A Lecture ON THE FUNDAMENTAL CONCEPTIONS OF BIOLOGY.

DELIVERED AT KING'S COLLEGE, LONDON,

BY

J. S. HALDANE, M.D., LL.D., F.R.S.,
OXFORD.

BIOLOGY is the branch of natural science which deals with life; and the question which will be discussed in this lecture is whether we are compelled, in dealing scientifically with the phenomena of life, to make use of any fundamental conception or axiom which differentiates biology from other branches of science. I shall endeavour to show that the answer to this question must be an affirmative one if we are to bring together a coherent and progressively developing body of knowledge relating to the phenomena of life. In other words, I shall try to show that biology is, or ought to be, an independent science.

There is at present little difficulty in distinguishing practically between what we call phenomena of life and what we call inorganic phenomena. But as to the nature of the distinction, and whether it is in any real sense fundamental, there has been no agreement. I shall first glance at the opinions which have been held on this subject in modern times, and the objections to these opinions.

The Mechanistic Theory of Life.

In the writings of Descartes, and particularly in his *De Homine* and *De Formatione Foetus*, we first find quite clearly expressed the doctrine that a living body is simply a piece of physical and chemical mechanism, produced by a mechanical process of development. He describes in detail, and with great clearness, the manner in which he believed that the machinery of a living animal works or may work, and the mechanical process by which this machinery is, or may be, formed in the embryo. Although it soon appeared that most of his details were entirely wrong, his belief that physiological processes are in ultimate analysis nothing but what may, broadly speaking, be called mechanical processes has survived, and at present represents the opinion which is generally regarded as orthodox in biology. Not only biologists, but also the general public, speak of the mechanism of the living body and of all the processes occurring in it. They even regard it as self-evident that, apart from conscious action, everything occurring in a living organism is mechanically determined. I cannot, therefore, pretend that my own conclusions on this subject are other than heretical for the present.

Descartes himself was no materialist. For him the soul was independent of the body; but as to how body and soul interact his account is far from clear, and on this point his successors took divergent views. It is interesting to remark that the extremest mechanistic theories of life have often been combined with the most orthodox theological opinions as to body and soul. To realize this we have only to glance through Paley's *Evidences*, or to remember that Theodore Schwann, though he was a leader of the modern mechanistic school in physiology, was also a devout and orthodox Catholic.

Animists and Vitalists.

The mechanistic conception of life, as put forward by Descartes, was only accepted by a minority of the biologists of his time, and was specially attacked by Stahl, the author of the phlogiston theory in chemistry. Stahl was so impressed by the apparent purposive character of physiological processes that he concluded that the soul acts directly at all parts of the body, though we may not be conscious of this action. For him, therefore, life was a process guided by the soul, and distinguished from inorganic processes by this fact. Stahl's teaching is known as animism, and the best known avowed modern representative of animism is Professor McDougall, whose well known book, *Body and Mind*, is a defence of this doctrine.

The majority of biologists in the eighteenth and first half of the nineteenth centuries followed neither Descartes nor Stahl, but took what may be described as a middle course. Since there is no consciousness of apparently purposive phenomena such as assimilation, growth, and reproduction,

these were attributed to an influence called the vital principle or vital force, which was conceived as something midway in character between the conscious soul and mechanism, and involved no such strained theory as that plants possess souls. On the other hand, mechanical explanation was adopted in all cases where it seemed capable of adoption. The boundary line between the action of vital force and mere mechanism was a shadowy one; but this dualistic system of explanation held its ground for long. The great comparative anatomist and physiologist Johannes Müller may be regarded as a typical representative of it as it existed last century. Liebig and Wöhler were other well known representatives.

The Neo-Mechanists of Last Century.

About the middle of last century the younger physiologists became altogether dissatisfied with the conception of vital force, and at the same time believed that they were finding a way towards dispensing with it altogether. Schwann, for instance, after discovering what is now familiar to us as the cellular composition of the bodies of higher animals, believed that he had also discovered that cell formation is only a form of precipitation. Mayer applied his new conceptions of energy to the living body, and pointed out that oxidation of food material is the source of the energy of muscular contraction. On all hands the younger biologists put forward mechanical theories of what had hitherto been attributed to the influence of vital force. The conception itself of vital force was also vigorously attacked, and the attack was a deadly one—not one whit the less so though most of the new mechanistic explanations of that time turned out to be wrong, like Schwann's theory of cell formation.

It was pointed out by the neo-mechanists that all manifestations of life are found to depend on physical and chemical conditions in the environment. There is thus no evidence whatever for the existence of an influence which is independent of physical and chemical conditions, as the vital force was assumed to be. All vital phenomena are dependent on such factors as the presence of oxygen, water, various mineral constituents, warmth or light, and suitable stimuli of various kinds. The more closely we investigate, the more certainly does this appear; and for this reason biologists will never go back to vitalism or animism.

It is true that there are still professed vitalists, among whom the best known is Driesch. He bases his vitalism especially on some of the facts revealed by experimental embryology, and particularly on his discovery that when the cells of an early developing embryo are separated from one another complete embryos may nevertheless be developed from each of the separated cells. A guiding influence seems, therefore, to be present in each cell, independently of the arrangement and amount of the material which was present in the original ovum. This guiding influence appears to cause each cell to behave in such a way as to contribute towards forming a complete embryo in spite of such confusion as is produced by artificially separating the cells. In reality, however, there is nothing to show that the behaviour of each cell is not a response to influences in its environment. When the cells are separated these influences must be changed. When they are left together each cell will influence its neighbour cells, stimulating or inhibiting their development in different directions, with the result that the embryo as a whole develops in the usual way. In the behaviour of the cells in a developing embryo there is therefore nothing fundamentally different from the responses to stimuli which we observe in any living structure. We can investigate these stimuli and the corresponding responses; and when our method is delicate enough we can always discover their connexion. Biology has no use for the vitalistic assumption of an internal guiding influence which is independent of the influence of external conditions. Such an assumption is only an artificial hindrance to investigation, and amounts to an attempt to strangle it.

Failure of the Neo-Mechanists.

In so far as the mechanistic movement which culminated about the middle of last century was a casting out of vitalism from biology I do not think there is anything further to be said. Nevertheless it seems to me that the coincident attempt to establish biology on a mechanistic basis has been a gigantic failure. It is one thing to conclude that the structure and activity of any living organism or part of it is dependent on its environment, but quite another thing to draw the additional conclusion that life must be a mechanical process, and can be investigated successfully on this assumption.

The usefulness within certain limits of mechanical explanations in physiology is, of course, evident, and was equally evident to the vitalists with their dualistic system of explanation. If we skim over the surface of physiology we can represent the life of any organism as if it were a series of mechanical processes such as the working of joints, the ingestion of oxygen into the lungs and blood, or of food material into the alimentary canal and blood, or the formation of images on the retina. Taken separately, each of these mechanical representations is in more or less close accordance with experience, and is correspondingly useful. Nevertheless it was the failure of attempts to extend mechanical conceptions to the phenomena of unconscious life as a whole that gave rise to vitalism; and it is quite evident now that the physiologists of the middle and later parts of last century were altogether mistaken in supposing that they were getting over this failure. The mere abolition of vitalism has in reality left physiology as an incoherent collection of details, with not even the very unsatisfactory vitalistic theory to produce some appearance of unity. The mechanistic cement which seemed so promising fifty or sixty years ago has crumbled away.

To understand this situation it is absolutely necessary to consider closely the characteristic phenomena of life. The outstanding feature which distinguishes what we call the phenomena of life from what we call inorganic phenomena is that in the case of life the form, size, properties, composition, and activity of each part of an organism and its immediate environment depend, broadly speaking, on its relations to the other parts, and that the relationship is actively maintained or reproduced in successive generations. Life is continuous from generation to generation, as was finally shown by Pasteur's famous investigations.

Internal Environment.

The specific character of each variety of organism and its mode of life have been thoroughly realized ever since animals and plants began to be classified. What has not been realized, however, is that not only are the form and activities of organic structure specific, but also its immediate environment. This feature of life is emphasized in my recently published book *Respiration*; but I wish to place before you in a broader manner the facts relating to immediate environment.

Pasteur's great contemporary, Claude Bernard, was the first to recognize the fact that in the higher organisms the living tissue elements live in an internal environment of a specific character, which is kept relatively constant by the combined activities of the various parts of the body. My own experimental work as a physiologist has been mainly in the development and extension of this conclusion. The tissue elements, for instance, are in relation with the external air through the process of respiration. If, now, we examine this relation we find that the concentration of carbon dioxide and oxygen in the air contained in the alveoli or air cells of the lung remains extraordinarily constant, particularly as regards the percentage of carbon dioxide. This is brought about by regulation of the breathing in accordance with the very variable amounts of carbon dioxide formed in the muscles or elsewhere and carried by the blood to the lungs, or else present in the outside air. Hence the concentration of carbon dioxide in the arterial blood is kept extremely steady, and the delicacy of this regulation is extraordinary. Carbon dioxide when in solution acts as a weak acid, and further investigation showed that what is regulated is not the mere amount of carbon dioxide in the blood, but its reaction or hydrogen ion concentration. This regulation of reaction is so delicate that not even the most sensitive of the available methods of measurement can follow it exactly.

The regulation of the oxygen concentration in the alveolar air is not nearly so delicate; but if we consider, not merely this oxygen concentration, but the percentage saturation with oxygen of the haemoglobin in the arterial blood, we find an almost equal delicacy of regulation. We have also every reason to believe that if we considered the reaction and partial pressure of oxygen, not merely in the arterial blood, but in the liquid bathing the tissue elements in the central nervous system, we should find a still greater accuracy of regulation, since the rate of blood flow is, in general, regulated in such a manner as to keep the reaction and oxygen pressure steady in spite of great local variation in consumption of oxygen and formation of carbon dioxide.

Let us now pass to the physiology of the kidneys. In this part of physiology recent advances have been almost as striking as in connexion with respiration. Within the last

few years it has become increasingly evident that renal excretion regulates the composition of the blood with a delicacy even greater than that connected with intake and output of gases by the lungs. To the smallest excess or deficiency of water or of chloride in the blood the kidneys react by greater or less excretion of water or chloride. To the minutest excess or deficiency in alkalinity they react similarly with a far greater excretion of alkali or acid. To excess in the percentage of sugar in the blood they react by excreting an enormously greater percentage of sugar in the urine. To minute percentages of urea and numerous other substances they react by concentrating them into the urine. By this selective action they keep the composition of the blood normal in a number of different respects and thus keep the specific internal environment steady.

When we look to what is known of other organs or parts of the body we find similar regulative activity. The influence of the liver in regulating the percentage of sugar in the blood was discovered by Claude Bernard himself, and every year adds to our knowledge of the regulative action of different organs and tissues. Perhaps the simplest case is that of the fat-storing tissues so widely distributed in animals and plants.

I have said enough to show that in higher organisms the maintenance of the immediate environment is just as striking a phenomenon as the maintenance of what we regard as the actually living structure. Is there any real difference in this respect, except in degree, between higher and lower organisms? I do not for a moment believe that there is, although in the case of lower organisms, and particularly unicellular organisms, it is difficult to obtain the clear evidence that we can easily obtain from the study of higher organisms, and particularly from the physiological study of man. In the case of unicellular organisms, or single cells of any kind, we are apt to assume that what has been called by the convenient but very misleading term "protoplasm" represents living structure, while anything outside the delicate cell wall represents environment. But all the probabilities are against this view. We have every reason to believe that within living cells the specific structural elements have an internal environment similar in function to the definitely known internal environment of higher compound organisms. There seems, for instance, to be little doubt that the contractile vacuoles present in fresh-water unicellular organisms are constantly engaged in excreting and pumping out the excess of water which leaks in through the semi-permeable cell wall in virtue of the higher "osmotic pressure" in the internal medium. The vacuoles are thus constantly performing the same function as the kidneys during the excretion of any excess of water that has been taken into the internal medium of a mammal.

Internal Nervous Environment.

It may appear at first sight as if the central nervous system is directly exposed through the sensory nerves to the full brunt of physical changes in the external environment, without the intervention of anything corresponding to an internal environment. In the case of any particular kind of sensory excitation we have, however, an automatic physiological raising or lowering of the threshold of excitation in accordance with the total strength of stimulus. This fact appears as the well known law of sensory excitation formulated by Weber. A light-stimulus which produces marked light-excitation with a dim general illumination may produce no excitation at all with a less dim general illumination. For instance, the light-stimulus of a bright star, which produces no excitation at all in even fading daylight, has a marked excitatory effect in the far dimmer illumination of night. Within very wide limits the unit of light-stimulus required to produce excitation varies with the general illumination of the visual field, so that the general excitation remains constant. Moreover, if all light-stimulus is cut off there is still general excitation of the visual field. In perfect darkness an illuminated field of subjective vision still remains.

We can thus compare the general constancy of the field of sensory excitation with the general constancy of the internal environment. In different parts of the circulatory system and round different cells there are very distinct differences in the internal environment, just as there are very distinct differences in different parts of the visual field. But these differences are extremely small in comparison with differences in the external environment, since they are controlled physiologically.

It is the physiological activities of the living tissue elements that regulate the internal environment and the fields of

sensory excitation. On the other hand, however, the evidence is no less clear that not only the normal activity of the living tissues, but also their normal structural maintenance, depends on the maintenance of the internal environment. For instance, not merely abnormal function, or cessation of function, results from imperfect regulative action of the lungs or kidneys, but also grave changes in structure. Analysis of the symptoms met with in disease of different organs, or in connexion with such great abnormalities of external environment that the compensatory resources of the body are overpowered, is constantly teaching this lesson in different directions. The question whether living structure determines environment, or environment determines living structure, is thus not one that can be answered. If we say that they act mutually on one another this is no answer: for apart from their active relationship they cease to exist except in the totally changed form of dead or dying material. Both living structure and internal environment are expressions of molecular and ionic flux. If the flux is interfered with both structure and environment are rapidly changed. Living structure and its immediate environment are not things which can be separated from one another like lifeless things which we regard as mutually acting on one another. In other words, the conception itself of mutual interaction is not applicable.

Organisms will continue to live in very different external environments; but this is only because they are still capable of maintaining their internal environment. The higher organisms are capable of doing this to a very marked extent, and this is one of their distinguishing characters.

Structure, Environment, and Activity.

The environments of the individual cells in any tissue or organ are not merely a general internal environment common to all the cells, but special environments dependent on the influence of neighbouring cells, and even of cells in distant organs, such as ductless glands or sexual organs. The effects of interference with either these special environments, or the general internal environment, are seen in the cell changes studied by pathological anatomists. It is on the special environments which establish themselves round individual cells that the specific structures of organs and tissues must ultimately depend. But on the other hand these specific environments depend on the activities of the cells themselves, just as does the general internal environment. Here again structure depends on environment and environment on structure; and if we attempt to separate living structure from its active environment we simply fail. Form, composition, activity, and environment are inseparably bound up together. They only exist relatively to one another. In biology relativity is no far-off principle behind ordinary observation. It confronts us at every turn when we attempt to express life as a mechanical process of interaction between organic structure and environment, or between cell and cell.

This relativity is the rock on which all past attempts to frame a mechanistic conception of life have foundered, and on which all future attempts will certainly founder. The gross external changes in which life manifests itself can be expressed in physical and chemical terms. But when we endeavour to express in similar terms the processes by which these changes are actuated and regulated we are everywhere baffled by an indefiniteness and complexity due to the fact that each phenomenon, whether of apparent structure or apparent activity, is relative to other phenomena. Instead of definite structural machinery such as Descartes or the neo-mechanists of last century imagined, we seem to find only that unstable and physically indefinite something which we call protoplasm.

If we nevertheless assume that definite though invisible structural machinery exists in all living cells and explains mechanically all the delicate and intensely specific reactions which we discover in living cells, we are at once faced by an insuperable difficulty. All of this assumed structural machinery must have developed in the development of the organism, and must have originated from a very minute part of the structural machinery of the parent organism or organisms. We are thus compelled to assume that in each germ of a future organism there is machinery for the building up of the machinery of the future adult organism, and the building up of this reproductive machinery itself has then to be accounted for, and of the machinery which built it up in previous generations *ad infinitum*.

The mechanistic theory of life involves us, therefore, in

meaningless absurdities. It is evident also that even where we can, as in the case, say, of the working of a joint, lay our hands on a piece of what seems to be definite anatomical machinery, we are equally involved in meaningless absurdities if we attempt to account on mechanistic principles for the reproduction of the joint in successive generations. If, moreover, we try to account on mechanistic principles for the physiological maintenance of the anatomical machinery, we are again faced by the relativity of the phenomena we are dealing with. The more we discover of apparent mechanism in a living organism, and the more delicate and complex this mechanism is, the more hopeless are the problems which face a mechanistic theory of life in connexion with the phenomena of maintenance and reproduction. The discovery of what we call mechanisms in connexion with the phenomena of life is never any advance towards a mechanistic conception of life, since the more of such apparent mechanisms we discover the more completely unintelligible from a mechanistic standpoint does their maintenance and reproduction appear.

To me it seems perfectly evident that not only the vitalistic, but also the mechanistic conception of life is totally unsatisfactory. The mechanists pointed out clearly the impossibility of vitalism, but they failed to see, at the same time, that their own conception of life was equally impossible. With either a vitalistic or a mechanistic conception biology is nothing but chaos. The mechanists are in reality always being driven back on vitalistic ideas to help out their mechanistic conception, just as the vitalists were always using mechanistic ideas to help out their vitalism. But this compromise only conceals, and in reality does nothing to obviate, the chaotic position on either conception. I have tried to analyse the reasons for this unsatisfactory position, and I shall now try to point out what seems to me the only way of escape from it.

Relativity and Persistent Wholeness in the Phenomena of Life.

As was so clearly pointed out in the opening lecture of this series by Professor Whitehead, the present generation has been witnessing a definite break-up in the fundamental mathematical and physical conceptions which we have inherited through Euclid, Galileo, and Newton. We can, however, still use the Euclidean, Galilean, and Newtonian working hypotheses for nearly all practical purposes in connexion with the mathematical and physical sciences, though their ultimate authority has disappeared. In connexion with the phenomena of life, however, we are everywhere in practical contact with the relativity to one another of the phenomena we are studying, as I have already pointed out. It seems to me, therefore, that in biology it is necessary to abandon, even for ordinary practical purposes, the Galilean or mechanistic conception of phenomena, and frankly embody the principle of relativity in our fundamental working conception. When we take this step we must take care, however, not straightway to introduce confusion by returning in part to the Galilean mechanistic conceptions which Descartes attempted to apply in biology. We must, in other words, treat the phenomena of life entirely from the biological standpoint, and not from that of the Galilean physics.

From the biological standpoint organism and biological environment, structure and activity of structure, parts and other parts, are not things separable in thought from one another, but existing only in their relations. If we attempt to separate them from one another they become from the biological standpoint just as meaningless as is motion or passage of time in an empty universe. Completely separated structural elements are, or at least seem to be, no longer alive, and have thus passed out of the ken of biology, where biologists can meanwhile leave them to the discussions between the new and the old physicists.

When we have admitted that the phenomena of life must be regarded as existing relatively to one another we have only taken a first step in defining a satisfactory conception of life. We have to take into consideration the further fact that life is persistent and continuous from generation to generation. The life of any species of organism is no mere fleeting appearance, but persists in all its essential characteristics. This persistence is also prominent in the life of the individual organism, and the parts of biology which we ordinarily call physiology and anatomy are based on the fact of this persistence. The structure, activities, and internal environment of the individual organism persist, and but for this a scientific treatment of anatomy and physiology would

be impossible. It is not merely relativity, but a definite and enduring order showing itself in the related phenomena, that biology deals with.

At this point I wish to emphasize once more the fact that biology does not begin with living structure, but includes environment. Moreover, there is no sharp distinction between an internal environment under organic control and the external environment. We see this clearly in the case of the air in the lung alveoli; and the same thing is also more or less clear in the case of the contents of the intestine or the temperature of the skin. Each organism, moreover, has its own special "habitat," and either by movements or in various other ways the influence on it of its environment is controlled biologically. It is a difference in the point of view from which we are compelled to regard biological phenomena, and not any spatial boundary, that separates them from what we distinguish as inorganic phenomena. The environment is not something outside of life and acting on it from without. Nor is life something localized within the living structure of an organism. Life is an organic whole without spatial boundaries, and hence cannot be localized definitely. What we can localize in relation to one another are only its manifestations, such as special organic structures or aspects of living activity. There is no more warrant for localizing life within the structure of an organism than for localizing consciousness in the brain.

If we attempt to resolve the life of an organism into a number of separate processes we reach no intelligible result. Nature laughs at us, just as she laughed at Michelson and Morley when they innocently attempted to measure the absolute velocity at which our planet is travelling. If, for instance, we continue to ask by what special pieces of machinery the kidneys or respiratory centre regulate the composition of the blood Nature will continue to mock us until we understand that such questions are meaningless. But if we ask her the sort of questions about the details of renal or respiratory regulation that scientific biology can put she answers us fully. These questions must be asked from the standpoint of the life of the body as a whole, as it is only from this standpoint that an answer can be looked for.

Since the time of the mechanistic movement in biology last century it has been generally taken for granted by physiologists that in the investigation of life all considerations of a so-called teleological character must be left out of account; and this assumption has in every direction fettered and misled investigators. The life of any organism persists as a whole. Both the persistence and the wholeness are just parts of the essential nature of life; and biology seeks out the details of structure and activity in which both the persistence and the wholeness of life manifest themselves. To the mechanistic biologists the appearance of wholeness in the life of an organism seemed to be only superficial. They allowed themselves to be overwhelmed intellectually by the Galilean ideas of the physical sciences; and this diverted them from the proper lines of biological investigation into vain quests for imaginary mechanisms.

The wholeness in the phenomena of life is not merely externally imposed, as in the case of a machine; and if we neglect the inherent element of wholeness we are also neglecting life itself. To bring into clear relief the elements of wholeness and persistence we have only to disturb in various directions the ordinary working or structure of the body. It will then be seen that the normal state soon asserts itself. The organism adapts itself to the new conditions; and life is in reality a constant process of adaptation to varying conditions of external environment. By studying the responses of renal excretion, of respiration, of circulation, of blood composition, of the nervous system, and of every other organ and tissue in the body, to changes in environment, we can discover how each organ or tissue plays its part in life as a whole; but if we leave out of account life as a whole because this consideration savours of teleology, we reach nothing but an unintelligible jumble of unconnected observations. On this point I most emphatically mean what I say.

The Relations of Organisms to One Another.

In the relations of organisms to one another, no less than in the relations of organism to environment, the wholeness of life is apparent. When Schleiden and Schwann discovered that all the higher organisms are compound it seemed at first as if the life of a compound organism could be resolved into the sum of the lives of the constituent cells. It is very evident now, however, that this would be a very misleading conclusion. The behaviour and structure of individual cells is very

different according as they are normally related to one another as in a compound organism or isolated as in a tissue culture. The behaviour of each cell in the compound organism depends on its specific environment there, which depends in turn on relations to the other cells and their environments. But, as already seen, we cannot, either in deed or thought, separate living structure from its environment. We cannot add up in a sum units which do not exist separately. Hence the life of a compound organism is no mere sum of the lives of its constituent cells.

When we consider the lives of separate organisms, whether compound or unicellular, similar considerations come in. The individuals of a species live and die in biological relation to the lives of one another and of members of other species, just as do the cells in a compound organism.

In accordance with the reasoning which has just been set before you physiology deals essentially, not with illusory quests after the mechanisms of different bodily activities, but with the particular manner in which each structural element plays its part in the life of the organism as a whole. To take an example: it is, and always has been, a vain quest to discover the mechanism of secretion by the kidneys. We can trace the complete failure of such attempts from the time of Descartes onwards through Ludwig and others to the present day. But our physiological knowledge of what the kidneys are actually doing in relation to the maintenance of the life of the body as a whole has steadily grown, and perhaps never so rapidly as during the last few years. It is the same with regard to respiration, circulation, nervous activity, and all other bodily activities. If we try to understand them from the point of view of ordinary physics and chemistry they appear as a chaotic tangle, becoming more chaotic with every advance in detailed knowledge; but from the distinctively biological standpoint which I have tried to present our knowledge of them is both coherent and steadily progressive.

The Future of Anatomy.

According to the conception which was popularized in the latter part of last century anatomy deals with the structural mechanism of organisms, and physiology with its working. This conception harmonized with the popular Galilean conceptions of the universe, and therefore appealed to what one may call "the masses," but left anatomy high and dry as soon as it became evident that with neither the scalpel nor microscope as applied to dead organisms could structure be found that was capable of throwing light on any fundamental physiological activity. The physiologists got the living organisms, and with them the living parts of biological science. In reality there ought to be no separation between anatomy and physiology except as regards technical methods of investigation. They both deal with the manifestations of life as such. Whether, in the investigation of life, use is made of the scalpel or microscope, or of other physical apparatus, or of chemical methods of different kinds, it is life that a biologist is investigating; and those who allow life to be banished from their mental vision by the nature of the technical methods they employ have no claim to be regarded as biologists. The details which their several methods reveal must be interpreted biologically or else remain outside the scope of biology as a science. The future anatomy will certainly be an experimental science, and will investigate structure as relative to environment and activity.

Conclusions.

The outcome of this discussion is that biology and the physical sciences are distinct from one another, not because they deal with spatially distinct parts of our world, but because they employ different working conceptions or axioms in interpreting their data. Relativity and persistence of a definite order in the related phenomena are of the essence of the conception of life, while they do not enter into the Galilean conception of the physical universe. Behind this Galilean conception, however, something strangely akin to the biological conception is now beginning to loom up. In addition to the conclusions of Einstein, the new conceptions, evolved by Rutherford and Nils Bohr, of what an atom is, seem to be bringing the physicists into touch with biological conceptions. In any case biology will never rest until biological conceptions have been extended to what is at present interpreted as the inorganic world. The well-meant attempt of the last generations of biologists to treat life as mechanism—in other words, to apply Galilean conceptions to life—has not only been an actual failure, but, if the reasoning

I have placed before you is correct, could not possibly be anything but a failure. In other words, the Galilean conception of the universe, since it cannot represent life, cannot possibly represent reality itself, but is only a preliminary and definitely insufficient working hypothesis with regard to reality. This universe is no disorderly spectacle of independent and self-existent things scattered about indiscriminately in infinite space and time. The facts of biology, even taken by themselves, render any such hypothesis impossible.

I chose the subject of this lecture because it seemed to me of the greatest importance at the present time that we should begin to realize more clearly that what we perceive is a matter of interpretation, and depends upon the axioms or working hypotheses which we adopt as consistent with our observations. In the distinction between biology and the physical sciences this fact comes definitely before us. Biological interpretation occupies a position midway between the Galilean interpretation and humanistic or spiritual interpretations. From the thorough-going Galilean standpoint of materialism the spiritual interpretation is mere illusion, and biology as a science independent of the physical sciences is non-existent. But the time has now come for examination of our axioms and a strict inquiry as to how far they are valid and consistent with experience.

In the course of this examination the spiritual interpretation as the supreme interpretation of our universe is coming again to its own, and a fundamental step seems to me to be the inquiry into the difference between the axioms of biology and those of the physical sciences. Had it been the case that the Galilean conceptions of the physical sciences applied to the phenomena of life the difficulties of a spiritual interpretation of our ordinary experience would have been very great. Biological interpretation provides us with a bridge towards psychological or spiritual interpretation.

Biology does not attempt to deal with distinctively psychological phenomena, although in connexion with the physiology of the nervous system it quite legitimately utilizes conscious responses as a mere index of physiological responses, while not attempting to take into account the distinctive characters of conscious responses as such. Hence biology is distinct from psychology. On the other hand, as I have tried to show, the attempts to extend mechanistic conceptions to life have only resulted in proving definitely that the phenomena of life must be interpreted in terms of the distinctive conception of life. For these reasons biology must be regarded as an independent science; and this is the thesis which I set out to establish.

THE LATE RESULTS OF MENINGEAL HAEMORRHAGE OF THE NEWLY BORN.

BY

HECTOR CHARLES CAMERON, M.A., M.D., F.R.C.P.,
PHYSICIAN IN CHARGE OF THE CHILDREN'S DEPARTMENT,

AND

A. A. OSMAN, M.R.C.S., L.R.C.P.,
CHIEF CLINICAL ASSISTANT IN THE CHILDREN'S DEPARTMENT,
GUY'S HOSPITAL.

Of cases which present themselves in later childhood as examples of infantile cerebral diplegia or paraplegia, dating from birth, what proportion owe their origin to meningeal haemorrhage occurring during or shortly after the moment of birth? It is a question which has often been asked and to which very different answers have been given. Sixty years ago Little,¹ the orthopaedic surgeon, had made up his mind that the majority of the children brought to him with spastic paralysis owed their unfortunate condition to accidents occurring at birth. So impressed was he with the truth and importance of this discovery that, introduced as a guest, he attended a meeting of the Obstetric Society of London and read a paper, thereafter famous, in which he invited the co-operation of his obstetric friends in investigating the origin of these disturbances, with the later results of which he was familiar and which he described graphically and with singular completeness.

The response to his appeal was apparently somewhat disappointing. The discussion which followed was meagre and barren. The distinguished obstetricians present had no knowledge of these unfortunate results of their ministrations. It was not until the year 1885 that a definite investigation

was undertaken by Sarah MacNutt.² In ten infants dying at birth or soon after birth, with symptoms of asphyxia, stupor, paralysis, rigidity, and convulsions, she demonstrated the presence of extensive meningeal haemorrhage below or above the tentorium cerebelli or in both situations. Gowers³ unhesitatingly accepted the views of Little and MacNutt as in accord with his own extensive experience and describes cases with symptoms similar to those of Little under the name "infantile meningeal haemorrhage." Of MacNutt's work he is reported as saying, "It is by far the most valuable contribution to medical science that the profession has yet received from members of her sex."

In 1889 Osler⁴ published his book *The Cerebral Palsies of Children*. He adopts and adduces evidence in favour of the views of Little and Gowers.

"Facts have gradually been accumulated to show that haemorrhage, usually meningeal, is a very frequent condition in children dying shortly after birth of asphyxia or convulsions, and as the birth palsies almost invariably have this history it seems reasonable to conclude that, in the cases which recover and subsequently present signs of motor disturbance, a similar, though less intense, lesion has existed."

In the last few years investigations into the causes of stillbirth have been carried out by numerous workers. In 167 cases examined Holland⁵ found tears of the tentorium in 81 (48 per cent.), and all of these except 6 were accompanied by subdural haemorrhage. There is general agreement that meningeal haemorrhage is by far the most common cause of death in fresh non-macerated fetuses and in infants dying shortly after the conclusion of labour. It is impossible not to conclude, with Osler, that many, and perhaps the larger number, escape with their lives, but suffer permanent damage in varying degree.

There are, however, difficulties in the way of unqualified acceptance of the view that in the numerous cases of cerebral diplegia which present themselves later in life we are encountering the aftermath of this damage at the moment of birth. The interval between the birth and the time when the crippled child is first brought for advice is often long, and it is not always possible to rely upon the mother's memory of the details of labour, if, indeed, these have ever been told her. Moreover, when after this long interval opportunity presents itself for making a *post-mortem* examination, the scarred and atrophied brain shows no evidence of the nature of the original lesion which occurred so long ago, and which has been so long extinct.

Apart from meningeal haemorrhage two other views have been held of the origin of cerebral diplegia dating from birth. There are those who regard the majority of cases as due to infective meningo-encephalitis, intra-natal or neo-natal. Virchow⁶ speaks of "encephalitis interstitialis congenita," Henoch⁷ of "haemorrhagic encephalitis." If we accept this view we must conclude that in general the infants recover, since routine investigations upon infants dying soon after birth show little evidence of encephalitis, but abundant evidence of haemorrhage. Cases which have come under our own notice suggest that trauma and haemorrhage themselves predispose to encephalitis. Probably the organization of the clot is always accompanied by a varying inflammatory reaction. The following is a good example of suppuration supervening upon haemorrhage. In this case there could be no doubt about the existence of the haemorrhage, because in addition to meningeal exudation there was a large clot within the substance of the brain.

An infant born at full time, in St. James's Hospital, Balham, with a breech presentation, after a difficult labour, was to some extent asphyxiated. Seen on the sixth day of life the fontanelle was tense and bulging, the pupils were unequal, and the limbs stiff and rigid. There had been repeated convulsions. On the sixth day the temperature rose to 104° F., and continued high. Death took place on the tenth day. At the autopsy the surface of the brain showed extensive suppurative meningitis as well as effusion of blood under the pia mater. In addition section of the brain showed a very large blood clot occupying a great part of the left hemisphere.

To assess the part played by developmental defect in the production of cerebral paraplegia and diplegia is even more difficult. Collier,⁸ in an important paper, which has clearly influenced much subsequent writing on the subject, is inclined to deny etiological significance to meningeal haemorrhage occurring at birth, and, basing his opinion upon *post-mortem* studies, to lay greater stress upon faults of development. Space will not permit a full discussion of this difficult question. We believe that in general it is true to say that in cases of diplegia due to developmental defect we find that the