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545TH ORDINARY GENERAL MEETING,

HELD (BY KIND PERMISSION) IN THE HALL OF THE ROYAL SOCIETY OF ARTS ON TUESDAY, MAY 6TH, AT 4.40 P.M.

THE PRESIDENT, THE RT. HON. THE EARL OF HALSBURY, TOOK THE CHAIR.

The Minutes of the preceding Meeting were read and signed, and the Secretary announced the election of Professor Theodore Flournoy, of Geneva, as a Life Associate.

THE ORIGIN OF LIFE—WHAT DO WE KNOW OF IT?

BY PROFESSOR G. SIMS WOODHEAD, M.A., M.D., LL.D.,
Fellow of Trinity Hall.

FROM the time of the first records of the human race, one subject more than any other appears to have aroused the thought and piqued the curiosity of man—the origin of life. Speculations thereon have ever occupied a prominent place and aroused the keenest interest in the human mind, which has busied itself with theories, crude or profound, according to the age, as to the beginnings of the powers which are associated with living matter, and which collectively are spoken of as LIFE.

Professor Schäfer, in his interesting and stimulating address delivered before the British Association in September of last year, before giving his definition of life, said, "Everybody knows, or thinks he knows, what life is; at least we are all acquainted with its ordinary manifestations"; but he went on to point out that the most profound and acute thinkers, after devoting themselves to the framing of a definition of life, have been constrained to admit, in the words of Herbert Spencer, that no definition has yet been found "which would embrace all the known manifestations of animate, and at the same time exclude those of inanimate, bodies."

It is not my intention to traverse much of the ground covered by Professor Schäfer, as to the non-identity of life with soul, the phenomena indicative of life—movement, assimilation, dis-assimilation—the chemical phenomena accompanying life, the possibility of its synthetic production, and the chemical constitution of living matter; though these, amongst other

points, must all be discussed where the question of the origin of life is under consideration.

It is evident from a study of the history of this question that, just as the alchemist, in his search for the philosopher's stone and the elixir of life, made observations and came upon facts that constituted much of the foundation of our modern chemistry, so the search for the meaning and origin of life, begun in darkness and continued in shadow, has stimulated most powerfully the development of science and philosophy, and has led men along paths now much more broadly and solidly laid than those "sheep-tracks" on the mountain-side of thought in which they began.

The earliest literature with which all are familiar—the Pentateuch—puts forward the hypothesis that life, in the first instance, was of supernatural origin, and then transmitted in perpetuity.

In contrast to this, the earlier Greek philosophers had a distinct conception of life as having spontaneous origin, accompanied, however, by the idea expressed by Thales in the words:* "All things are full of gods." This idea was more fully developed by Plato and Aristotle as a belief in a "World-soul sustaining and moving all that is." Aristotle makes clear his belief that living organisms may arise spontaneously. It must be realised, moreover, that, following the earlier Ionic philosophers, he looked on the universe and the elements from which it was constructed, as being endowed with energy and life, which might be imparted to the organisms developed from and in them. This view was adopted by the poet Lucretius: "The earth has rightly received the name of Mother, since all things are begotten of it, and many living creatures arise out of it, having been generated by the mists and by the warm sun."†

During the Middle Ages, the influence of Christianity secured the universal acceptance of the Hebrew view of the creation of life in the first place by supernatural action. But along with

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* Adam, *Religious Teachers of Greece*, p. 185.

† Given by Macallum from:

"Linquitur ut merito maternum nomen adepta
Terra sit, e terra quoniam sunt cuncta creata.
Multaque nunc etiam exsistant animalia terris,
Imbribus et calido solis concreta vapore."

De Rerum Natura, Lib. V, pp. 793 *sqq.*

NOTE.—I wish here to express my great indebtedness for many valuable suggestions to a paper—"The Origin of Life on the Globe"—contributed to the *Transactions of the Canadian Institute*, vol. viii, pp. 423–441, by A. B. Macallum, Sc.D., F.R.S., Professor of Biological Chemistry in the University of Toronto.

this, there was current the notion that some of the lower forms of life could arise spontaneously. Accurate observation was at a discount in an age that was far from critical. Before the time of Malpighi and Leeuwenhoek, with their lenses and magnifiers, it was impossible to follow the development of those minute organisms in which we can study life in its simplest form; but even had such instruments already existed, they would have been of little use, apart from the more accurate observation and sounder reasoning that followed the Renaissance in Europe.

It is exceedingly interesting to follow this question of spontaneous generation, and the various steps by which the arguments advanced in favour of it have been overthrown.

Professor Schäfer pointed out that, in the present state of knowledge of the "man in the street," it seems scarcely credible that spontaneous generation, abiogenesis, or the development of living organisms from dead matter, should have assumed such large proportions in the minds of some of the most able of the early scientific investigators. Nothing appears to have been too outrageous to be believed by those who wrote on spontaneous generation. Even as late as the sixteenth century, one able and usually reliable observer, Van Helmont,* stated that it was possible to "create" mice by placing some dirty linen in a receptacle along with a few grains of wheat or a bit of cheese. Later, an Italian, Buonanni, gave a no less startling example of alleged spontaneous generation with elaboration and embellishments of even more fantastic character. Timber rotting in the sea, he said, gave rise to worms, these in turn changed to butterflies, the butterflies ultimately becoming birds.

Those who believed in spontaneous generation, however, had not matters all their own way. Francesco Redi,† an Italian poet and physician, was able by a simple experiment, made in 1668, to demonstrate that the worms found in putrefying meat are not, as was generally supposed, the product of spontaneous generation. He simply placed the meat in a wide-mouthed vessel and covered the opening with a piece of gauze. Flies, attracted by the meat, deposited their eggs on the gauze and from the eggs in this position were hatched the worms which, until this experiment was carried out, had been supposed to become organized spontaneously and to receive life in the meat itself.

These experiments appeared to settle the point under

* *Ortus medicinæ . . . ed. ab authoris filio*, Amst., 1648.

† *Experimenta circa generationem insectorum*, Amstelodami, 1671.

dispute; but in 1683 and subsequent years, Leeuwenhoek* described minute organisms, which we now recognize as bacteria, the origin of which soon became a matter of keen contention. He says: "I saw with very great astonishment, especially in the material mentioned" (from the teeth of an old man who had never used a tooth brush) "that there were many extremely small animals which moved about in a most amusing fashion; the largest of these" (represented by him in an admirable figure) "showed the liveliest and most active motion, moving through rain-water or saliva like a fish of prey darts through the water: this form, though few in actual numbers, was met with everywhere. A second form moved round, often in a circle, or in a kind of curve; these were present in greater numbers. The form of a third kind, I could not distinguish clearly; sometimes it appeared oblong, sometimes quite round. They were very tiny, in addition to which they moved forward so rapidly that they tore through one another; they presented an appearance like a swarm of midges and flies buzzing in and out between one another. I had the impression that I saw several thousands in a single drop of water or saliva which was mixed with a small part of the above-named material not larger than a grain of sand, even when nine parts of water or saliva were added to one part of the material taken from the incisor or molar teeth. Further examination of the material showed that out of a large number which were very different in length, all were of the same thickness. Some were curved, some straight, lying irregularly and interlaced." Since, he says, "I had seen minute living animalculæ of the same shape in water, I endeavoured most carefully to observe whether these also were living or not, but I was unable to recognize even the slightest movement as a sign of life." Erasmus Darwin,† speaking of these organisms in 1794, says, perhaps they may be creatures of stagnation or putridity or perhaps no creatures at all Leeuwenhoek's demonstration of the presence of minute organisms in various kinds of putrefying organic matter and even in rainwater was to others an occasion for again calling in spontaneous generation as affording an explanation of the presence of these simple living forms. But he stuck to his views of their function, and to his opposition to the theory of spontaneous generation, which had to wait almost until our time before it was

* *Omnia Opera, seu Arcana Naturæ ope microscopiorum exactissimorum detecta*, Lugd. Bat., 1722.

† *Zoonomia; or the Laws of Organic Life*, London, 1794–1798.

finally crushed by Tyndall and Pasteur. Indeed Leeuwenhoek, "fought steadily against the view that living things are bred from corruption, and showed that weevils (supposed to be bred from wheat as well as in it) are grubs hatched from eggs deposited by insects; and also that the sea mussel was not generated from sand and mud, as Aristotle thought, but from spawn, and he maintained that the same was true of the fresh-water mussel . . . He showed that eels were not produced from dew, as was then supposed by respectable and learned men . . . And many with good reason judge that Nature keeps the same method in invisible creatures that it does in all the sizes of visible, and that even the least as well as the greatest, can be no more made out of corruption than one of the greatest, as a horse."* A fellow countryman of our own, Needham,† took up the cudgels on the other side. With Buffon, he maintained, against his own preconceived notions, however—that spontaneous generation took place continually and universally after death, and sometimes during life, that intestinal worms were formed from the dead matter in the contents of the intestine, certain molecules of the organic matter being set free, becoming re-arranged and entering into a combination that became vitalized. "The eels in flour paste, those of vinegar, all those so-called microscopic animals, are but different shapes taken spontaneously, according to circumstances, by that ever-active matter which only tends to organization." Needham said that dead matter might be heated over a fire, and protected from the air, but that organisms would still be generated in it. An Italian Abbé —Spallanzani‡—insisted, however, that there were two weak points in Needham's work. In the first place, he had not exposed the vessels to a sufficient degree of heat to kill the seeds that were inside, and, secondly, as Needham had only closed his vessels with porous cork stoppers, the seeds of living germs could easily have entered the vessels by the pores and so have given birth to animalculæ. Repeating the experiments, Spallanzani used hermetically sealed vases. "I kept them," he says, "for an hour in boiling water, and, after having opened them and examined their contents within a reasonable time, I found not the slightest trace of animalculæ, though I had examined with

* H. G. Plimmer, F.R.S., *Jl. Roy. Mic. Soc.*, 1913, p. 133.

† *Observations upon the Generation, Composition and Decomposition of Animal and Vegetable Substances*, London, 1749; *Notes s. les Nouvelles Découvertes de Spallanzani*, Paris, 1768.

‡ *Phys. u. Math. Abhandl.*, Leipzig, 1769; *Opuscules de Physique, par Senebier* (1776), 1777.

the microscope the infusions from 19 different vases." F. Schulze* then demonstrated that the sterility of the contents of these vessels was not dependent upon any alteration of the air within the flask, or the small quantity of air contained in it, and that it was not due to any alteration brought about in the liquid by the heating process. Any quantity of air, if properly purified, might be sent through the flask, and no growth would follow, whilst on the other hand the fluid that had been boiled, but which was left exposed to the air, rapidly underwent decomposition, a process accompanied by the development of micro-organisms in very large numbers. Finally, Hoffmann and Pasteur,† independently of each other, demonstrated that it was not even necessary to close the mouth of the heated vessel with cotton-wool, as had been done by Schroeder and von Dusch.‡ It was quite sufficient to draw out and bend backwards the neck of a flask in which the germ-free infusion was contained, in order to ensure the continuance of a non-putrefactive condition and the perfect freedom from germs of the fluid contained within the flask. Germs, he said, like all other solid particles, when not blown about by currents, obey the law of gravitation and must settle down upon an upper surface, so that, when the tube was bent downwards, the organisms could not fall into the mouth. Pasteur was able to keep his broth sterile in hermetically sealed glass bulbs. This broth was then exposed to the air in crowded rooms and on mountain heights by breaking the points of the bulbs and sealing them up rapidly after the exposure had been made. Of thirteen vessels of broth exposed in a sleeping hut, nearly all gave evidence of the growth of organisms, whilst of twenty exposed on the Mer de Glace, all but one remained sterile. He found that different kinds of change took place. Various vessels, exposed in different places, contained different organisms, and he concluded that the particles suspended in atmospheric air, with the germs or seeds attached to them, are the exclusive origin, the necessary condition, of life in infusions.

Charles Darwin at this time failed to see how it was possible to bridge the gap between the living and the non-living. His closing argument in *The Origin of Species* brings this out very forcibly: "There is a [simple] grandeur in this" (the evolu-

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* Gilbert's *Annalen de Phys. u. Chemie*, Bd. xxxix, 1836, p. 836.

† Hoffmann, *Botan. Zeitung*, 1860; Pasteur, *Compt. rend. Acad. Sci.*, Paris, t. 50 (1860), p. 306.

‡ *Ann. der Chemie u. Pharm.*, Bd. lxxxix, 1854; *Journ. f. Pract. Chemie*, Bd. lxi, 1854.

tionary) "view of life, with its several powers of growth, reproduction, and of sensation, having been originally breathed into matter under a few forms, perhaps into only one, and that, whilst this planet has gone cycling onwards according to the fixed laws of gravity, and whilst land and water have gone on replacing each other—from so simple an origin, through the selection of infinitesimal varieties, endless forms, most beautiful and most wonderful, have been evolved."* His theory of evolution never led him beyond this.

In this, naturally enough, he was not followed by some of the great scientists and philosophers of his time. One school, in answer to the question, "Where did life come in?" refers us to the time when the earth's crust was cooling, when conditions not now present prevailed, when chemical combinations now unobtainable were taking place; and it suggested that matter, at that time in a condition of exceedingly unstable equilibrium, was moulded by these great cosmic forces into the most elementary forms of life, capable of deriving nutrition from substances not nutrient to the living matter of to-day, of existing at temperatures not nearly approached by those which the heat-resisting organisms now met with could sustain. It is suggested that this exceedingly simple living matter gradually acquired features and properties similar to those now possessed by animals and plants, but that this could have been compassed only in a period infinitely longer even than that allowed by the geologists for the development of our earth. "Such a form," says Macallum, *op. cit.*, "once brought into being, would start on its long career; out of it would develop the protoplasmic mass just visible under the highest powers of the microscope, and gradually and eventually from that again the living cell, the parent form of all structures such as we ordinarily recognize as animal and vegetable forms."

The possibility of this generation of life under special conditions was seized upon by Charlton Bastian (for whose industry and pertinacity I have the greatest respect, though I cannot follow him in his hypothesis), who maintains that: "If a genesis of living matter occurred in some one place in far remote ages, and if such a process can be shown still to occur, it would be only natural to conclude that the same chemico-physical changes have in all probability been operative in

* "The Foundations of the Origin of Species." Two essays written in 1842 and 1844 by Charles Darwin, edited by his son, Francis Darwin Cambridge, 1909.

innumerable regions over the surface of the earth, not only from primeval, but in all succeeding ages up to the present day."* Although both Weissmann and Haeckel agree with him as to the possibility of the process, they are unconvinced that we have ever been, or shall ever be, able to solve so great a mystery. As Weissmann, quoted by Bastian, puts it: "Up till now, all attempts to discover these conditions have been futile, and I do not believe that they will ever be successful; not because the conditions must be so peculiar in nature that we cannot produce them, but, above all, because we should not be able to perceive the results of a successful experiment." Haeckel's contention that when organic life first appeared on the cool surface of the earth, at the beginning of the Laurentian age, the conditions of existence were totally different from what they are now, is to my mind the great stumbling-block in regard to our acceptance of the results of Bastian's experiments. The development of any living form that we can recognize under the microscope must have involved time almost illimitable as we reckon it, and our puny and ephemeral experiments, even were we to obtain the other necessary conditions, must fail: first, because we know of no method of determining in what period the complex of living material could be formed; and, secondly, because we have evidence that even should the generation of life under cosmic conditions be possible, the modifications of the conditions must have been so gradual and must have extended over such a prolonged period, that time, as we count it, is absolutely insufficient for the completion of our experiments.

Huxley, in his address to the British Association in 1870, put the matter very tersely in his statement that, although he was unable to hold any belief as to the primal origin of life, he held that "expectation is permissible where belief is not; and if it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions which it can no more see again than a man can recall his infancy, I should expect to see it appear under forms of great simplicity, endowed like existing fungi with power of determining the formation of new protoplasm from such matters as ammonium carbonates, oxalates and tartrates, alkaline and earthy phosphates, and water, without the aid of life." We are still far from the solution of this great question, however

* *The Origin of Life* by H. Charlton Bastian, F.R.S., 1911, p. 22.

crude these last few lines have been made to sound by recent discoveries of the physicist, chemist and biologist.

It is sometimes stated that Sir William Thomson—Lord Kelvin—offered to the British Association his hypothesis of the transference of living matter from other planets to our own, through the agency of meteorites, as a jest; but (in view of his announced conviction that the impossibility of converting lifeless matter into matter endowed with life was as definitely established as the law of gravitation) we must assume that his sense of humour in this case was subordinated to his reason. For this suggestion, sneered at and almost laughed out of court by lesser scientific and philosophical lights, had a surer and more reasonable foundation, and has since been supported by more credible evidence than at that time appeared to be conceivable. Thomson's instincts were truer than other men's reasoned convictions. "Look," they said, "at the nearest of the fixed stars; they are some 22,000,000,000,000 miles away. Meteors containing living matter despatched from those stars and travelling at the rate of an express train—sixty miles an hour—would take nearly 42 million years to reach our planet." The thing seemed to be absurd; living matter capable of germinating at the end of such a journey was inconceivable. "Yes," says Arrhenius, the great physicist, "but my researches on radiant energy enable me to say that living organisms may be transported over that 22 billion miles in a trifle of 9,000 years and from Mars to Earth in twenty days!" But only to come into an atmosphere, between which and a falling meteor the friction is so great and prolonged that the great majority of these meteors are dispersed in luminous vapour. How would germinal living matter fare, were it to reach the earth's atmosphere unaccompanied by the meteor? It was maintained that the intense light and cold to which this living matter would be subjected must exert upon it a profound devitalising effect. But new observations, rendered possible by the use of liquid air in the lowering of temperature, enabled A. McFadyen* to demonstrate that spores of bacteria maintained at a temperature of $-200°$ C. remain capable of development at the end of a couple of months. Indeed, it is now recognized that whilst on the one hand a rise in temperature accelerates the chemical changes that are associated with the gradual loss of

* *Proc. Roy. Soc. Lond.*, 1900, vol. lxvi, pp. 180, 489; *ibid.*, 1902, vol. lxxi, p. 76.

vitality by living matter, conversely the rate of change is checked as the temperature is lowered. As Macallum has put it: "Thus in the case of vital processes which have been investigated, a fall of 10° C. reduces the speed of reaction to 2/5, and, therefore, the rate of reaction responsible for the ultimate loss of vitality would proceed at −220° C. (the temperature of intra-stellar space) at one-thousand-millionth of the rate which obtains at 10° C.; so that a journey of three thousand million years in space would be no more injurious in effect than one day's exposure to a spring temperature and sunlight on this planet." In the passage of living protoplasm through space, in which the temperature is known to be so low, the amount of drying which it would undergo would be comparatively slight—a most important matter, as extreme desiccation is incompatible with continued vitality. Roux's* observations on the action of light on the anthrax bacillus make it clear that sunlight, which in the presence of oxygen exerts such a profound influence on the vitality of this micro-organism, is apparently harmless when acting in a vacuum such as that met with beyond the atmosphere that surrounds our globe.

It is evident that the Panspermic theory of the origin of life explains nothing, even if life was first met with in some other planet than our own. Even there life must have had its origin, and in all probability must have developed progressively from lower and less specific forms to those endowed with much higher attributes; and as it is impossible for us to prove that life did not originate primarily either here or in another world than ours, the enormous difficulties by which this hypothesis is surrounded are only too obvious. Even the difficulties concerning the origin of matter, of its passage through its various phases, afford us little help in our consideration of the origin of life, beyond this, that the same power that moulded the universe must necessarily have endowed some of that matter with the power of housing "life." With all this, is it not well that constant controversy should go on between the chemico-physicist and the biologist? that the physicist should claim that some comparatively highly developed matter endowed with life must have passed from some planet to our own, though it would be difficult to maintain that both animal and plant life can have been developed from such comparatively highly specialized organisms? the biologist maintaining that

* *Ann. de l'Inst. Pasteur*, Paris, 1887, t. I, p. 445.

the conditions of life vary so greatly in different planets that only extremely simple forms could have been transferred from one planet to another with any real chance of survival, and only such simple forms could act as a stem from which the two branches leading up to the higher plants on the one hand, and the animals on the other, could develop.

Whether life was generated in this globe of ours, or whether it arose in some other planet, is, after all, a matter of comparatively little import as regards the main question at issue. Should we be able to prove that living matter has come to us from the nearest star on which life existed previously, it carries us but one step further back, and helps us little towards the solution of the main question. As Professor Schäfer pointed out in his address before the British Association at Dundee, Fischer and his school are gradually proving by synthetic methods that even the constitution of the proteins is no longer an altogether unsolved secret to the chemist. Our knowledge of protoplasm and its chemical constitution is gradually expanding, and at the same time evidence is being obtained, mostly from pathological investigations, that there are forms of living matter so minute that they do not come within the direct range of our most powerful microscopes, and that though they are not kept back by our finest filters, they have the power of multiplying and of inducing diseases during which the most profound changes take place in the animal body. These organisms are highly specialized in their functions, and probably require special surroundings and conditions for their existence; nevertheless, they are beyond our ken, we can see nothing but their shadows, they are imponderable, and we have no means of measuring them in any way except by the results they produce. Minute as they are—much smaller than the ordinary cells of plants and animals—we know that they must be complex bodies, constructed out of many molecules, and pervaded by many ions and electrons, and can have developed but with time and opportunity.

The pathologist engaged in the study of the changes that take place in function and structure during the course of what we speak of as "disease," especially those in connection with the method of attack and defence of the organism, is invariably first attracted by the chemico-physical explanation of the course of events. One of the first results of Pasteur's demonstrations of the continuity and specificity of living matter was the increased importance that was attached to the chemical side of vital processes. Living organisms came to be looked

upon more and more as machines, carefully built up, and delicately adjusted, capable when supplied with proper material of doing such and such work, and of turning out so much finished product, much of it useful, but much of it not only of the nature of waste, but in part actually deleterious. Following the lead of the physiologist, it was insisted that each organism had its exact structure and function defined and regulated to one pattern, and that, although in accordance with the doctrine of evolution slight variations may take place in the individual which may become more accentuated in its progeny, such variations, to become marked and permanent, must be present through a long succession of generations. When we come to consider certain of the changes produced during the course of disease, however, something far more striking and apparently infinitely more important, from our point of view, emerges. The animal body, endowed with life, may, under the influence of certain substances often classified as proteids or albuminoids, and especially those of a poisonous nature, become greatly modified in respect to its reactions to these substances.

Everyone has heard of antitoxins, but how many of us realize that in their production in the animal body we have probably one of the strongest of our proofs of the existence of something more than any mere chemical or chemico-physical process, especially since Ehrlich and Weigert were able to demonstrate that these antitoxins are the result of some specific reaction between proteid toxins and the tissues of the body? Let us take a definite example. If a horse which is extremely sensitive to the poisonous effects of the diphtheria toxin, a poison proved by Sidney Martin and others to be of a proteid or albuminoid nature, be treated with very minute, but gradually increasing doses of this toxin, its tissues may become so modified that, although at first they would have been unable to withstand the action of some arbitrary quantity determined by experiment and called the "Minimal Lethal Dose," coming out, say, at fifteen drops, they will, after carefully graduated injection with this same toxin, withstand the action of 15,000 drops of it. The blood of an animal so treated is found to contain a substance which, even when mixed with the toxin in a test tube, neutralises the activity of the toxin and renders it harmless; and the same thing occurs when the blood is injected into a patient suffering from diphtheria. We thus see that the toxin injected into the horse has caused some reaction in the tissues of that animal, as a result of which they give off a

substance, antitoxin, in sufficient quantities to neutralize the large doses of toxin injected in the later stages of treatment. But more than this (and this is proved by the amount of antitoxin that is found circulating in the blood), not only is the antitoxin formed in sufficient quantities to meet the immediate demands of the organism,—*i.e.*, to neutralize the toxin present —but the process of antitoxin formation goes on long after the need for its protection or neutralizing influence has ceased.

Chemical analogies of all kinds have been put forward to explain certain of the processes above described, but where apart from living matter do we find this profound modification of function taking place within a very short period, and continuing long after the exciting cause has been removed?* Here we have something that differs in almost every essential feature from the most complicated chemical reactions of which we have any knowledge; and although one can imagine that the chemist in his enthusiasm may be tempted in contemplation of his greatest triumphs to say "This is a process but little removed from those involved in the generation of life," I know of nothing in the chemical or physico-chemical realm that corresponds in nature to the marvellous process of modified reaction to the special stimulation mentioned above. Similar specific reactions with the production of antitoxins all point to the presence of what we must still look upon as a purely biological phenomenon—adaptation—a phenomenon far more clearly illustrated in these specific processes than in connection with any physiological process as ordinarily studied.

Driesch, in his Gifford Lectures ("The Science and Philosophy of the Organism," delivered in Aberdeen in 1907), puts the matter very clearly and concisely, on page 209. Whilst admitting that the considerations already mentioned afford no actual proof of the autonomy of life, he holds that we "have gained many indicia for the statement that the organism is not of the type of a machine, in which every single regulation is to be regarded as properly prepared and outlined." "It is precisely," he says, "in the field of immunity that such a machine-like preparation of the adaptive effects seems almost impossible to be imagined. How indeed could there be a machine the chemical constituents of which were such as to correspond adaptively to every requirement? to say nothing of the fact that the production of more

* "Report on the Bacteriological Diagnosis and Antitoxic Treatment of Cases admitted to the Hospitals of the Metropolitan Asylums Board during the years 1895-96," by G. Sims Woodhead.

of the protecting substance than is actually necessary can hardly be said to be 'chemical.'

"In fact, we are well entitled to say that we have reached here the very heart of life and of biology. If nevertheless we do not call the sum of our facts a real proof of vitalism, it is only because we feel unable to formulate the analysis of what happens in such a manner as to make a machine as the basis of all reactions absolutely unimaginable and unthinkable."

For my part I am convinced that the study of the Origin of Life must in future be very closely connected and concerned with these adaptive processes that can only be carried on with any promise of success in organisms whose tissues react to the various nutritive, fermentative, and toxic proteids, and in reacting produce antibodies in great variety, but of high specificity.

In these days of great specialisation, necessary owing to the enormous development of the various branches of scientific work and investigation, few men have time to give, or training, to enable them to carry on experiments involving investigations of the most delicate and complicated nature in many branches of science. Where men have attempted this almost impossible task, their expertness and wide knowledge of their own special subject have rendered them impatient of their own ignorance—though they will not always admit this—in other branches of research. Not many years ago a physicist of some standing and experience applied to me for a place in our laboratory, where he wished to carry out a series of experiments with radium. He was convinced that in radium he had a substance the emanations from which had the power of vitalising matter. After a chat with him, I advised him to study the elements of bacteriology, and suggested that he should attend the class of elementary bacteriology, in order to familiarize himself with the necessary details of work and to be able to take the necessary precautions against contamination. He attended one or two lectures and a similar number of meetings of the practical class. What was my surprise and amusement to find, a month later, that this was the extent of his condescension. He had commenced his work, and had been observed removing the cotton-wool from the test-tubes in which was the material supposed to be protected from contamination from without, and picking out, with his stylographic pen, threads of cotton-wool that appeared to be interfering with his observations! This, of course, is an extreme case.

Some time there will arise amongst us a great philosopher

whose outlook is wide, and who can found his philosophy on a broad scientific basis. Until then we are scarcely likely to make any great advance in our knowledge of the Origin of Life.

The Biologist will continue to study protoplasm, to place unfertilised eggs in artificial sea-water, and he will find evidence of departure from the ordinary processes of development in that these unfertile eggs may become fertile even under these conditions. He will bisect embryos that under ordinary conditions would develop into a single organism, and will find that each half will develop into a complete organism, differing from the other only in size. The Pathologist will find that amongst bacteria, certain changes in function and sometimes even in structure may be demonstrated, and will note that as the result of their activity profound variations of function may be set up in the organs and tissues of the animal body. The Chemist will, by synthetic methods, go on building up substances indistinguishable from proteins and pepteids, substances that hitherto have been turned out from Nature's crucibles only. The Physicist will bombard us with electrons and ions, the Chemico-physicist will point out how the colloids manufactured in the body have many of the properties of living matter, and also what part surface tension plays in living organisms in determining their chemical activities, and he will demonstrate the accumulation of potassium salts in certain positions, in multiplying cells, and the like. The Astronomer and the Geologist will each contribute his mite to the treasury of knowledge, and it is well; for truth is always truth, though we do not always recognize it. Let us accept any isolated fact that is fully demonstrated, and where possible let us fit it into the great scheme of Nature, by the magnitude of which we are overwhelmed, and, therefore, but little astonished at the comparatively small part of it that has hitherto been filled in, but of which even the most sceptical must admit the wonderful order and law that rule throughout. So marvellous and complete are they that, when I am informed that there is no personal God, I answer to myself that of this great scheme I have but one experience, and that is that all the will, the ruling power, the intellect, the soul and spirit of which I have cognizance are personal; and that if I am to argue from the less to the greater, I must accept it that there is a great Power above all, ruling, guiding, and regulating, Personal, but all pervading, to Whom, in however small a degree, we are allowed to liken ourselves; rebelling against Whose laws, we are bound to suffer directly or indirectly; but obeying with

the freedom of sons, we become more like that from which we come.

"Lo, these are parts of his ways: but how small a whisper do we hear of him? but the thunder of his power who can withstand?" Job xxvi, 14.

Discussion.

The Rev. A. Irving, D.Sc., B.A., said that as no one else seemed ready to start the discussion, he would venture to express his gratitude to Professor Sims Woodhead, and his warmest appreciation of the most useful and telling paper, to which they had just listened. He thought the Victoria Institute was to be congratulated on receiving such an able and thorough-going treatment of perhaps the most difficult of all questions that confront the serious student of science. No one could doubt that the Professor was speaking as a master in his own field, and with authority second to none in his own department of work and research. One great value of the paper was perhaps the additional light thrown upon questions raised by Professor Schäfer's Dundee address to the British Association, while it seemed to serve as a wholesome check upon some hasty and rash deductions that had been drawn from that in some journalistic quarters. He ventured to say that Professor Sims Woodhead had in his short paper done much to restore mental equilibrium in many quarters, where people's minds had been rendered unsteady from the public utterances of his distinguished confrère at Dundee; and the more so since he had sternly resisted the temptation, which ever besets the specialist in original work, to predict what we shall know before we do know it, thus making *scientific faith* do the duty of actual knowledge. To those who had been straining towards the attainment of such an intellectual standpoint as should enable them to see the teachings of theology and science in one philosophical perspective, the concluding paragraphs of the Professor's paper gave perhaps the most illuminating summing up of the essential factors of this great problem, which the twentieth century had yet seen. And so, thank God! there comes to us out of a Cambridge laboratory of European fame, and from the heart of Cambridge academical life, a voice teaching the student of science the lesson of "sincerity and truth" in his studies, reminding us of those depths of human experience and

consciousness which carry us beyond the necessary limitations of science (as such) in our relation to the great creative and directive Power of the universe of Being.

Professor LANGHORNE ORCHARD: It gives me pleasure to second the vote of thanks. Not I only, but all of us present, thank the able author for the clear, succinct, and interesting account he has given us of one of the most important controversies which have agitated the scientific world.

After the investigation which, under his guidance, we have been making, our conclusion will (I think) be that (1) Abiogenesis is not proven, (2) Abiogenesis is disproven.

In this investigation the author gives a salutary caution against supposing that powerful microscopes are of much use apart from accurate observation and sound reasoning. The advocates of spontaneous generation can certainly not plume themselves upon accuracy of observation. If we turn to a later page in the paper we learn something as to the soundness of their reasoning. It is suggested that "matter, at that time in a condition of exceedingly unstable equilibrium, was moulded by the great cosmic forces into the most elementary forms of life, capable of deriving nutrition from substances not nutrient to the living matter of to-day, of existing at temperatures not nearly approached by those which the heat-resisting organisms now met with could sustain." It is further suggested that from this matter developed all that magical succession of living organisms which, like it, finds origin and home in the fancy of the evolutionist.

With regard to the reasoning just quoted, the most diligent search would not be successful in discovering anywhere a more flagrant example of the logical fallacy known as "Begging the question." There is no attempt to *prove* the point at issue. It is unscrupulously *assumed* in the interests of a hypothesis. Admittedly those conditions which science affirms necessary for the production and maintenance of "living matter" are absent at the hypothetical period postulated. To you and me this fact may appear to settle the question. Not so to the abiogenesist. "Perish conditions!" he says, "the living matter must have somehow managed without them." But talk of this sort is not science.

Science admits of hypothesis, but not of every kind of hypothesis. A scientific hypothesis is one which is in accordance with facts, and

should be suggested by them. It is never contradictory to facts. Huxley well says that, if a hypothesis be in contradiction to a single known fact, that hypothesis must "go." The hypothesis of "spontaneous generation" is in contradiction to a known fact of science, namely, that when all air is excluded, and no germs permitted to enter, the living organisms do not appear. Therefore, the hypothesis of "spontaneous generation" should "go"; science demands that it be abandoned. Life can make use of and direct physical and chemical forces, but it is distinct from them. They can be measured and transmuted, Life cannot. Its unique character evidences itself also in the direction and regulation of the movements of bioplasm, and in the processes of assimilation and dissimilation, nutrition and growth, development and reproduction; in its action with regard to enantiomorphs (as pointed out by Professor Japp), and in the formation of an excess of antitoxin substances against proteid poisons.

The author seems in doubt as to whether Lord Kelvin's meteoric hypothesis was, or was not, a jest. I had it, however, on the authority of Sir George Stokes, at that time our honoured President and a close personal friend of Lord Kelvin, that the supposition was really put forward as a joke. Sir George's own view was that all life is originated by the action of Spirit. I think this view will hold the field. Does not the Christian religion throw light on the origin of life when it tells us that "the Spirit gives life," and that eternal life is heart-knowledge of God and of Jesus Christ whom He has sent to us?

Mr. M. L. ROUSE, B.A., M.R.A.C., said: The following conclusion and illustration found in a very recent scientific work will show how inscrutable a force is life, and how it exists before the tissue is formed by means of which it afterwards works throughout the career of the living creature. Mr. G. P. Mudge (F.Z.S., etc.), in his text-book of zoology, at p. 14 (ed. 1901), writes:—

"It is rather the nature of the forces at play that determine the structure of an organ than the structure of an organ that prescribes its activity. The beating heart of a three-day chick is actively contractile; but it contains not a trace of muscle fibre; the structure is absent, but the activity is present."

I remember well about thirty years ago reading the report of a lecture by Huxley upon crystallization, in which he used such

words as these: "We are here face to face with a great mystery. Does this process differ from life?" Yet not long afterwards, in commenting upon most careful experiments that had been made to ascertain whether spontaneous generation were possible, he declared with Tyndall that there was "an unbridgeable chasm between living matter and dead" (including, of course, mineral substances in every form). And there are at least two deep distinctions between crystals and all living organisms:—namely, that a crystal thickens by laying matter on from without, whereas a cell thickens by depositing matter within; and that a set of crystals cannot split up a chemical compound to take out thence any required ingredient, whereas a set of cells making up a living animal or plant can do so, and, building up thereby one or more tiny facsimiles of itself, can impart to them the same power, so that in the end they commonly grow to the full size of their parent. Endosmose and reproduction of species are properties of living creatures and not of mineral combinations.

To the instances given by Professor Woodhead of old pagan belief in spontaneous generation, one may add Virgil's description, in his Fourth Georgic, of the way in which to renew a stock of bees discovered by the first great bee-master, Aristaeus of Arcadia. A two-year old bullock is brought into a small tiled shed, with a window open to each of the four winds; and, while his mouth and nostrils are held close he is slain by blows that crush and mash his body without cutting his skin. His carcase is then left for some days in the shed surrounded by sweet-scented boughs and herbs; and gradually "through the fermenting of its inward moisture, strange forms of life arise, at first short of feet, then with good feet and buzzing wings, then swarming together, and thicker and thicker stemming the fleeting air, until at length, as a shower shed from the summer clouds, they all at once burst forth" in search of their flowery food.

The cruelty and credulity of paganism are here combined. Men shook both vices largely off at the establishment of Christianity and again at the Reformation, which while it freed men's souls from fatal error freed their understandings for deep and fearless searching into nature. And this has led us to find it everywhere filled with the tokens of design, and to prove that no being can spring into life without the Creator's agency.

Mr. MARCHANT asked whether, supposing the origin of life were discovered, it would necessarily destroy belief in the existence of God.

Mr. A. W. SUTTON asked the lecturer if he was convinced that new life could only be produced from pre-existing life.

At this stage the President had to leave, but took the opportunity of saying that when he came into the room he knew very little about the subject, and if the lecturer would pardon him for saying it, he felt that after hearing the paper, and the discussion, he knew very little more.

Mr. A. W. SUTTON then took the chair and proposed a vote of thanks to the lecturer, which was carried unanimously. The lecturer replied and the meeting adjourned.

WRITTEN CONTRIBUTIONS.

Archdeacon POTTER writes:—

I feel that the unravelling of the secret of the mystery of the origin of life is, as this paper well puts it, to be found in the belief in the existence and personality of God.

God is everywhere and eternal; so is the principle of life—it only needs certain conditions to bring it into action. Life is God and God is life. He is constantly imparting His life to forms in which it develops upward to higher things. Without belief in a personal God the mystery of life is a greater mystery than ever; with that belief, it is easier to understand.

Mr. F. S. BISHOP writes:—

Were it possible to build up life synthetically, or to accomplish the further problem set to chemico-physicists, to produce a reaction which at present seems outside the range of chemistry and to be purely biological, would it not be but a further proof of the immanence of God in nature? In the early verses of St. John's Gospel we have the plain statement that the Logos made all things and that "that which was made was life in Him." Life is not God, for it was made; but it comes from God. Science traces everything to ether and energy, but can get no farther back than these. St. John gives the origin of all things as Life, the agent of the Logos, a quietly persistent universal power accomplishing the Will of God in the universe. When a portion of that universe becomes in the "due" time suitable for the action of this life, there it is to be

found, ready to show itself, it may be ultramicroscopically, but none the less really, and then and there begin on matter its directive energies. Is not this also a case covered by the words of an ancient collect "the tranquil operation of Thy perpetual Providence?"

The Lecturer's Reply.

The Lecturer subsequently received the whole of the discussion in writing, and has been kind enough to amplify the reply which he made at the time, as follows:—

In replying to the various suggestions and criticisms advanced this afternoon, it may be well that I should attempt to answer individual questions rather than to make a general statement. To begin with, however, I should like to insist on the necessity of drawing a sharp line between the somewhat rash deductions of those expounding Professor Schäfer's views and what Professor Schäfer really advanced. In adopting any scientific method of research or criticism, it is essential that we should be honest with ourselves, and, at the same time, acknowledge the honesty of others. We have to bear in mind the danger that, having once commenced to work along a certain line, we are apt to expect that it will lead us in a certain direction and to a certain point; and I agree most cordially with the Rev. Dr. Irving that it is impossible for us "to predict what we shall know before we know it." Intelligent anticipation may be permissible in helping to form a working hypothesis, but it is ever dangerous and unjustifiable when we use it to raise a hypothesis to the level and dignity of a theory. It is impossible to make good the claim for any hypothesis that it can be of the value of a theory. We may test experience by further observation; but in making observations our judgment must remain unbiassed and our mind open to all but credulity, whilst our records of these observations must be clear and honest. How long does it take us to realize that method and apparatus are of little value apart from accurate observation and sound reasoning, and that all scientific hypotheses should be in accord with ascertained facts.

It is exceedingly interesting to learn from Professor Orchard that Sir Gabriel Stokes was convinced that Lord Kelvin was entirely "jocular" in his suggestion that living matter may have been conveyed—on a meteorite—to this sphere from another world.

can only repeat that some people's jokes may have more in them than other people's solemn statements ; but, jocular or solemn, we are not very much helped by it in our quest.

I should like to point out in connection with Mr. Rouse's quotation from G. P. Mudge, that contractility is to be looked upon as a function of practically all protoplasm, and that although it is highly developed in muscular tissue, we should not be astonished that it early becomes a prominent feature in the developing heart tissue, for it is a function even of the protoplasm of the embryonic cell from which that muscle has developed. This active contractility forms part of Huxley's "unbridgeable chasm between living matter and dead."

I agree with Mr. Marchant that the tracing of the origin of life to any one of the many suggested sources should not curtail, in the slightest, our belief in the existence of an Omniscient and Omnipotent God. Would it not tend rather, and has it not tended as knowledge grew, to arouse our wonder at the law and unity pervading the world as we know it? It is ever borne in on most of us more and more that our added experience and expanding knowledge have given us proof of no power greater than that which we attribute to GOD.

With full conviction that we never need fear the truth, let us face the problems of the origin of life confidently and cheerfully, not neglecting our higher and spiritual needs, needs as real as are our physical wants, at all times reading one in the light of our knowledge of the other. Above all, let us from time to time review our knowledge and our position, and apply the results of our revision to the difficult problems with which we are constantly faced. Which of us would study man merely as regards his "dead" physical basis—mere matter without soul or intellect; or which of us would study intellect in terms merely of what we now know of the physical and chemical constitution of brain-matter? As to dead matter, have we not to realize that corruption is only part of an endless chain in the transformation of matter? Matter is often endowed with life, but it may lose its endowment. As the world keeps on, living matter is always coming to the aid of living matter, lowly developed living forms helping the higher, and ultimately helping to develop the highest.

I realize, of course, that some of you will be at one with our

President. I can now but ask you to give some little further thought to this subject; many of us may be long in becoming much wiser, but I cannot help thinking that if we work and study steadily and perseveringly, neither knowledge nor wisdom will linger indefinitely and that coming they will help us to advance a step or two in spiritual development, a step or two that we might otherwise be unable to take.