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The Origin of Life.

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Among the various questions belonging to the sphere of natural science which are sometimes considered to possess significance for theology, is the problem of the origin of life. An historical account of the progress of scientific research and speculation on this matter may therefore prove to be not without interest to readers of a theological journal. The present paper is intended to offer such an account, and at the same time to confirm the belief that theology is indifferent to the still disputed question as to whether the theory of Biogenesis be true or not.

The name *Biogenesis* was given by Professor Huxley to the doctrine that all living matter originates from pre-existing living matter. The same view has sometimes been denoted by *Panspermism*. The opposite doctrine, which maintains the possibility of living organisms arising from inorganic matter, has been termed *Abiogenesis* (Huxley), *Archebiosis* (Bastian), spontaneous generation, *Generatio aequivoca* (in earlier periods); Haeckel uses *Archigony* to describe the origin of living organisms from lifeless matter in the past.

The latter belief obtained universally throughout the ancient and medieval periods. Anaximander held that life arose from water, and especially asserts that eels were known to spring from dead matter. Parmenides held that men were derived from the primitive earth-slime under the influence of the sun's heat. Aristotle and others among the ancient Greek philosophers entertained the belief that certain of the lower animals at least, such as fish and insects, had a similar origin; while Democritus and Epicurus taught that plants are produced from the earth like feathers and hairs from the bodies of animals. Lucretius gives expression to the same idea when he asserts (*De Rerum Natura*, v. 793 ff.) that living creatures still spring out of the earth after sunshine and rain; and we find it again in Ovid (*Met.* i. 416 ff.).

From Aristotle the belief in *generatio aequivoca* passed to the schoolmen. In the writings of some of the alchemists it takes very curious shapes. Van Helmont describes a method for producing a live mouse; the scientist Caesalpino held that frogs were generated from slime in sunshine; and the philosopher Bacon (of Verulam) believed that certain stout plants arose spontaneously from the earth. Indeed, the belief in spontaneous generation was undisputed until the seventeenth century, and it is not quite clear whether even Harvey did not sanction it.

The first to test the traditional theory in a scientific way was the Italian physician, Francesco Redi. By the simple experiment of covering fresh meat with a fine gauze, he showed that although the meat putrefied it produced no maggots; these, therefore, in ordinary circumstances, developed from something introduced from without: in fact, from the eggs deposited by the flies. Redi's experiments threw doubt on the spontaneous generation of any but the humblest form of life, and went far to establish the doctrine *omne vivum e vivo*, which soon became hardened into a dogma of orthodox science. For the development of

microscopy revealed the complexity of organization of the lowest living forms as compared with non-living matter, and tended to widen the gulf between the organic and the inorganic.

The belief in spontaneous generation, as a process now going on, has, however, died hard, even in scientific circles. The doctrine of biogenesis was supposed to be contrary to the teaching of the Bible, and the first scientific protest against Redi's results came from a priest, a Scotchman of the name of Needham. Needham deserves to be remembered as the originator of the method of studying the problem of the origin of organisms by means of infusions in sealed tubes—a method always employed afterwards, with increased refinements. After endeavouring to revive experimental evidence for the spontaneous generation of a species of worm, he made infusions of hay, which were known to breed organisms, boiled them and corked them in order to kill such organisms as were present at the time and to prevent the access of germs from without; and he found nevertheless, that in time his preparations bred animalcules. Needham's results were useful to Buffon, who at the time was constructing his theory of 'organic molecules.' According to this theory, life is a property of certain molecules, supposed to be indestructible, which, in a dead animal or vegetable, remain dormant, until maceration, such as takes place in the making infusions of meat or hay, gives them the opportunity to manifest their vitality. These molecules were identified with the living bodies produced in Needham's boiled solutions.

Needham's results were in turn challenged by a contemporary Italian investigator, Abbé Spallanzani, who repeated his experiments with a view to ascertaining whether he had really succeeded, as had been supposed, in excluding access of air to his corked vessels, or in heating his fluids sufficiently to kill all living matter. Spallanzani therefore boiled for three-quarters of an hour, and sealed his vessels by fusion instead of by corks. In these circumstances, he showed, even the minutest organisms did not appear. To Spallanzani, Needham replied that probably his long-continued boiling had changed the composition of the air left in his vessels, rendering it incapable of supporting life. That the air *was* changed, was proved by Gay-Lussac's analysis. On the strength of this and similar objections, the appeal to experiment had to be made afresh, the sources of possible error being eliminated.

This was done by Schultze and Schwann (1836–37), and with still further precautions by Schroeder and Dusch, some twenty years later. These observers confirmed the view of Spallanzani, and showed that the life which appeared in boiled infusions was due to something which was killed by extreme heat or by sulphuric acid, and which could be filtered from the air by a plug of cotton wool. In the meanwhile Cagniard de la Tour and others had been led to the supposition that all kinds of putrefactive processes were due to the effects of minute organisms; and thenceforward the cause of putrefaction and the question of biogenesis were closely associated.

The theory of spontaneous generation was by no means dying when Pasteur commenced his classical researches. It had been adopted, from *à priori* reasons, by no less a naturalist than Lamarck in his *Philosophie Zoologique*, published in 1809; and it had found support from Cabanis, Oken, Burdach, and many other distinguished men. About the middle of last century the question was warmly discussed in France; and though the authority of Milne Edwards, de Quatrefages, Claude Bernard, and the chemist Dumas was on the side of biogenesis, Pouchet, who championed the cause of spontaneous generation, found numerous supporters. It was Pouchet's results which called forth the researches of Pasteur.

Pasteur began by actually demonstrating the presence in the atmosphere of microscopic germs which could be filtered out by cotton wool. By means of ingeniously devised apparatus he further showed that when every precaution is taken to kill existing organisms in an infusion, and to prevent any but absolutely sterilized air from entering, no life afterwards appears; that when, on the other hand, these conditions are reversed, it does so abundantly.

The question was by no means settled, however, by Pasteur. His foremost critic and opponent in this country was Dr. Bastian, who published, between 1871 and 1874, three works bearing on the controversy. This writer argued that investigations as to what the air does or does not contain throw no light as to the mode of origin of bacteria, and insisted that Pasteur had not proved the presence of bacteria in air, but only of presumably organized bodies which he could not identify. On

the other hand, Bastian, like Mantegozza before him, watched the gradual appearance of bacteria in infusions, and affirmed that they arose *de novo* at points at which they could not previously be detected. Also he heated infusions to 275° F.—a temperature below which he had found all bacteria, as he thought, to be killed, and yet discovered germs appearing in them.

At the time when Bastian's researches were undertaken, the life-history of bacteria was but very imperfectly known. The increased light thrown upon the subject by subsequent investigations has disarmed his criticism. That bacteria are abundantly present in the air, is now familiar to every one. That they are the actual agents in putrefactive decomposition has been completely put beyond doubt by Dr. W. Roberts and other experimenters. Cohn, of Breslau, showed that the bacteria which arise in boiled infusions were only such kinds as formed spores, and Dallinger and Drysdale, who studied the continuous history of many species of these organisms through all its stages, proved that their spores are not killed by exposure to temperatures fatal to the whole organism, and certainly not at the highest temperature to which Bastian heated his infusions. These spores have indeed been proved capable of germination after ten minutes' exposure to so high a temperature as 300° F. Thus every objection to Pasteur's results has been experimentally disposed of, and *saprobiosis* has become an exploded theory, in virtue of our fuller knowledge of the conditions of life and reproduction in the lowest living forms. The question can hardly arise again in connexion with bacteria. So far as these organisms are concerned, it may safely be said that 'the present state of knowledge furnishes us with no link between the living and the not-living.'

The non-occurrence of spontaneous generation, so far as this kind of observation has gone, by no means excludes, however, its *possibility*, either now, or in the past, or in the future. Dr. Bastian, indeed, still maintains that new beginnings of the simplest forms of life have constantly been taking place from the earliest period of the history of the earth (*The Nature and Origin of Living Matter*, 1905). The thorough-going evolutionist is compelled to postulate abiogenesis in the indefinite past; but this, as will be emphasized presently, is to shift the question from science to philosophy, or, rather, from ascertained fact to conjecture. Meanwhile, it may be mentioned that various attempts have been made to produce living from non-living matter in the laboratory. One investigator thought he had done this by the action of powerful electric currents on certain mineral solutions; but it is generally believed that the appearance of the organism which he observed was due to imperfect sterilization. More recently bodies have been observed to be produced in sterilized infusions by the action of radium salts. But whether these 'radiobes' are living, or 'the missing link between the animate and the inanimate,' is at present very doubtful. The scepticism evinced on the point by experienced investigators rather encourages the doubt that they may follow in the wake of the *Bathybius* of Huxley which for a short time promised to reveal the link between the inorganic and the organic, but turned out to be an artificially produced mineral precipitate. Artificial substances have been observed, in certain circumstances, to creep about under the action of the purely physical forces of surface-tension or capillarity, in a manner so closely resembling that of living amœbæ, that even biologists have been deceived into pronouncing them to be organisms. But movement is by no means an exclusive character of vitality. When such bodies grow and reproduce themselves, we shall have better grounds for considering the gulf between the organic and the inorganic to be bridged. And even then we should hardly have disproved the dictum *omne vivum e vivo*, but rather have given it a new sense. For it is one thing for living and thinking beings to devise means and discover conditions in which living protoplasm may arise, and quite another for Nature, unaided by human instrumentality, to make the transition herself. Some men of science confidently hope that living protoplasm will be, by chemical means, produced from non-living matter, others maintain that we have no ground for such a hope. 'The chemist,' says Sir H. Roscoe, 'may successfully synthesize any of the component compounds (of protoplasm), but he has no more reason to look forward to the synthetic production of the structure than to imagine that the synthesis of gallic acid leads to the artificial production of gall-nuts.' It is, generally speaking, the biologists (*e.g.* Huxley,

Ray Lankester, etc.) who consider the forces at work in living and in non-living matter not to be necessarily and essentially different, and who regard it as the aim of physiology to conceive all organic processes as physical or chemical. Physicists, on the other hand, frequently deny this absence of fundamental differences. Professor Tait wrote: 'To say that even the very lowest form of life, not to speak of its higher forms . . . can be fully explained on physical principles alone, is simply unscientific. There is absolutely nothing known in physical science which can lend the slightest support to such an idea.' Similarly, Lord Kelvin, on the ground that the processes which go on in living things are directly contrary to those known in the physical realm, goes so far as to say: 'The only contribution of dynamics to theoretical biology is absolute negation of automatic commencement or automatic maintenance of life.'

With regard to the first appearance of life upon our planet, there have been many speculative attempts to conceive how protoplasm may have been naturally synthesized from inorganic bodies. Pflüger has suggested that when the earth was in a state of incandescence, cyanogen compounds (*e.g.* prussic acid) might easily be produced, and after the earth had cooled, a long series of changes in these might lead up to protoplasm, in whose decomposition-products cyanogen is found. Haeckel's imagination that the lowest organisms, the Monera, were spontaneously generated from hypothetical nitro-carbonates, is too remote from science to call for serious notice. Reference may be made to Dr. Roberts' contention that the primordial organism could hardly have been a saprophyte, such as Bacterium, but must necessarily have been a chlorophyll-containing body; and to Professor Preyer's bold conception that the inorganic may have arisen from the organic, instead of the organic from the inorganic.

It has already been pointed out that the occurrence of abiogenesis in the indefinite past is a necessary postulate of a thorough-going theory of cosmic evolution. And so Professor Huxley, a strenuous opponent of the view that organisms at present arise from dead matter, thought it likely that if it were given him 'to look beyond the abyss of geologically recorded time,' he would be a spectator of 'the evolution of living protoplasm from not-living matter.' But instead of endorsing Haeckel's dictum that such an origin for life is 'a logical postulate of scientific natural history,' we may choose the much safer and more natural alternative of recognizing that, at present, evolution has its limits, and that it is not concerned with origins.

The question of biogenesis has no bearing upon theology. When the materialists discovered that the doctrine of spontaneous generation served as a new argument for materialism, theologians sometimes made the mistake of denying the doctrine instead of the use to which it was put. But whether the universe admits of description in terms of one conception such as that of cosmic evolution, or whether it requires more, is a point as to which theology is entirely indifferent.[1]

[1] The following works are recommended for fuller study of the subject:—Redi, *Esperienze intorno alla generazione degl' Insetti*. Needham, *Nouvelles observations sur la système de la génération*. Spallanzani, French tr. by Senebier, *Opuscules de Physique Animale et Végétale*, Geneva, 1767; or Eng. tr. by Dalzell, *Tracts on the Nat. Hist. of Animals and Vegetables*. Pouchet, *Hétérogénie*. A full account of Pasteur's work, with refs., will be found in Ostwald's *Klassiker der Exakt. Wissenschaften*, No. 39. Bastian, *The Origin of the Lowest Organisms*, *The Beginnings of Life*, *Evolution and the Origin of Life*, *The Nature and Origin of Living Matter* (1905). Huxley, *Critiques and Addresses*, pp. 239 ff. (*Essays*, viii.), and art. 'Biology,' *Encyc. Brit.* Verworn, *General Physiology* (Eng. tr. 1899). J. A. Thomson, *The Science of Life*, pp. 93 ff. Roberts, *On Spont. Generation and the Doctrine of Contagium Vivum*. Dallinger, *The Origin of Life* ('Glasgow Science Lectures,' John Heywood). Bastian has recently touched on Archebiosis in an art. on 'The Origin of Bacteria and their allies by Heterogenesis,' in *Ann. and Mag. of Nat. Hist.*, 1903, pp. 381 ff.