Discorso di E. S. Russell

VITALISM

From the strict standpoint of science any theory of biological method which asserts the indipendence and uniqueness of the laws of biology is a vitalistic theory, and may be contrasted with the theories which deny to biology any independence of the physical sciences, the theories which we may call mechanistic. There have been many attempst, especially in recent years by the Neo-Vitalist, to show that biology is an indipendent science, but these attempst have as a rule taken the line of denying that physical and chemical laws apply throughout to living organisms. They have claimed that somewhere or somehow there is a gap in the physico-chemical determinism of life, and that some vitalistic agent, psychical or metaphysical, intervenes at the gap and exerts an influence on vital processes. Thus Driesch's Entelechy has the power of inhibiting for the proper length of time the transformation within the organisms of one kind of energy into another.

But it seems clear that to admit a psychical or metaphysical influence upon the physical is in effect to deny the absolute validity of physical laws, for on this admission every one of them could be altered by a non physical agent. Any attempt then to reconcile the vitalistic theories which admit an interaction of the physical and the psychical with the prevailing mechanistic conceptions of the physical sciences is doomed to failure. One may be an adherent of Neo-Vitalism, or an adherent of the mechanistic theory; one cannot hold both views.

But it would seem that there is a third attitude possible. One may concede the universal validity of physical and chemical laws and yet hold that the laws of biology cannot be reduced to their level. To admit the physico-chemical determinism of life is not to admit that physico-chemical laws are adequate to explain life. All vital activities can conceivably be analysed into a particular combination in space and time of processes each of which is explicable by physical and chemical laws; but it does not follow that the combination of these processes is itself explained by the lavs which explain each single process. And it is just this particular combination which transmutes a complex of physical and chemical reactions into the activity of a living organism.

In this paper we shall therefore admit the applicabiliy of physics and chemistry to the study of vital phenomena, but challenge the utility of their application.

I.

The phenomena presented by living creatures, the phenomena ordinarily called biological, are of two kinds. There are phenomena which living things show in common with non-living things, and there are phenomena peculiar to living things. Hence in biology as ordinarily conceived there are two orders of problems, biological and non-biological. Present day biology is accordingly a composite science, and takes cognisance of facts which are not distinctively biological.

Now it may be admitted at once that a physico-chemical explanation of what one might call the inorganic aspect of life is not only possible but useful and adequate.

In the living organism chemical reactions continually take place which are identical with reactions occurring outside the organism either under natural conditions or under the artificial conditions of experiment. Thus the oxidation of haemoglobin into oxy-haemoglobin may be effected by shaking a solution of it in a test tube. There is nothing distinctively vital abeut this most essential part of the process of respiration. So too the digestive enzymes will act just as well outside the body as in the alimentary canal, provided that suitable conditions are present for their action. Pepsin for instance will digest a piece of fibrin if a weak solution of hydrochloric acid is added and the whole incubated at a temperature of about 32° C. Even this dependence of the digestive enzimes (and of enzymes generally) upon the conditions of action is not a distinctively vital property, since it is shared by other colloids. Platinum in a colloidal state can be « killed » by heat, narcotised by chloroform, and poisoned by hydrocyanic acid.

It is true that most of the substances of which the organism is composed are very complex and found nowhere else in nature, being products of vital activity. But their study is none the less the task of the chemist alone. He is not concerned primarily with the origin of these complex proteins and enzymes whose reactions he studies, though he may strive to ascertain how they are actually synthesised by the activity of the organism.

There are many processes therefore which are not distinctively vital, though they may play a most important part in the life of the organism, and the explanation of these devolves upon the chemist, not upon the biologist. Physiological chemistry is indeed a branch of chemistry, not a branch of biology.

Not only are there many purely chemical processes discoverable in living things, but these processes are modifiable in the same sense as the chemical processes occurring in inorganic nature.

The effect of temperature upon vital activities is very marked and is manifested in many different ways. Heat accelerates development, the rate of transmission of a nervous impulse, the speed of muscular contraction; it may even heighten the tension of life and stimulate psychical activity.

Now there is every reason to think that all these various effects are simply consequences of the general law that the rate of chemical reactions is accelerated by heat and retarded by cold. Underlying development, muscular contraction, nervous activity, there are chemical processes, and any acceleration of these must change the rate of the vital processes which are their manifestation.

The empirical law which states the relation between temperature-change and the rate of chemical reactions is due to van t' Hoff. It reads that the velocity of chemical reaction is reduced to one half or less by a decrease in temperature of 10° C.

But this same relation has been observed in some instances of the influence of temperature upon vital processes. Thus the rate of heart-beat in the tortoise, and in *Daphnia*, is reduced to about one half when the temperature is lowered 10° C. The rate of transmission of a nervous impulse is about halved when the temperature falls

10° C. The rate of development of sea-urchin and frog shows this same relation to temperature.

All the direct effects of change of temperature upon living things may then be regarded as consequences of a general law which holds for all chemical reactions. They are accordingly to be studied by the methods of physical chemistry, applied with such success by Loeb and his fellow-workers to vital phenomena. They do not afford problems of a distinctively biological nature, and they do not manifest any law peculiar to living things.

But while many of the phenomena presented by living things are thus to be explained as the direct result of simple physical and chemical relations, there still remain a vast number of facts of life which cannot be explained by any direct reference to chemical laws. They present truly biological problems which can be resolved only by biological laws.

Examples are hardly necessary, for all the great problems fall under this category.

We have just mentioned the influence of temperature upon the rate of vital processes as an instance of a class of biological facts which are capable of chemical explanation. But there is another effect of temperature-change upon living beings which cannot be expressed as a simple consequence of chemical laws — the acclimatisation of the organism to the changed temperature. Dallinger' s classical experiments showed that an infusorian could be gradually accustomed to endure higher and higher temperatures, until it was able to thrive in water which killed any individual which had not been acclimatised.

Another instance is afforded by the eggs of a toad (*Bufo lentiginosus*). Davenport and Castle found that if these eggs were reared for four weeks at a temperature of 15° C., the temperature at which heat rigor set in was 40° C. If however the eggs had been reared for four weeks at 24-25° C., heat rigor did not occur till they were raised to a temperature of 43. 2° C.

These cases of adaptation to change of temperature are typical of many others, and they inevitably recall the similar adataptions of living beings to other environmental changes, for example the acquirement of immunity to poisons, or the adaptation of the alimentary canal to changes in diet. An interesting case of this latter kind of adaptation has been fully worked out by Babak, who showed that tadpoles fed on flesh had short wide intestines, while tadpoles fed on vegetable food, difficult to digest, developed a long and very much coiled intestine. All living organisms indeed possess to some extent this power of reacting to environmental change in such a way as to preserve their life and make the most of the new conditions.

These facts can certainly not be immediately expressed as depending upon chemical laws. They are facts peculiar to living things and require a biological explanation first of all. Whether this biological explanation can be reduced to a physico-chemical explanation is just what we have to discuss.

The striking character of the active adaptational response of living things to meet changes in their normal environment is apt to distract our attention from what is even more wonderful, the adaptation of the parts of the organism to one another.

This harmony of organisation is indeed so obvious a fact that we too often regard it as a commonplace. But in reality the whole of biology lies in this fact. If we could but explain how an organism comes to have such a marvellous and harmonious structure, whose parts are so admirably adapted to subserve the common good, we should solve the deepest and most vital of all biological problems.

When one feels inclined to think that life is nothing but a complex whirl of chemical actions it is salutary to reflect upon such a wonderful process as, say, the development of bone, with its armies of « osteoblasts » and « osteoclasts » building up and eating out the framework of calcareous deposits, in such a coordinated fashion that there results a bone with its definite shape, consistency, and structure. It requires only the slightest direct contact with the concrete facts to teach us how very far we are from understanding anything at all about life.

Not only is internal structure manifestly adapted to the efficient working of the life-machine, but the organism shows adaptations to its particular environment. Thus the *Radiolaria* which float in the surface of the ocean have globules of oil in their protoplasm, or long radiating spicules which tend to prevent them sinking to the bottom.

Then there are the facts of development, growth, and regeneration, all of them facts which find no parallel in the inorganic world.

Finally there are the problems of form. Why are organism segregated at the present day into groups which repeat their characteristic form from generation to generation? Why are these groups classifiable into larger groups? Why are organism generally of two sexes.

But it is unnecessary to labour the point.

All the real problems of biology are peculiar to biology. Biological facts can be classified into generalisations, and these cannot, at first sight at least, be seen to be consequences of simpler laws, laws of chemistry and physics. So far all is fair sailing. We have now to consider whether it is possible to reduce biological laws to physical or chemical laws, having admitted *a limine* that every biological event is a physico-chemically determined thing.

II.

The aim of biology is to make the structure and activities of living things more intelligible to us. Now the subject matter of biology consists of a large number of concrete facts and the first business of the biologist is to understand these concrete facts.

After he has explained the facts by relating them to some more general fact or law of living things he may proceed to explain if possible this general law. But the explanation proceeds from the particular to the general, and the aim is always to explain the particular.

For instance, it was recently discovered that the eels of Northern and Western Europe migrate at the breeding season hundreds of miles out into the deep, warm, and salt waters of the Atlantic to the west of Ireland, where they find suitable conditions for spawning. The eel seems to require, like many other fish, very definite conditions of depth, salinity, and temperature for spawning, and on the approach of the spawning season it exhibits a remarcable sensitiveness to slight differences in these conditions. Water containing 34.7 ‰ of salts will not content it; it seeks water of 35-35.2 ‰ salinity. It will not breed in the cold and shallow waters of the North Sea, nor in the deep but cold waters of the Norwegian Sea.

That it is the physical conditions of the spawning ground and not its mere locality that are sought after is shown by the fact that the eels round the Mediterranean breed in the deep waters of the Mediterranean, which are of a high salinity and temperature.

Now this observation about eels is a typical biological fact, and it is not any more mysterious and hard to be understood than most biological facts. Think of the migration of birds, of lemmings, of reindeer, all facts of a similar nature and equally difficult to explain. But it is these concrete facts which form the subject matter of biology and it is these which must be explained.

This point requires emphasis, for it is often maintained that the first aim of biology is to explain the most general properties of living things, the metabolism and movements of protoplasm, by analysing these into their physical and chemical components. This is, I believe, a radically mistaken method, for it is impossible to rise from knowledge of the physics and chemistry of protoplasm to an explanation of the concrete facts of biology. For instance, the swimming movements of an eel on its way out to the spawning grounds depend upon the chemical structure of its muscles, and the energy required is got by a purely chemical process of combustion of reserve materials in the myotome muscles of the tail. But even if we knew the exact chemical mechanism of muscular contraction, and of nervous conduction, for muscular movement is dependent upon nervous stimuli, we should not be a whit nearer an explanation of the fact that the eel was taking this long journey to a particular area of the North Atlantic for the purpose of spawning. The fact is that the laws of metabolism and of the physico-chemical side of life lose by their very generality all power to explain concrete facts of a higher order. One may quite well admit that every single process in the metabolism of the eel is determined physico-chemically by its morphological and chemical structure and by the action of the surrounding media, and that every phase of ist activity, the swimming movements of ist tail, ist reactions to changes in temperature and salinity, could be deduced in advance by anyone having sufficient knowledge of the chemical state of its organs; yet one would not be any further on the way to an understanding of the eel' s migration.

The migration is, so to speak, a fact of a higher order than any physical or chemical fact, although it is made up of an indefinitely large number of physical and chemical facts. To explain the fact one must accept it as a whole, not seek to conquer by dividing it, for if one analyses it into its components one inevitably misses the bond of union. One can show no necessary and inevitable connection between the components of the act; the movements of the tail and the physico-chemical processes into which they can be analysed would be the same even if the eel were not travelling to a definite area to spawn; it is the connection of there movements with the guiding and directing sensibility of the animal which constitutes the fact which is to be explained. If each of the component facts were known we should still have to enquire the reason for their particular connection, which alone unifies the component physico-chemical facts into the biological fact of migration. The explanation of a biological fact cannot be obtained by decomposing it, any more than the properties of a chemical compound can be deduced from the properties of its constituent elements.

A biological fact is something more than a mere arbitrary assemblage of component physical and chemical facts, and the component facts may be explained without touching at all the problem of their composition. In the case of the eel it is possible to decompose the act of the migration into a large number of acts of a different order, into the chemical reactions occurring in muscular movement, in nervous conduction, in the stimulation of peripheral sense organs, but by doing so one cannot but lose sight of the interconnection of these single acts, the inter connection which really binds together all these acts into the single act of migration.

A knowledge of the chemistry of a contracting muscle, of a conducting nerve, of a receptive sense organ, is not at all sufficient when one wishes to explain a complex act which involves all of these processes, for it involves them in a particular order in space and time, and this order is something which cannot be explained by a mere knowledge of the constituent processes. That is not to say that such knowledge is not valuable in its proper place, but it is clear that one cannot rise from a knowledge of the chemical processes of life to an explanation of complex biological tacts which involve these processes in a particular spatial and temporal order.

It is all a question of point of view. To decompose the act of migration into an infinity of physico-chemical processes is to take an infinity of little partial views, of the act, but what one needs for an explanation of the fact is a comprehensive view which will unite all the relevant features of it into one picture. To the chemist confronted with this problem there is no fact of migration at all. there is only an intricate enravelment of chemical reaction; to the biologist the fact of migration to a particular region for a particular purpose is cardinal, and the chemical processes involved in the action are negligible.

The two points of view are radically distinct, and it is impossible, for a human intelligence at least, to combine them into one all-comprehesive view. Physics and chemistry have indeed a right of attack on vital phenomena, but they cannot hope to explain concrete biological facts. Physico-chemical explanation touches only some of the widest and most general, and by that the most abstract and unvital of the properties of living protoplasm, and it is powerless to tackle any problem of a higher order. That means of course that the concrete facts of biology require a quite different kind of explanation from that required by the physico-chemical facts, which are themselves only partial aspects of vital phenomena.

Physico-chemical explanations, we said at the beginning, were to be judged by their utility, not by their applicability. Such explanations, we have seen, are theoretically applicable to the case of the migrating eel, but they do not explain the migration; they are not *useful*, for they do not make the biological fact of migration more intelligible. It is clear then that since it is the aim of biology to make the facts of biology more intelligible, and since physico-chemical explanations have been found inadequate to render a typical biological fact intelligible, explanations of a different kind are necessary.

It is not difficult to see the general lines along which such an explanation must be sought in the case of the migration of eels. This tendency or instinct to seek out a particular combination of physical conditions for spawning is clearly something inherited, and to explain it we must accordingly look at it in the light of the past history, both individual and racial, of the eel.

Here at once we are on a different plane of explanation from the mechanistic. For by history is meant something which is peculiar to living things, something which has no analogies in the inorganic world. No machine can acquire experience, and no machine can transmit it. But development and heredity mean simply the acquirement and retention of experience, whether experience be materialised in structure or manifested more subtly as tendency. An organism is above all an historical being, for its structure and activities are determined by its individual experience and by its heredity, that is to say, by the stored up experience of the race. A knowledge of the past experience, the genetic history, of the organism is therefore an indispensable condition for the understanding of its present activities.

This fundamental fact is by itself sufficient to differentiate absolutely the biological sciences from the physical sciences. In the organism the past is alwayas in some degree involved in the present, « le passé se prolonge dans le present », to use Bergson' s phrase. Living things therefore require an historical explanation. Non-living things on the contrary have no history in the biological sense of the word, and no inorganic thing carries its past about with it.

Our conclusion therefore is that the fact with which we started can be explained only by taking account of the past history of the organism which exhibits it, and that the method of explanation thus adopted is radically different in kind from that employed in the physical sciences.

III.

But it is possible to show the insufficiency of mechanistic explanations not only in the case of such a relatively mysterious problem as the eel' s spawning migration, but also in the case of problems which appear more readily attackable by the methods of physics and chemistry.

Thus thy physiology of digestion has been studied of recent years with much success by the methods of physiological chemistry. We may enquire therefore how far the results of this work will take us towards a full understanding of the vital processes involved in digestion. We shall find that they leave major part of the problem unsolved, even untouched.

First the facts which have been established. It has been shown that the actual breaking down of the food is a purely chemical process, carried out by special chemical agents — enzymes — produced for the purpose by the organism. Ptyalin in the mouth, pepsin and rennin in the stomach, pancreatic juice in the duodenum, succus entericus in the small intestine, act in turn upon the complex molecules of the food and break them down into simpler compounds, amino-acids, fatty acids, monosaccharids, and the like. There is in these processes nothing distinctively vital, nothing which will not in time receive a purely chemical explanation. It is probable also that the more hidden and elusive processes of the production of enzymes in the cells of the digestive glands are purely chemical in nature and may some day find their explanation from physiological chemistry. All these problems are of the kind which we distinguisted above as non-biological. The problems are purely chemical and can profitably be studied only by chemical methods.

But there are also truly biological problems involved, which escape a mechanistic solution. There is the broad fact of the adaptation of the parts of the organism to the harmonious performance of function.

Enzymes are not produced at random, nor are they continually dribbled out by the secreting cells. On the contrary, they are produced only at the right time and in the right place. It is true that their production is brought about by physical means, by the stimulation of the gland cells along a defined nervous path, but it is the adaptedness of these reflex paths which enables the proper sensory excitation to travel to the appropriate group of secreting cells. For a full explanation of digestion therefore it would be necessary to explain the origin of this adaptedness of structure.

Not only is the production of enzymes entirely conditioned by the adaptedness of structure but the enzymes themselves are adapted to the particular kind of food taken. Thus the digestive enzymes are of three kinds, proteolytic, amylolytic, and fat spilitting, in adaptation to to the three types of foods, proteins, carbohydrates, and fats. In young mammals there is even a special enzyme in the small intestine which splits milk sugar and so enables the organism to deal effectively with the milk which is at first its sole autriment.

There has even been observed an active adaptation of the digestive secretions in response to particular diets. Thus the pancreatic juice whith its three enzymes, a trypsin, a diastase, and a lipase, varies in composition according to the diet given.

If bread is given, relatively large amounts of the proteolytic and of the diastatic and a small amount of the fat splitting enzyme are produced, since bread contains much starch, a protein difficult of digestion, and very little fat. Milk on the other hand contains much fat, and when it is given the proportion of lipase in the pancreatic juice secreted is high, the proportions of trypsin and diastase relatively low.

Now it is no doubt the case that the production and activation of the digestive enzymes are physico-chemical determined processes. They are dependent upon nervous impulses or upon chemical stimuli, and it is theoretically possible that the conduction and mode of action of the nervous stimuli could be expressed in terms of the chemical changes in the nervefibres and their terminations, and also that the mode of action of the chemical stimuli, of secretin for instance upon the pancreatic secretion, could also be explained in chemical terms.

But it is clear that while an analytical description of the phenomena in this way is possible it would not furnish any real explanation of the fact that the digestive enzymes are adapted to the work which they perform and are produced at the right time and in the right place. That is a task for biological method, interpreting the facts in the light of the past history of the organism.

To make this clear let us consider for a moment what sort of facts would be furnished by a purely chemical study of the vital processes involved in digestion.

In the first place it would not be the business of such a science to describe the whole physico-chemical determinism of every change in the organism. That would be a task too immense for human powers, and besides it would not be science. Physiological chemistry must on the contrary simplify its problem by making a classification of vital processes. It must study the chemistry of a contracting muscle, of a conducting nerve, of a secreting gland. It must take the individual organism as typical of the species, as typical in a less degree of the genus, the order, the class to which it belongs. It must seek to establish the general schema of the chemical changes which occur when a muscle contracts, whether that muscle belongs to a dog or a frog or a crayfish. It must try to discover the general formulae which will describe the chemical changes in a nerve cell and its processes when an impulse is passing through it.

If such a science were practicable, and there are no theoretical obstacles in the way, its results would be summed up in some such fashion as this. When a nerve is stimulated, a chain of chemical reactions in set up of which such and such formulae are the generalised expression. These formulae hotd with certain modifications throughout the vertebrate series. Among Arthropods the general type of the formulae is the same, but there are important differences in detail, owing to the fact that chemical composition of the Arthropod nerve is somewhat different. Similar statements could be made for the other kinds of vital activity.

Now apply this knowledge which we have supposed gained to the elucidation of the reflexes involved in the production of enzymes. It will tell us what sort of chemical changes occur when the sight of food makes a hungry dog's mouth water or causes a reflex secretion of gastric juice in its stomach; it will explain in chemical language just what happens in the end-organs, nerve fibres, and nerve cells concerned.

But clearly it cannot explain why the « chemical structure » of the dog's nerves is such as to admit of this rapid transmission of an impulse, why the ingoing neurons are linked up in the central nervous system in such a way that the outgoing impulse passes down just the right outgoing neurons, why the secreting cells of the salivary or of the gastric glands are situated just in the proper places and provided with the proper ducts to allow their secretion to pass out into the proper place. In a word, this perfected physiological chemistry is quite powerless to explain the adaptedness of structure to function. If it takes the spatial relations of the parts of the organism for granted, and assumes also those more minute but still spatial relations which may be summed up as « chemical structure » of each type of cell, it can then describe sufficiently well the chemical changes which occur during the functioning of these parts.

It may explain these changes as being particular cases of chemical laws established for the inorganic world, and thus claim to have given a mechanistic explanation of vital activities. But it is clear that in renouncing the attempt to explain the origin of the morphological and chemical structure of the organism with which it deals it has precisely left out of account the very facts which demand explanation, the facts which are characteristic of the living organism.

But it may he objected that a physico-chemical description of the development of the organism, could conceivably be given, and the origin of its adaptive structure thus explained. Admitting for argument's sake that such a description were possible, it is still not apparent that the physico-chemical explanation of development could arrive at any true chemical law of development. It could decompose development into a series of chemical processes, each of which could be summed up and explained by some one of the laws of chemistry, but it would still be powerless to account for the particular combination in time and space of these processes, that combination which alone makes them vital.

Given to start with the actual combination of such in the fertilised ovum, given the specific chemical structure of the ovum, an adequate knowledge of physical chemistry would no doubt enable one to predict the chemical events of future development. But the specific structure of the ovum has itself to be explained, and however far back the origin of the given combination may be relegated, it must still be taken as given *in potentia* at some time in the past.

But not only is the origin of the particular combination of physico-chemical processes which constitute life quite beyond the reach of physico-chemical explanation, — for mechanistic science cannot deal with origins, — but even given the initial combination chemistry cannot supply any explanation of development. All it can discover is that many laws of chemistry are verified in the development of an organism. It can analyse the processes constituing development, but it cannot explain that harmony of them, that apparent striving towards an end, which is the most striking characteristic of development. All the real problems of development, its apparent autonomy and invariability. its great indipendence of environment, are beyond the reach of physico-chemical explanation. (1)

The biological problems centering round the study of digestion are indeed the same problems which presented themselves in our study of the migration of the eel, and in both cases no physico-chemical explanation is of any use in making the facts intelligible.

Even if every part of the digestive process, every reflex, every muscular movement, could be shown to consist of purely physico-chemical processes, and these processes explained by reference to chemical laws we should not be in the least degree nearer an understanding of how the gross structure of the organism and the minute structure of its tissue elements have come to be adapted so closely to subserve the common good of the organism. This adaptive structure can be explained only if its origin is rendered intelligible to us, if we know how it has developed in the individual and how it has evolved in the race.

For a full understanding then of the biological process of digestion we must seek the help of other methods of explanation. We must regard the organism as an historical being and interpret its present structure and activities in the light of its past history. We must discover the laws of development, heredity, and evolution, and these laws can only be biological; they must by their very

(1) See E. S. Russel, *The Evidence for natural Selection,* « Scientia », vol. V, N. IX-1.

nature be incapable of being reduced to the laws of physics and chemistry. Their content will be richer than the content of physical and chemical laws, and they will represent the true gains of the science of biology.

IV.

Strictly speaking, whatever theory of evolution one holds, one thereby adopts a method of explaining biological facts which is different in kind from any method employed in the physical sciences. It is therefore a contradiction in terms to speak of a mechanistic theory of evolution. Even the theory of natural selection in the extreme form given to it by the Neo-Darwinians is not entirely mechanistic. It is true that on this theory evolution comes about by a mechanical elimination of fortuitous variations, (though it is noteworthy that Weismann with a true sense of the difficulty of this position has invented a theory to account for the appearance of the right variation at the right time). But natural selection has to take for granted certain distinctively vital properties, variability and inheritance, and it does not pretend to offer a mechanical explanation of these. The theory is therefore a biological and not a mechanistic one.

For an understanding of evolution we require not only a knowledge of how the unfit are eliminated, but also and principally, a knowledge of the laws of development, heredity, and variation. To discover these we must first investigate the facts in detail, a work which is going on vigorously at the present day, then classify the facts and try te relate them to some simpler and mere general property of living things. An interesting attempt in this direction is shown by the mnemonic theories of development and evolution, which establish a continuity between individual development and racial evolution, interpreting both as in the last resort due to the property possessed by all organisms of retaining a trace, a physical memory, of all the stimuli which have acted upon them. Whether or not these theories are adequate to explain the laws of heredity and development they at least show the line of explanation which a sound biological method must take, namely the reduction of the manifold activities of living things to the simplest vital properties.

To sum up then, biology is an indipendent science with laws of its own, and the explanation of its facts is not to be sought outside of the science in the laws of physics and chemistry. We must not refuse to admit that it is possible to treat living things as if they were simply physico-chemical mechanisms and that for the practical ends of medical science this may even be the most useful course te take. But physiological chemistry can take no account of the historical aspect of the organism; it must take the organism as given, and it can deal only with the present of the organism, the past is out its reach. It can describe and explain the mechanism of the organism's responses to stimulation, but it cannot explain why this mechanism exists, for this is a problem of origins. Its field is in the present, but the organism is the product of the past, which refuses itself to chemical investigation.

In contrast therefore to the sciences of inorganic nature, whose objects are not capable of historical explanation, biology is a science of origins. Not of absolute origins certainly, for biology must start out from the fundamental properties of, living things. But biology may trace the historical development which is rendered possible to the organism by the possession of these properties, and so be a science of relative origins. Its object must therefore be to discover those properties of living matter which have rendered evolution possible. It must seek these properties not by studying the physics and chemistry of protoplasm, for by so doing it can arrive at only a vague and abstract description of vital activities in terms of a lower order. It must work down from the concrete facts of biology to the general vital properties underlying them. For indeed it is not the discovery of the laws or their mere abstract statement which is the important thing, but the interpretation of the facts, the illumination of experience which they provide. A law is an empty and uninteresting formula unless we have knowledge of the concrete facts which it explains. Biology must therefore work down from the facts to the laws, but reascend from the abstract laws to a vision of the facts as they appear lighted up by the laws.