

THE NATURE
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LIVING MATTER

H. CHARLTON BASTIAN

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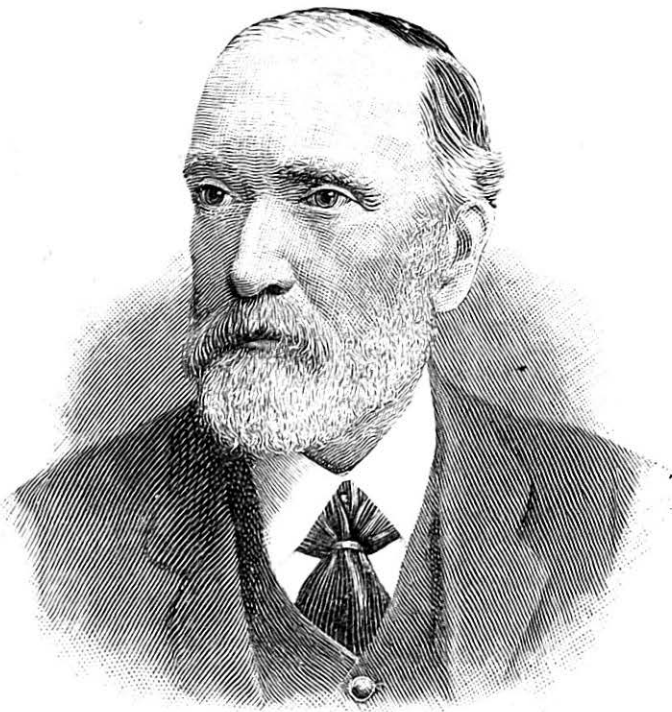
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OF
LIVING MATTER

BY

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Revised and slightly Abbreviated Edition

[ISSUED FOR THE RATIONALIST PRESS ASSOCIATION, LIMITED]

LONDON:
WATTS & CO.
17, JOHNSON'S COURT, FLEET STREET, E.C.4
1910

“To experience we refer, as the only ground of all physical inquiry. But before experience itself can be used with advantage, there is one preliminary step to make, which depends wholly on ourselves: it is the absolute dismissal and clearing of the mind of all prejudice from whatsoever source arising, and the determination to stand or fall by the result of a direct appeal to facts in the first instance, and of strict logical deduction from them afterwards.”—SIR JOHN HERSCHELL: *Discourse on the Study of Natural Philosophy.*

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The Illustrations pertain to Chapters VIII., IX., and X., and the description of the several figures will be found in the text in their immediate neighbourhood.

INTRODUCTION

THE majority of biologists would be found to agree with the celebrated physiologist Max Verworn when he says¹ :—

Living substance could not exist while the earth was a molten sphere without a solid, cool crust; it was obliged to appear with the same inevitable necessity as a chemical combination when the necessary conditions were given; and it was obliged to change its form and its composition in the same measure as the external conditions of life changed in the course of the earth's development. It is only a portion of the earth's matter. The combination of this matter into living substance was as much the necessary product of the earth's development as was the origin of water.

After speaking in much the same sense, another celebrated biologist, August Weismann, follows up the argument in this way² :—

There could at first only have been inorganic substances in existence.....an albuminoid substance must therefore have arisen from inorganic combinations. No one will maintain that this is impossible, for we continually see albuminoid substances produced in plants from inorganic materials.....In order to prove "spontaneous generation," therefore, it would be necessary to try to find out from what mingling of inorganic combinations organisms could arise.

Although views of this kind on the origin of life question are in accord with, and form, as it were, the starting-point for, those expounded in this work, it seems needful to call special attention to some important points concerning which notable differences of opinion exist. To a few of these problems a brief reference may now be made.

1. *Was Archebiosis limited to the very remote past?* The actual origin of life from not-living materials—the process which I term "Archebiosis"—is commonly assumed to have taken place once only, or, rather, in one remote period only of the earth's history. This view was even from the first, and on general grounds, highly improbable, as being at variance with the "law of continuity." A great botanist, Nägeli, has said :—

If in the physical world all things stand in causal connection with one another, if all phenomena proceed along natural paths, then organisms, which build themselves up from and finally disintegrate into the substances of which inorganic nature consists, must have originated primitively from

¹ *General Physiology*, Translation, 1899, p. 319.

² *The Evolution Theory*, Translation, 1904, vol. ii., pp. 366, 369.

inorganic compounds. To deny spontaneous generation is to proclaim a miracle.¹

But if living matter came into being originally by purely natural processes, such processes should have been continually recurring, almost all over the earth, in succeeding ages as well as at the present day. To believe otherwise would, in fact, be tantamount to proclaiming that the first origin of living matter was a non-natural or miraculous event.

2. *Was Archebiosis necessarily preceded by the formation of organic matter to serve as food for the first-formed living things?* I think not; yet in a recent authoritative work the following statement may be found² :—

By whatever steps of change that high complex of organic molecules which we call protoplasm—the physical basis of life—came into existence, it very probably fed, in the first few æons of its existence, on the masses of proteid-like material which, it may be supposed, were formed in no small quantity as antecedents to the final evolution of living matter.

These are mere surmises, wholly unsupported by any attempt at evidence, either as to the original or the present evolution in nature of any such “proteid-like material.” If a material of this kind had been formed once “in no small quantity,” there is no reason why it also should not have continued to form in succeeding ages and at the present day. The view above expressed is, moreover, absolutely unnecessary, seeing that many of the lowest known living things are capable of feeding directly on inorganic materials. Thus, after referring to such facts, Professor Alfred Fischer says³ it is

probable that the first organisms did really arise from inorganic matter by “spontaneous generation,” and that, as the evolutionary theory assumes, all other living things have been gradually evolved from them in continued series. The doctrine of Evolution is, indeed, incomplete without the assumption of such a commencement. Its possibility once granted, there is no *à priori* reason to deny that it still takes place, and that, side by side with the ceaseless evolution of new species, there may actually arise new organisms by spontaneous generation.

3. *Are Bacteria some of the primordial forms of living matter, or are they derivatives from other forms of life?* This question has to be formally put, because of the statement by Sir Ray Lankester that Bacteria cannot be regarded as primordial forms of life, and that they have been “derived from chlorophyll-bearing ancestors.”⁴ This latter assertion is also made without any attempt to support it by evidence. Yet, in the absence of good evidence, any such view would seem directly negatived by the fact of the existence of the well-known group of “prototrophic Bacteria,” which build up their

¹ Quoted by Max Verworn, *loc. cit.*, p. 309.

² Ray Lankester's *Treatise on Zoology*, Part I., Introduction, 1909, p. xv.

³ *The Structure and Functions of Bacteria*, Translation, 1900, p. 50.

⁴ *Loc. cit.*, pp. xii. and xvi.

substance from inorganic materials, and concerning which Professor Fischer says¹ they are "prototrophic in the strictest sense of the word, for a simpler synthesis of proteids than theirs is scarcely conceivable."

The other two groups of Bacteria, feeding as they do on organic matter, dead or living, would naturally and easily be derived from the prototrophic group. I showed, indeed, long ago how readily one of these forms of metabolism may be exchanged for the other, by inoculating a simple solution of ammoniac tartrate in distilled water with Bacteria that have been bred in an organic infusion, and *vice versa*.² This subject is again dealt with in the Appendix to the present work.

Instead, therefore, of agreeing with Ray Lankester when he says,³ "We must look for the representatives of the most primitive forms of life among the minute Protozoa possessing the simplest methods of nourishing themselves by the digestion of already elaborated proteid," such as *Amœbæ* of one or other variety, I believe this to be an altogether mistaken view. Prototrophic Bacteria, certain *Torulæ*, and some of the simplest *Algæ*—all of them non-nucleated organisms, capable of building up their substance from inorganic materials—have the best of claims to be regarded as the real primordial types of life, and, as such, the starting-points for ever-varying forms of *Protophyta* and *Protozoa*.

This view is not based upon mere general considerations, but upon experimental evidence of the strictest kind. I claim to have proved, by evidence adduced in Chapter VIII. and in my work, *The Evolution of Life* (admitting of no other explanation consistent with existing knowledge), that Bacteria and *Torulæ* are primordial forms of life, seeing that they can now take origin in suitable inorganic media, as they probably have done in all past ages since they made their first appearance upon the earth. And, as bearing upon this latter point, it is highly important to note that, according to B. Renault, different kinds of *Micrococci* and *Bacilli*, as well as *Zooglæa*, have been found in animal and vegetal remains in the Triassic and Permian strata, in Carboniferous Limestone, and even as low as the Upper Devonian strata.⁴ Is it conceivable that such variable living things could retain the same primitive forms through all these changing ages, as Sir Ray Lankester and those who think with him would have us believe? Is it not far simpler and more probable to suppose—especially in the light of the experimental evidence now adduced—that, instead of having to do with a case of unbroken descent from ancestors through all these æons of time, we have to do, in the case of Bacteria and their allies, with successive new births of such organisms through all these ages, as primordial forms of life—compelled by their different, but recurring, molecular constitutions to take such and such

¹ *Loc. cit.*, pp. 48, 166.

² *The Beginnings of Life*, 1872, vol. ii., Appendix, pp. xlvii.—liii.

³ *Loc. cit.*, p. xv.

⁴ "*Rech. sur les Bactériacées Fossiles*," *Ann. des Sciences Nat. (Bot.)*, 1896, II., pp. 275–349.

recurring forms, just as would be the case with successive new births of different kinds of crystals?

Pflüger's "cyanogen hypothesis" may, of course, be no more necessary to account for the first beginnings of living matter on the cooling, yet still heated, surface of the earth than for its origin at the present day. It may seem, indeed, to many not a little inconsistent to assume, as he did, and as others following him believe, that great heat was needful for the original up-building of the proteid compounds of which living matter is composed, when over the whole surface of the earth at the present day this same kind of synthesis is ever taking place, in the tissues of plants, at all grades of temperature, ranging from very cold to very warm.

Then, again, as to the view that Amœbæ of one or other kind are the probable primordial types of life, strong additional evidence against this doctrine is forthcoming in Chapter X. of the present work, showing that aggregates of Bacteria (in the form of small Zooglœa masses) are capable of individualisation, and then of undergoing a series of molecular changes and segmentations, ultimately resulting in the production, now of Fungus-germs, and now of flagellate Monads or Amœbæ. So that by actual microscopical evidence, rather than by mere hypothetical imaginings, it is shown that organisms of this latter type are secondary or derivative rather than primary forms of life, as many have supposed. In order of appearance, Amœbæ (living as they do on other organisms, or on dead organic matter) have, in fact, to give place to prototrophic Bacteria, with simplest types of Mould and Algæ—none of which require to feed, in "the first few æons" of their existence, on a purely hypothetical "proteid-like material."

H. C. B.

January, 1910.

APPENDIX

THE SIMPLEST KIND OF PROTOPLASM:

A NOTE ON THE FREE GROWTH OF BACTERIA AND TORULÆ IN A SOLUTION OF NEUTRAL AMMONIUM TARTRATE IN DISTILLED WATER.

(From "Knowledge and Scientific News," August, 1905. With slight abbreviations.)

IN his work on *The Structure and Functions of Bacteria*, Professor A. Fischer places the nitrifying Bacteria that were discovered and isolated in 1888-91 by Winogradsky among his group of "Prototrophic Bacteria." He says their life-processes are "characterised by an extremely primitive metabolism—a physiological humility which shows them to occupy the very lowest rung of the ladder of life." While on another page¹ he says the materials from which they build up their cells are "inorganic compounds of the very simplest character—carbon dioxide and ammonia, or nitrous acid, with a few mineral salts. They are thus prototrophic in the strictest sense of the word, for a simpler synthesis of proteids than theirs is scarcely conceivable." He further says: "As might be expected in the case of organisms with oxidising functions, all the nitrifying Bacteria are ærobic. They require no light, and yet, in spite of this, are able to assimilate the CO₂ of the atmosphere."

His other two groups of Bacteria are supposed to be absolutely separated from this primitive group—the "Metatrophic Bacteria," under which are included most of the known forms, because they "cannot live unless they have organic substances at their disposal, both nitrogenous and carbonaceous"; and the "Paratrophic Bacteria," because they "can exist only within the living tissues of other organisms"—that is, as true parasites.

It is the object of this article, however, to show that a sharp distinction between these first two groups does not exist, seeing that common "Metatrophic Bacteria," as

well as some Torulæ, are capable of taking on life-processes even simpler than those shown by any of the hitherto described forms of the "Prototrophic Bacteria".....

The verification of these statements can be easily made. It will only be necessary to prepare solutions of neutral ammonium tartrate in distilled water, using about 0.65 of a gramme of the salt to 30 cubic centimetres of the water (that is, 10 grains to the ounce); and, after the crystals have been dissolved, to add to one of the solutions a single drop of a recently-prepared turbid hay infusion, and to another a single drop of a recently-prepared turbid infusion made from beef or mutton. The two solutions thus inoculated with common active Bacteria may then be placed in the dark within an incubator maintained at a temperature of 30°-32° C. (86°-89° F.). In about thirty-six hours both fluids will be found to have become slightly opalescent, owing to the growth, as the microscope will show, of myriads of minute Bacteria, and occasionally of a number of very minute Torulæ.

Though these common Bacteria and Torulæ are thus capable of growing freely in the saline solution without the aid of light, I have found that light distinctly favours the process, since solutions similarly inoculated and left exposed to ordinary daylight have become turbid rather more quickly, even though the temperature to which the solutions has been exposed has been about 11° C. (20° F.) lower than that of the incubator.

In order to get rid of the complication caused by the presence even of a single drop of an organic infusion, such as was present at first, other solutions may be

¹ *Loc. cit.*, *trans.*, 1900, pp. 48 and 106.

inoculated with Bacteria taken from one of the original solutions after five or six days, when their turbidity has become more marked. As the Bacteria in these solutions are probably less numerous and less vigorous than those in the organic infusions, three drops (rather than one) are now introduced into each of two other freshly-prepared ammonium tartrate solutions, one of which may be placed in the incubator as before, and the other left in a corked flask exposed to daylight, and at the lower temperature. The growth of these less vigorous Bacteria is now decidedly less rapid, and seems only capable of occurring at all freely when aided by daylight. In the flask on the table the fluid will become slightly opalescent in four or five days; and this opalescence increases for a few days, when a sediment begins to form. But the fluid in the incubator may show no distinct opalescence, even for a couple of weeks or more, though a very minute amount of sediment will accumulate.

Examination of the sediment taken from one of these second inoculation flasks which have been exposed to daylight will show masses of Bacteria, mixed with *Torulæ* or other Fungus-germs, together with a delicate, much-twisted mycelium.[†].....

My claim that the organisms growing in this solution of ammonium tartrate in distilled water are building up protoplasm in the simplest known manner may be objected to on the ground of the ultimate organic origin of the tartaric acid, but I am told by Sir William Ramsay that "ammonium tartrate can be synthesised from inorganic material, and this substance is, so far as we know, absolutely identical with ammonium tartrate derived from tartaric acid extracted from wine-lees."

Seeing that the formula of neutral ammonium tartrate is $(\text{NH}_4)_2 \text{C}_4 \text{H}_4 \text{O}_4$, if there were no impurity in the solution, the micro-organisms would have to build up their protoplasm in some way with the aid only of C, H, O, and N—which seems almost incredible. I may say that the ammonium tartrate used was specially prepared for me, some years since, by Messrs. Hopkin and Williams, and that the solutions were made in small flasks of hard Bohemian glass. Such solutions

were formerly twice analysed for me by a skilled chemist, who reported that not the least trace of either sulphur or phosphorus could be detected. Sir William Ramsay has, however, been kind enough to analyse another specimen of the solution for me after it had been in the flask for five days,[‡] and his report is that the "liquid contained an excessively minute trace of sulphur, probably as sulphate; but no phosphoric acid could be detected by the molybdate of ammonium test."

Looking, therefore, to the fact that the nitrifying Bacteria would have at their disposal the "few mineral salts" referred to by Fischer, we may safely assume that the micro-organisms growing in this solution of ammonium tartrate, contaminated only by an "excessively minute trace of sulphur," have, in reality, been building up the simplest known variety of protoplasm. But how much the process would be aided by a little phosphorus may easily be shown by the addition of three grains of sodium phosphate to the solution. An inoculated ammonium tartrate solution with this addition will become turbid more quickly, and will soon yield a far larger amount of micro-organisms.

Looking to the nature of the primary inoculating material, it was only to be expected that several different kinds of common Bacteria would be found growing in the solutions; and this has proved to be the case. Dr. Gordon Holmes, the Director of the "Research Fund" at the National Hospital, kindly made a gelatine plate-culture from a second fluid, the first having been inoculated with a drop of a turbid hay infusion, and he reports that there were at least seven different kinds of Bacteria found—Cocci, Diplococci, Bacilli, and a kind of Streptothrix.

It certainly is very remarkable that these common micro-organisms, previously carrying on their life-processes in organic infusions, should be able so rapidly to adapt themselves to an entirely different metabolism. It is much to be desired that some skilled chemists would take the matter up and endeavour to throw some light upon the steps by which this marvellously simple synthesis of living matter is brought about.

[‡] The solution was one which had been inoculated with three drops from a first solution, and, having been in the dark incubator, it showed no trace of opalescence.

[†] A photomicrograph of these organisms was reproduced in the original paper.