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Life and Death.

MAN must have speculated on the meaning and source of life ever since a race of beings arose on this planet endowed with the power of reasoning, the particular form taken by his speculations depending on the stage of civilisation and culture reached. At all times there have been those—fewer now than even a century ago—who drew a sharp line of distinction between the living and the non-living, between the inorganic and the organic world ; but the advance of scientific knowledge has slowly broken down the barriers between the animate and the inanimate, first when it was discovered that organic substances, previously supposed peculiar to the tissues of living beings, could be prepared in the test-tube in exactly similar manner to inorganic compounds, until nowadays many confidently assert that the phenomena of life will be explicable in the terms of the more exact sciences. Others, more cautious perhaps, consider that though it may be possible to describe these phenomena in the terms used in mathematics, physics, or chemistry, yet such description will still not provide us with a final and complete explanation.

That the laws which govern the phenomena of life are undiscoverable, that the basis of life is some vital principle, the nature of which can never be known, is a position which few would hold to-day, leading as it does to a paralysis of the power of investigation, and refuted, as it is, by our rapidly increasing knowledge of these very phenomena. The fundamental distinction between the living and the non-living is that whilst it is possible to isolate the phenomena of the inorganic world, it is impossible to consider a living organism apart from its environment ; it is, in fact, its reactions and adaptations to changes in its surroundings which distinguish the living from the inanimate and form the basis of the science of biology.

What light, then, do the recent advances in chemistry and physics throw on the phenomena of life ? And how far are the laws of these sciences applicable to the reactions of living beings ? To a consideration of these questions Prof. Donnan applied himself in his recent evening discourse to the British Association at Glasgow. The investigations of physiologists early showed that organisms obey the laws of the conservation of matter and of energy. The energy for the heat produced and the work performed by a living being is derived from the energy value of the food consumed, by its oxidation in the presence of the oxygen taken in during respiration, and it is easy to construct a balance sheet of the incoming and outgoing energy and show that there is no credit or debit balance. Again, plants and animals conform also to the second law of thermodynamics, so far as is known at present; it is the free or available energy of their environment which is the sole source of their life and activity, and the origin of this available energy is the radiation from the sun. If this radiation were in thermal equilibrium with the average temperature of the earth's crust, practically all life as we know it would cease, since the green plant would be unable to assimilate carbon dioxide and water by the absorption of free energy by means of its contained chlorophyll, and the synthesis to sugar and starch would fail to occur. This synthesis represents an increase in free energy, since starch will produce energy on oxidation, and would be impossible unless there were at the same time a compensating degradation of energy.

All living things live and act by utilising the free energy of their environment; the living cell, in fact, acts as an energy transformer. Thus some nitrifying bacteria oxidise ammonia to nitrous or nitric acid and so obtain the necessary energy to build up carbonic acid to sugar or protein; other microbes utilise the free energy of sulphuretted hydrogen and oxygen. Up to the present, all the energy transformations of the living cell so far investigated have been found to obey the second law of thermodynamics, so that all activity depends on the nature and amount of the free energy in the immediate environment, and this applies both to the organism as a whole as well as to its individual cells. If the blood-flow to the brain is stopped, the nerve cells soon cease to function and consciousness is lost; if the entry of oxygen into the lungs is prevented, all the cells of the body sooner or later cease to live.

In the investigation of living phenomena, it is essential to reduce the problems to their simplest terms and study each under controlled conditions; but it must not be forgotten that every action of a cell within the body has its repercussions upon the action of some other cell or cells, so that, having studied a series of isolated phenomena, it is necessary to find the influence each exerts upon the others, to synthesise the parts again into the whole. It is by the application of the laws and facts of physics and chemistry to the elementary phenomena that we are gradually arriving at an understanding of the whole. Whether these laws will suffice to describe all the phenomena or whether a new form of energy will be discovered, none can say.

Among living phenomena recently analysed, those of muscular contraction and the equilibrium between the red blood cells and the plasma are especially noteworthy. The energy of work is obtained from the rapid exothermic conversion of glycogen into lactic acid; when the contraction is over, the glycogen, the muscle's store of free energy, is replaced by the reconversion of the major part of the lactic acid into the polysaccharide, the necessary energy being obtained from the oxidation of the remainder. A balance sheet of the energy changes can be constructed, and it is found that the whole process obeys the known laws of physics and chemistry; that the heat given out or energy absorbed is the same as in the corresponding changes carried out in the test-tube; that there is no loss or gain of total energy. The equilibrium between the red blood cells and the plasma illustrates how one change in a system may set in motion a whole series of changes designed to compensate for the first and bring the system back again to its unstable equilibrium; the whole series of changes can be written in a set of precise mathematical equations; the effects of a given change can be calculated and, when examined experimentally, found to agree with those predicted. Thus each event depends on some preceding event, and the whole series follows exact laws; so far, no phenomena have been found to follow the laws of probability, though this is not to say that such may not be discovered in the future; but at present each event follows inexorably in the footsteps of those preceding and depends upon and is conditioned by them.

There is, however, always the possibility that events occurring in communities of cells such as compose one of the higher organisms, may not be really analogous to those taking place within a single cell, or that the laws governing the phenomena of the large molecules of which the cell protoplasm is composed may not apply to the behaviour of simple molecules, or atoms, or electrons. Sometimes it has appeared as though the movements of the latter might be due to chance rather than to some preceding event occurring in the neighbourhood; but even in the case of such phenomena it is sometimes possible, by application of the laws of chance, to predict the probability, or otherwise, of some future occurrence. It must also always be remembered that what appears to us a chance event may in fact be the sequence of some one preceding, although owing to our ignorance of the phenomena and our inability to repeat the required conditions, appearing to be quite unrelated.

The chief distinction between the inorganic world and life is that in living organisms structure depends on function, and that whereas the structure of the inorganic world may be looked upon as static, the structure of a living cell is dynamic. The cell consists of protoplasm surrounded by a membrane and containing a nucleus: the protoplasmic system of the cell body and nucleus exists in what is known as the colloidal state. Protoplasm has as the basis of its composition protein compounds; but fat-like substances, carbohydrates, salts, and water are also present in the cell. Each living cell acts as an energy transformer; on death it ceases to take up oxygen and other substances from the surrounding medium and to give out energy in one of its various forms. But at the same time it does not simply remain, so to speak, *in statu quo*, like a run-down machine; it disintegrates. In other words, its very structure depends on its being alive, and at the moment of death, this structure begins to fall to pieces; in fact, the cell is destroyed by certain enzymes present in it, which, at death, attack its structure and destroy it.

The reason why these enzymes do not break down the living cell must be because it is alive, and the solution of this problem would go far towards solving the mystery of life itself. It appears that the structure of the cell is chemico-dynamic, and depends on the supply of oxygen for its preservation. Thus the machine of a cell is totally unlike an inorganic machine, which is not destroyed, but simply fails to run, when the supply of fuel gives out. The equilibrium between the cell and its surroundings is thus not static but dynamic; death leads to an irreversible breakdown of structure and the final production of a static equilibrium. In this dynamic equilibrium lies the power of the cell to react and adapt itself to changes in its environment.

At the moment, such investigations throw little light on the origin of life upon this planet, but they do suggest that further research may bring us nearer to a solution of this problem. Astronomy teaches that the earth, thrown off like the other planets of our solar system from the sun under the gravitational pull of a passing star, and held by the sun's attraction in a revolving orbit, cooled down and finally acquired a solid crust, probably at least a thousand million years ago. Since then the water vapour in its atmosphere condensed to form seas and lakes and rivers, and living beings, plant and animal, appeared. Did spores of life, scattered through the universe, reach this planet accidentally, or did life arise from inorganic matter already present on the earth's surface? The theory of 'Panspermia,' besides having to surmount many apparently insuperable obstacles, shuts the doors to all investigation of life's origin; on the other hand, if life arose upon the earth, it is permissible to speculate upon the conditions necessary for its appearance and upon the form or forms it first assumed.

From the fact that the nature and amounts of the inorganic salts in the tissue fluids reflect almost certainly the composition of the oceans a hundred million years ago, it appears justifiable to assume that life arose in the waters of this period of the earth's history. It is probable that the atmosphere at this time contained carbon dioxide and ammonia or sulphuretted hydrogen, so that certain bacteria could have flourished as they do to-day. But whence came the organic matter, the protoplasm, of their cell bodies? Now it has been shown that in the presence of light, moisture, and carbon dioxide, formaldehyde and sugar can be produced at the surface of certain inorganic compounds, such as nickel carbonate, so that it is easy to imagine how certain organic substances might have been produced from inorganic; and similar syntheses of other organic compounds may be found in the future when science discovers the necessary conditions. A further obstacle, however, now requires surmounting: the protein components of the protoplasmic system are optically active, and so far no asymmetric synthesis has been carried out in the laboratory, starting from symmetrical, optically inactive substances. Even when this difficulty is surmounted, as no doubt it will be in the future, the conditions necessary for the production of the complicated structure of the dynamic living protoplasm will have to be obtained.

It is always possible that the origin of life was an exceedingly rare fluctuation from the average of happenings in which organic material arose from inorganic, or structured organic from the structureless. The minute organisms of the filter-passing viruses are of the same order of size as many non-living colloidal particles, so that on the score of size there is no insuperable difficulty in the way of postulating some such origin for living beings. By patient investigation man will delve deeper and deeper into the heart of the mystery of life, possibly forging new tools of technique and reasoning in the process, but whether he will obtain such control of the conditions as to be able to see life arise from the non-living, or whether even it is possible to attain the necessary conditions in the world as we know it to-day, must be left to the future to decide.