological studies to which a charter has just been granted by King Edward. In so far as this academy is intended to designate forty-nine 'immortals' in certain departments, permitting them to attach several letters to their names and letting their chief corporate duty be the election of their successors, membership is a kind of order or title which belongs to an aristocratic rather than to a democratic age and people. When academies were established, chiefly in the seventeenth and the first part of the eighteenth centuries, it was possible and desirable for all the scientific men of the nation to meet together for experiment and discussion, and membership in the academy usually carried with it a pension or other tangible advantage. Whether membership in an academy simply as an honorary distinction stimulates scientific work in those who are called and in those who would like to be called is perhaps somewhat analogous to the question as to whether good works are encouraged by the rewards and punishments formerly prominent in theological systems. There is partial truth in Tennyson's verses:

The man of science himself is fonder  
of glory, and vain;  
An eye well-practiced in nature, a  
spirit bounded and poor.

The desire for fame has doubtless been useful in the course of social evolu-

tion, but the time may come when its survival will be a nuisance.

An academy may of course perform valuable services as a center of organization. This is the case with the Royal Society, which to a certain extent corresponds to the continental academies, but with three or four hundred members it is reasonably democratic. As the eighteenth century was the era of academies, the nineteenth was the era of special societies for the separate sciences and of democratic associations for the advancement of science. In the present century specialization will increase still further and men of science will become still more numerous; it will be necessary to replace an aristocracy and a plebescite with a representative form of government.

*THE PRESIDENT'S ADDRESS BEFORE THE BRITISH ASSOCIATION.*

THE French Association for the Advancement of Science held its annual meeting in August, and the corresponding German and British associations held their meetings in September. Reports of these meetings have not as yet come to hand, except that an abstract of Professor James Dewar's presidential address before the Belfast meeting of the British Association has been cabled to the daily papers. It appears from this report that the address was largely devoted to a review of the progress of physical chemistry, but reference was made to recent munificent benefactions to science and education, especially the gifts of Mr. Carnegie and the late Cecil Rhodes. Professor Dewar said he thought that the means chosen by Mr. Rhodes were not the most effective which could have been selected, but that it must be remembered that Mr. Rhodes's aims were political as much as educational. "He had a noble and worthy ambition to promote the enduring friendship of the great English-speaking communities of the world, and he was probably also

influenced by the hope that a large influx of strangers would broaden Oxford's notions."

Referring to Mr. Carnegie's endowment of Scottish universities and the foundation of an institution at Washington as of more direct benefit to higher education than the bequest of Mr. Rhodes, Professor Dewar is reported to have remarked that the establishment of the institution at Washington meant a scouring of the Old World as well as the New for the best men in every department. In fact, he said, the assiduous collecting of brains for the benefit of America was similar to the collecting of rare books and works of art which Americans were now carrying on so lavishly.

Reviewing the meager gifts to the Royal Institution of Great Britain during the past century, he said that, without such endowments as Mr. Carnegie's, the outlook for disinterested research was rather dark. The Carnegie Institution could dispose in one year of as much money as the Royal Institution had expended in a century on its purely scientific work, and it would be interesting to note how far the output of scientific work corresponded to the hundredfold application of money to its production.

Speaking on the subject of applied chemistry, Professor Dewar criticized the 'deplorable backwardness' of Great Britain, as compared with foreign countries. Taking Germany as an example, he declared that, notwithstanding the immense range of chemical industries in which the United Kingdom had once been prominent, Germany today employed a professional staff three times as great as the United Kingdom, and as superior in technical training and acquirements as it was numerically. German chemical manufacturers enjoyed a practical monopoly, which enabled them to exact huge profits from the rest of the world and to establish in an almost unassailable position industries which were largely

founded on basic discoveries made by English chemists, but which had never been properly developed in the land of their birth.

The explanation of this 'disastrous phenomenon' Professor Dewar gave in three words: 'Want of education.' He said it was the failure of schools to turn out, and of manufacturers to demand, properly trained men which explained Great Britain's loss of valuable industries and the country's precarious hold upon others. 'To my mind,' said he, 'the really appalling thing is not that the Germans have seized upon this or the other industry, but that the German population has reached a point of general training and specialized equipment which it will take us two generations of hard and intelligently directed educational work to attain.'

#### THE INTERNATIONAL COUNCIL FOR THE STUDY OF THE SEA.

THIS Council was constituted at Copenhagen on July 22 by delegates from Great Britain, Germany, Holland, Denmark, Norway, Sweden, Russia and Finland. According to the report in the September number of the *Journal* of the Royal Geographical Society, the principle of simultaneous observations four times a year as the basis of a system of regular observations of temperature, density and plankton was adopted, and the share to be taken in the work by each of the participating nations was practically settled. The two ships which the British Government has voted for the work will undertake periodical trips in the Færoe-Shetland channel and across the northern end of the North Sea, working from a central harbor in Shetland, and also simultaneous trips in the western part of the English channel. The southern half of the North Sea will be investigated by the Dutch, the northern half by the German ships. Denmark undertakes the sea between Færoe and Ice-

land, while Norway has the heavy task of making observations in the North Atlantic off the extensive western seaboard of Scandinavia. Russia has undertaken similar work along the Murman coast and across Barents Sea to Novaya Zemlya, while the Baltic will be studied in detail by Danish, Swedish, Finnish, Russian and German ships. While the periodical oceanographical trips are the framework of the whole system of observations, they are intended to be connected and completed by observations at fixed stations, such as light-ships and by the cooperation, as far as surface observations are concerned, of regular lines of steamers crossing the North Sea and the Atlantic.

The biological work of the council has been limited, by the conditions which most of the governments concerned have attached to their grants, to the investigation of special problems of urgent practical importance to fisheries. Two such problems were selected. A committee has been charged with the duty of investigating the migrations of such fish as the cod and herring, and another with the investigation of the whole question of over-fishing in the parts of the North Sea most frequented by trawlers.

The organization of the central bureau of the Council was also determined, Dr. Herwig being appointed as president. The seat of the bureau is in Copenhagen, and the chief assistant will be Dr. Knudsen, lecturer on physics in the Polytechnic school there. All the publications of the council will be issued by the bureau, which will also form the medium of communication between the various national organizations, the special committees and others.

The international laboratory has been established in Christiania, with Dr. Nansen as honorary director and Dr. Walfrid Ekman as assistant for physical work; an assistant for chemical work is also about to be appointed.

The laboratory will undertake the training of observers for the various national organizations, the testing of instruments, the supply of standard sea-water for controlling salinity determinations, and also gas-analysis. It will also carry out experiments with improved apparatus and methods in order to ensure a degree of accuracy never before aimed at in work at sea. It was recommended that the laboratory should, if possible, be opened in October, and that the periodical cruises be commenced as soon as possible, but at the latest by the spring of 1903.

#### SCIENTIFIC ITEMS.

DR. ALEXANDER AGASSIZ and Lord Avebury have been appointed members of the Prussian order, 'pour le mérite.' We understand that Dr. Agassiz is the only American on whom this honor has been conferred except the historian Bancroft.—Dr. Wilhelm Wundt, the eminent psychologist and philosopher, celebrated his seventieth birthday on August 16. A volume of researches carried out by his former students was presented to him on the occasion.—M. Levasseur, professor of agriculture at the Collège de France, has been elected president of the French Association for the Advance-

ment of Science. The Association will hold its meeting in 1903 at Angiers.—The Iron and Steel Institute of Great Britain held its meeting at Düsseldorf last month. Among those who made addresses at the opening meeting was Professor Henry M. Howe, of Columbia University. Mr. Andrew Carnegie has been elected president of the Institute.—The centenary of the birth of Hugh Miller was celebrated at Cromarty on August 22. The principal address was made by Sir Archibald Geikie. An address was also made by Dr. John M. Clarke, of Albany.—The centenary of the birth of the eminent mathematician, Abel, was celebrated at Christiania last month. On this occasion honorary degrees were given to a number of mathematicians, including Professors Simon Newcomb and J. Willard Gibbs.—The committee of the fund raised to commemorate the eightieth birthday of Professor Virchow announces that it has handed over a sum of over \$12,000 to the Rudolf Virchow Foundation.—Gilbert White's house at Selbourne is for sale, and the suggestion is made by Mr. E. A. Martin, member of the council of the Selbourne Society, that it should be purchased as a permanent memorial of the father of British naturalists.

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