undertaking will surely triumph. Schemes skilfully devised may delay, but they cannot prevent, the establishment of a University of the United States.

JOHN W. HOYT,
Chairman National University Committee.

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*ADDRESS OF THE PRESIDENT OF THE PHYSIOLOGICAL SECTION OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.**

WHEN the British Association met in Glasgow twenty-five years ago I had the honor of presiding over Physiology, which was then only a subsection of Section D. The progress of the science during the quarter of a century has been such as to entitle it to the dignity of a section of its own, and I feel it to be a great honor to be again put in charge of the subject. While twenty-five years form a considerable portion of the life of a man, from some points of view they constitute only a short period in the life of a science. But just as the growth of an organism does not always proceed at the same rate, so is it with the growth of a science. There are times when the application of new methods or the promulgation of a new theory causes rapid development, and there are other times when progress seems to be slow. But even in these quiet periods there may be steady progress in the accumulation of facts, and in the critical survey of old questions from newer points of view. So far as physiology is concerned, the last quarter of a century has been singularly fruitful, not merely in the gathering in of accurate data by scientific methods of research, but in the way of getting a deeper insight into many of the problems of life. Thus our knowledge of the phenomena of muscular contraction, of the changes in the secreting cell, of the interdependence of organs illustrated by what we now speak of as internal secretion, of the events that occur in the fecundated ovum and in the actively growing cell, of the remarkable processes connected with the activity of an electrical organ, and of the physiological anatomy of the central nervous organs, is very different from what it was twenty-five years ago. Our knowledge is now more accurate, it goes deeper into the subject and it has more of the character of scientific truth. For a long period the generalizations of physiology were so vague, and apparently so much of the nature of more or less happy guesses, that our brethren, the physicists and chemists, scarcely admitted the subject into the circle of the sciences. Even now we are sometimes reproached with our inability to give a complete solution of a physiological problem, such as, for example, what happens in a muscle when it contracts; and not long ago physiologists were taunted by the remark that the average duration of a physiological theory was about three years. But this view of the matter can only be entertained by those who know very little about the science. They do not form a just conception of the difficulties that surround all physiological investigation, difficulties far transcending those relating to research in dead matter; nor do they recollect that many of the more common phenomena of dead matter are still inadequately explained. What, for example, is the real nature of elasticity; what occurs in dissolving a little sugar or common salt in water; what is electrical conductivity? In no domain of science, except in mathematics, is our knowledge absolute; and physiology shares with the other sciences the possession of problems that, if I may use a paradox, seem to be more insoluble the nearer we approach their solution.

The body of one of the higher animals—say that of man—is a highly complex mechanism, consisting of systems of organs, of individual organs and of tissues. Physi-

* Glasgow meeting, 1901.

ologists have been able to give an explanation of the more obvious phenomena. Thus locomotion, the circulation of the blood, respiration, digestion, the mechanism of the senses and the general phenomena of the nervous system have all been investigated, and in a general way they are understood. The same statement may be made as to the majority of individual organs. It is when we come to the phenomena in the living tissues that we find ourselves in difficulties. The changes happening in any living cell, let it be a connective tissue corpuscle or a secreting cell or a nerve-cell, are still imperfectly understood; and yet it is upon these changes that the phenomena of life depend. This has led the more thoughtful physiologists in recent years back again to the study of the cell and of the simple tissues that are formed from cells. Further, it is now recognized that if we are to give an adequate explanation of the phenomena of life, we should study these, not in the body of one of the lower organisms, as was at one time the fashion, where there is little if any differentiation of function—the whole body of an amœboid organism showing capacities for locomotion, respiration, digestion, etc.—but in the specialized tissue of one of the higher animals. Thus the muscle-cell is specialized for contraction, and varieties of epithelium have highly specialized functions.

But when cells are examined with the highest microscopic powers, and with the aid of the highly elaborated methods of modern histology, we do not seem to have advanced very far towards an explanation of the ultimate phenomena. There is the same feeling in the mind of the physiologist when he attacks the cell from the chemical side. By using large numbers of cellular elements, or by the more modern and fruitful methods of micro-chemistry, he resolves the cell-substance into proteids, carbohydrates, fats, saline matter and water, with possibly other substances derived from the chemical changes happening in the cell while it was alive; but he obtains little information as to how these proximate constituents, as they are called, are built up into the living substance of the cell. But if we consider the matter it will be evident that the phenomena of life depend on changes occurring in the interactions of particles of matter far too small even to be seen by the microscope. The physicist and the chemist have not been content with the investigation of large masses of dead matter, but to explain many phenomena they have had recourse to the conceptions of molecules and atoms and of the dynamical laws that regulate their movements. Thus the conception of a gas as consisting of molecules having a to-and-fro motion, first advanced by Krönig in 1856 and by Clausius in 1857, has enabled physicists to explain in a satisfactory manner the general phenomena of gases, such as pressure, viscosity, diffusion, etc. In physiology few attempts have been made in this direction, probably because it was felt that data had not been collected in sufficient numbers and with sufficient accuracy to warrant any hypothesis of the molecular structure of living matter, and physiologists have been content with the microscopic and chemical examination of cells, of protoplasm and of the simpler tissues formed from cells. An exception to this general remark is the well-known hypothesis of Du Bois-Reymond as to the existence in muscle of molecules having certain electrical properties, by which he endeavored to explain the more obvious electrical phenomena of muscle and nerve. The conception of gemmules by Darwin and of biophors by Weismann are examples also of a hypothetical method of discussing certain vital phenomena.

The conception, however, of the existence in living matter of molecules has not escaped some astute physicists. The subject is discussed with his usual suggestiveness by Clerk Maxwell in the article 'Atom' in the 'Encyclopædia Britannica' in the volume published in 1875, and he places before the physiologist a curious dilemma. After referring to estimates of the diameter of a molecule made by Loschmidt in 1865, by Stoney in 1868, and by Lord Kelvin (then Sir W. Thomson) in 1870, Clerk Maxwell writes:

"The diameter and the mass of a molecule, as estimated by these methods, are, of course, very small, but by no means infinitely so. About two millions of the molecules of hydrogen in a row would occupy a millimeter, and about two hundred million million million of them would weigh a milligram. These numbers must be considered as exceedingly rough guesses; they must be corrected by more extensive and accurate experiments as science advances; but the main result, which appears to be well established, is that the determination of the mass of a molecule is a legitimate object of scientific research, and that this mass is by no means immeasurably small.

"Loschmidt illustrates these molecular measurements by a comparison with the smallest magnitudes visible by means of a microscope. Nobert, he tells us, can draw 4,000 lines in the breadth of a millimeter. The intervals between these lines can be observed with a good microscope. A cube, whose side is the 4,000th of a millimeter, may be taken as the *minimum visible* for the observers of the present day. Such a cube would contain from 60 to 100 million molecules of oxygen or of nitrogen; but since the molecules of organized substances contain on an average about fifty of the more elementary atoms, we may assume that the smallest organized particle visible under the microscope contains about two million molecules of organic matter. At least half of every living organism consists of water, so that the smallest living being visible under the microscope does not contain more than about a million organic molecules. Some exceedingly simple organism may be supposed built up of not more than a million similar molecules. It is impossible, however, to conceive so small a number sufficient to form a being furnished with a whole system of specialized organs.

"Thus molecular science sets us face to face with physiological theories. It forbids the physiologist from imagining that structural details of infinitely small dimensions can furnish an explanation of the infinite variety which exists in the properties and functions of the most minute organisms.

"A microscopic germ is, we know, capable of development into a highly organized animal. Another germ, equally microscopic, becomes when developed an animal of a totally different kind. Do all the differences, infinite in number, which distinguish the one animal from the other arise each from some difference in the structure of the respective germs? Even if we admit this as possible, we shall be called upon by the advocates of pangenesis to admit still greater marvels. For the microscopic germ, according to this theory, is no mere individual but a representative body, containing members collected from every rank of the long-drawn ramification of the ancestral tree, the number of these members being amply sufficient not only to furnish the hereditary characteristics of every organ of the body and every habit of the animal from birth to death, but also to afford a stock of latent gemmules to be passed on in an inactive state from germ to germ, till at last the ancestral peculiarity which it represents is revived in some remote descendant.

"Some of the exponents of this theory of heredity have attempted to elude the difficulty of placing a whole world of wonders within a body so small and so devoid of visible structure as a germ by using the phrase structureless germs. Now one material system can differ from another only in the configuration and motion which it has at a given instant. To explain differences of function and development of a germ without assuming differences of structure is, therefore, to admit that the properties of a germ are not those of a purely material system."

The dilemma thus put by Clerk Maxwell is (first) that the germ cannot be structureless, otherwise it could not develop into a future being, with its thousands of characteristics; or (second) if it is structural it is too small to contain a sufficient number of molecules to account for all the characteristics that are transmitted. A third alternative might be suggested, namely, that the germ is not a purely material system, an alternative that is tantamount to abandoning all attempts to solve the problem by the methods of science.

It is interesting to inquire how far the argument of Clerk Maxwell holds good in the light of the knowledge we now possess. First, as regards the *minimum visible*. The smallest particle of matter that can now be seen with the powerful objective and compensating eyepieces of the present day is between the $\frac{1}{4000000}$ and the $\frac{1}{5000000}$ of an inch, or $\frac{1}{200000}$ of a millimeter in diameter, that is to say, five times smaller than the estimate of Helmholtz of $\frac{1}{4000}$ of a millimeter. The diffraction of light in the microscope forbids the possibility of seeing still smaller objects, and when we are informed by the physicists that the thickness of an atom or molecule of the substances investigated is not much less than a millionth of a millimeter, we see how far short the limits of visibility fall of the ultimate structure of matter.

Suppose, then, we can see with the highest powers of the microscope a minute particle having a diameter of $\frac{1}{20000}$ of a millimeter, it is possible to conceive that some of the phenomena of vitality may be exhibited by a body even of such small dimensions. The spores of some of the minute objects now studied by the bacteriologist are probably of this minute size, and it is possible that some may be so minute that they can never be seen. It has been observed that certain fluids derived from the culture of microorganisms may be filtered through thick asbestos filters, so that no particles are seen with the highest powers, and yet those fluids have properties that cannot be explained by supposing that they contain toxic substances in solution, but rather by the assumption that they contain a greater or less number of organic particles so small as to be microscopically invisible. I am of opinion, therefore, that it is quite justifiable to assume that vitality may be associated with such small particles, and that we have by no means reached what may be called the vital unit when we examine either the most minute cell or even the smallest particle of protoplasm that can be seen. This supposition may ultimately be of service in the framing of a theory of vital action.

Weismann in his ingenious speculations has imagined such a vital unit to which he gives the name of a biophor, and he has even attempted numerical estimates. Before giving his figures let us look at the matter in another way. Take the average diameter of a molecule as the millionth of a millimeter, and the smallest particle visible as the $\frac{1}{20000}$ of a millimeter. Imagine this small particle to be in the form of a cube. Then there would be in the side of the cube, in a row, fifty such molecules, or in the cube $50 \times 50 \times 50 = 125{,}000$ molecules. But a molecule of organized matter contains about fifty elementary atoms. So that the 125,000 molecules in groups of about fifty would number $\frac{125000}{50} = 2{,}500$ organic particles. Suppose, as was done by Clerk Maxwell, one-half to be water; there would remain 1,250 organic particles. The smallest particle that can be seen by the microscope may thus contain as many as 1,250 molecules of such a substance as a proteid.

Weismann's estimates as to the dimensions of the vital unit to which he gives the name of biophor may be shortly stated. He takes the diameter of a molecule at $\frac{1}{2000000}$ of a millimeter (instead of the one millionth) and he assumes that the biophor contains 1,000 molecules. Suppose the biopher to be cubical, it would contain ten in a row, or $10 \times 10 \times 10 = 1{,}000$. Then the diameter of the biophor would be the sum of ten molecules, or $\frac{1}{2000000} \times 10 = \frac{10}{2000000}$ or $\frac{1}{200000}$ of a millimeter. Two hundred biophors would therefore measure $\frac{200}{200000}$ or $\frac{1}{1000}$ mm. or $1\,\mu$ (micron $= \frac{1}{1000}$ mm.). Thus a cube one side of which was $1\,\mu$ would contain $200 \times 200 \times 200 = 8{,}000{,}000$ biophors. A human red blood corpuscle measures about $7.7\,\mu$; suppose it to be cubed, it would contain as many as 3,652,264,000 biophors.

Now if the smallest particle that can be seen ($\frac{1}{20000}$ mm.) may contain 1,250 molecules, let us consider how many exist in a biophor, which we may imagine as a little cube, each side of which is $\frac{1}{200000}$ mm. There would then be five in a row of such molecules, or in the cube $5 \times 5 \times 5 = 125$ molecules; and if the half consisted of water about sixty molecules.

Let us apply these figures to the minute particles of matter connected with the hereditary transmission of qualities. The diameter of the germinal vesicle of the ovum is $\frac{1}{20}$ of a millimeter. Imagine this a little cube. Taking the diameter of an atom at $\frac{1}{10000000}$ of a millimeter, and assuming that about fifty exist in each organic molecule (proteid, etc.), the cube would contain at least 25,000,000,000,000 organic molecules. Again, the head of the spermatozoid, which is all that is needed for the fecundation of an ovum, has a diameter of about $\frac{1}{200}$ mm. Imagine it to be cubed; it would then contain 25,000,000,000,000 organic molecules. When the two are fused together, as in fecundation, the ovum starts on its life with over 25,000,000,000,000 organic molecules. If we assume that one-half consists of water, then we may say that the fecundated ovum may contain as many as about 12,000,000,000,000 organic molecules. Clerk Maxwell's argument that there were too few organic molecules in an ovum to account for the transmission of hereditary peculiarities does not apparently hold good. Instead of the number of organic molecules in the germinal vesicle of an ovum numbering something like a million, the fecundated ovum probably contains millions of millions. Thus the imagination can conceive of complicated arrangements of these molecules suitable for the development of all the parts of a highly complicated organism, and a sufficient number, in my opinion, to satisfy all demands of a theory of heredity. Such a thing as a structureless germ cannot exist. Each germ must contain peculiarities of structure sufficient to account for the evolution of the new being, and the germ must therefore be considered as a material system.

Further, the conception of the physicist is that molecules are more or less in a state of movement, and the most advanced thinkers are striving towards a kinetic theory of molecules and of atoms of solid matter which will be as fruitful as the kinetic theory of gases. The ultimate elements of bodies are not freely movable each by itself; the elements are bound together by mutual forces, so that atoms are combined to form molecules. Thus there may be two kinds of motion, atomic and molecular.

By molecular motion is meant, "the translatory motion of the centroid of the atoms that form the molecule, while as atomic motion we count all the motions which the atoms can individually execute without breaking up the molecule. Atomic motion includes, therefore, not only the oscillations that take place within the molecule, but also the rotation of the atoms about the centroid of the molecule." *

Thus it is conceivable that vital activities may also be determined by the *kind* of motion that takes place in the molecules of what we speak of as living matter. It may be different in kind from some of the motions known to physicists, and it is conceivable that life may be the transmission to dead matter, the molecules of which have already a special kind of motion, of a form of motion *sui generis*.

I offer these remarks with much diffidence, and I am well aware that much that I have said may be regarded as purely speculative. They may, however, stimulate thought, and if they do so they will have served a good purpose, although they may afterwards be assigned to the dust-heap of effete speculations. Meyer writes as follows in the introduction to his great work on 'The Kinetic Theory of Gases,' p. 4: "It would, however, be a considerable restriction of investigation to follow out only those laws of nature which have a general application and are free from hypothesis; for mathematical physics has won most of its successes in the opposite way, namely, by starting from an unproved and unprovable, but probable, hypothesis, analytically following out its consequences in every direction, and determining its value by comparison of these conclusions with the result of experiment."

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* Meyer, 'Kinetic Theory of Gases.' Translated by Baynes, London, 1899, p. 6.

DATA ON SONG IN BIRDS. OBSERVATIONS ON THE SONG OF BALTIMORE ORIOLES IN CAPTIVITY.

Much has been written in regard to the songs of birds, and no small part of the literature of the subject has dealt with the problem of the way in which many kinds of birds have acquired the distinctive song that characterizes each different species.

In the eastern United States many of us recognize, without seeing, the singer, on hearing the song of one of our commoner native birds. We say, 'A robin is singing,' 'Listen to the bobolink,' 'That is a song sparrow.'

Some who pay close and particular attention realize that individuals of a given kind have sometimes slight, though marked, variations in the method of song that distinguish them from the mass of their kind and characterize them as individuals which are readily known by their *peculiar personal song*. So we say, 'This robin is a good singer,' 'The note of that thrush is particularly pleasing,' 'That oriole has some harsh notes.' Such comments are indicative of the taste or appreciation of the listener and are only introduced here to emphasize two facts. First, that the song of all the individuals of a given kind of bird, as the robins, is so characteristic that we call it the robin's song, readily recognize it, and know that, in the main, all the robins of a given region have a common song, so much alike that we do not individualize the singer. Second, that now and again individual birds of a given kind, robins again for example, are readily distinguishable as individuals by some turn or phrasing of the notes that gives to the individual singer an identity as a particular robin, with an individual song, different, to a greater or less degree, from the mass of robins in the same region.

The question at once suggests itself: How is this characteristic song acquired?