THE ORIGIN OF LIFE ON THE EARTH

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PREFACE

MY FIRST WORK on the origin of life was published as a small booklet in 1924 (*Proiskhozhdenie zhizni.* Moscow: Izd. Moskovskiĭ Rabochiĭ). In it I formulated, though very schematically, the essentials of this problem.

I explained these propositions in an expanded form in my book *Vozniknovenie zhizni na zemle* (*The origin of life on the Earth*) (Moscow: Izd. AN SSSR), the first edition of which was published in 1936. The second edition was published in 1941 without substantial alteration.

After a lapse of 20 years there has accumulated a very large amount of factual material bearing on the origin of life derived from various fields of scientific endeavour. This allows us to draw a considerably more definite picture of the successive stages in the development of matter on the way to the origin of life.

The 1941 edition of the book has, accordingly, been thoroughly revised in the light of this new factual material. The only important features which have been retained from the earlier editions are the fundamental ideas and propositions.

I wish to express my profound thanks to Professors N. M. Sisakyan, A. G. Pasynskiĭ, A. N. Belozerskiĭ, V. L. Kretovich and G. A. Deborin for looking over particular chapters of the book and for their valuable criticisms and advice, and also to all my colleagues in the A.N. Bach Institute of Biochemistry of the Academy of Sciences of the U.S.S.R. who have helped me in my work on this edition.

I wish also to make special recognition of the hard and valuable work expended on this task by Candidate in Biological Sciences N. S. Gel'man.

In connection with the English language edition of the book I should like to extend my hearty thanks to Mrs. Ann Synge for her work in translating it and also to the publishers, Messrs. Oliver and Boyd.

A. OPARIN

16.10.56.

TRANSLATOR'S PREFACE

THIS BOOK is a complete translation of the text of the third and completely revised edition of Professor Oparin's book, although some of the illustrations have been left out. The Russian and English editions should appear more or less simultaneously. The first edition was translated into English by Professor Sergius Morgulis and was published under the title *The origin of life* by the Macmillan Company (New York, 1938). It was reprinted by Dover Publications Inc. (New York, 1953).

I could not have undertaken this translation unaided and have received much help from many sources. My husband has helped at all stages. In particular, he has dealt with the bibliography and checked the spelling of all proper names which had to be transliterated from the Russian alphabet. He writes: "Transliteration of Russian names is by the system used in *Chemical Abstracts* (see annual author index). Titles of periodicals have been abbreviated, in general, as in the *World list of scientific periodicals published in the years 1900-1950* (London (Butterworth Scientific Publications), 1952). However, for most Russian journals the abbreviations are as in *Chemical Abstracts* (see indexes for 1951 and 1956); these will be found as good, or better, for tracing the periodicals in the *World list* itself. Alternative transliterations of the names of authors are given in brackets where this seems bibliographically helpful. Where the author cites Russian review articles and books I would like to have included supplementary references to works more accessible to English readers, but circumstances have prevented me from doing this in more than a few instances. In connection with verifying the references I am grateful for their unstinted help to many librarians, and especially to the staffs of the Reid Library, Bucksburn, and of the Library of the University of Aberdeen."

I have also received advice and help from Mr. N. W. Pirie, who read the typescript, and from Dr. H. Lees and Mr.

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M. V. Tracey who read the proofs. My technical and terminological advisers are in no way responsible for the views expressed in the book. I hope their, perhaps unconscious, attempts to use it as a platform for their own scientific views have not distracted me from an accurate presentation of Professor Oparin's ideas. He has, in any case, checked the translation in detail from beginning to end.

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My thanks are due to all those I have mentioned and to my teacher, Mrs. Vera Raitt, who has helped me in my struggles with the Russian language, as well as to many others who have helped with typing, illustrations, references and other matters, not forgetting the publishers, Messrs. Oliver and Boyd, who have made strenuous efforts to get the book out in time for the first international Symposium on the Origin of Life, organised by the Academy of Sciences of the U.S.S.R. under the auspices of the International Union of Biochemistry.

ANN SYNGE

Aberdeen,
April 1957.

INTRODUCTION

The question of the emergence of life, of the origin on the Earth of the first living things, raises a number of important and fundamental problems of natural philosophy. Every man, whatever his stage of development, has, consciously or unconsciously, put this question to himself and found some sort of answer to it, for without some such answer one cannot form even the most primitive picture of the world.

History shows that the problem of the emergence of life has fascinated the human mind from time immemorial. There has been no religious or philosophic system and no great thinker that has not devoted serious attention to this problem. In different epochs and at different stages of cultural development the question of the origin of life has been answered in different ways. This problem has however always been the focus of a bitter conflict of ideas between two irreconcilable schools of philosophy—the conflict between idealism and materialism.

At the beginning of our century this conflict did not merely fail to abate but took on a special bitterness because, although science had already achieved glittering and dizzy successes in many fields, it seemed unable to give a rational, scientifically based answer to the question of the origin of life. It appeared that a dead end had been reached as far as this problem was concerned.

Such a state of affairs was by no means fortuitous. It may be explained as follows. About a century ago almost everybody held that the principle of spontaneous generation prevailed so far as the origin of life was concerned. They were convinced that living things could originate, not only from others like themselves, but that they could also come into being spontaneously, appearing all at once, fully formed and organised, among inanimate objects.

Both idealists and materialists held this point of view. The only point of dispute was: what was the cause and what the nature of the forces determining this coming into being.

According to the idealistic way of thinking all living things, including human beings, originally came into being in more or less the same form in which we now see them, owing to the effect of supernatural spiritual forces, that is to say as the result of a creative act by a deity, formative originating spirit, life force, entelechy or some such concept. In other words, they arose as the result of the influence of a primary spiritual cause which was, itself, according to the idealists, the essence of life.

In opposition to this, the materialistically minded scientists and philosophers set out from the premise that life is material in nature like everything else in the world, and that no spiritual force need be invoked to explain its origin. As most of them accepted spontaneous generation as a fully confirmed 'fact', they had to explain it as the result of the action of natural laws, while denying the intervention of any spiritual force whatever. It seemed to them that the most direct approach to a solution of the problem of the origin of life was to find in nature, or produce in the laboratory, instances of spontaneous generation, and to study the phenomenon by all the available scientific methods.

However, very accurate observations and experiments, especially the researches of Louis Pasteur, demonstrated conclusively the illusory nature of the very 'fact' of the spontaneous generation of even the most primitive organisms from inanimate material. It was established with complete certainty that all previous reports of the occurrence of spontaneous generation had been the fruit of errors of method, incorrect setting up of experiments or superficial interpretation of them.

This removed the ground from under the feet of those students of nature who saw spontaneous generation as the only conceivable way in which life could have arisen. After Pasteur they lost all possibility of an experimental approach to the solution of this problem and this led them to form very pessimistic conclusions and to assert that the problem of the origin or life was 'accursed' and that it was an insoluble question unworthy of the work of any serious investigator and to study it would be simply a waste of his time.

This led to a serious crisis in the ideas of many scientists of our century concerning the problem with which we are dealing. Some of these scientists tried to get out of the question by suggesting that life never arose on Earth but that the first living things were brought here from somewhere else such as the surface of one of the nearer or more distant planets. Others got round the question of the origin of life by adopting openly idealistic positions and declaring that the problem belonged, not to the province of science but to that of faith.

It was, of course, not the nature of the problem which led to this crisis but the fact that scientists were using faulty methods in their approach to it.

It was the outstanding service of Charles Darwin to biology that he broke with the earlier metaphysical methods for attacking the problem of the origin of the existing forms of animals and plants. He showed, beyond question, that highly organised living creatures can appear on the Earth only as the result of prolonged development, that is, evolution of higher forms from lower ones. In the absence of such evolution it was impossible to maintain that human beings or other highly developed organisms had arisen by natural means without the intervention of any spiritual or supernatural agency.

However, even after Darwin's work, scientists approached the problem of the origin of the very simplest living things, which were the first ancestors of every living thing on Earth, in the same metaphysical way which had prevailed in regard to more highly organised organisms before Darwin's time. We have, however, already seen that, even after the work of Darwin, people tried to explain the origin of life by separating it from the general development of matter. They regarded it as a sudden act of spontaneous generation of organisms which, though themselves primitive, were still endowed with all the complicated attributes of life. This approach to a solution of the question was, however, found to be radically inconsistent with the results of experiment and observation and could therefore lead to nothing but bitter disappointment.

A completely different prospect opens out before us if we try to approach a solution of the problem dialectically rather

than metaphysically, on the basis of a study of the successive changes in matter which preceded the appearance of life and led to its emergence. Matter never remains at rest, it is constantly moving and developing and in this development it changes over from one form of motion to another and yet another, each more complicated and harmonious than the last. Life thus appears as a particular very complicated form of the motion of matter, arising as a new property at a definite stage in the general development of matter.

As early as the end of last century Frederick Engels indicated that a study of the history of the development of matter is by far the most hopeful line of approach to a solution of the problem of the origin of life. These ideas of Engels were not, however, reflected to a sufficient extent in the scientific thought of his time.

Even in the first decades of this century only a very few of the leading scientists came out in support of the idea that life originated as the result of an evolutionary process. Their pronouncements were, however, still of a very general character and could not overcome the stagnation in the scientific fields concerned with the problem of the origin of life.

Scientists have acquired a large number of facts during the twentieth century and it is only on the basis of these that we have now, at last, been able to draw a schematic picture of the evolutionary development of matter and set out the stages through which it must successively have progressed on the way to the emergence of life. As a result of this, wide possibilities for experimental work on the problem of the origin of life have been opened up. This time, though, interest was not focussed on hopeless attempts to discover instances of spontaneous generation but on the study and experimental reproduction of phenomena which were not merely possibilities but were completely subject to natural laws and took place successively in the evolutionary development of matter.

This situation gave rise to a complete recasting of the ideas of scientists in relation to the problem of the origin of life. During the course of nearly all the first half of the twentieth century this problem was almost entirely excluded from the domain of science and it only received an insignifi-

cant amount of space in the scientific literature of the world. Now, however, large numbers of books, articles, reviews and experimental papers are already being devoted to it. To-day we are not satisfied by any merely speculative interpretation of the history of the phenomena which have occurred at some time or another on our planet. We must check our knowledge by experiment. We must reproduce experimentally the separate stages in the historical development of matter and finally create life again, synthetically, not by the long and devious route by which this synthesis took place in nature, but by a route based on a thorough understanding of those forms of organisation which we find already in a finished state in existing living things.

This task is certainly exceptionally complicated but contemporary science has indications upon which it can, at least, make an estimate of the work in real terms.

In what follows I shall do my best to make clear the ways in which human minds have tried to solve the problem of the origin of life. I shall give a short account of the numerous doctrines and theories which have been formed during many centuries, but I shall devote the greater part of my attention to drawing a picture of the progressive development of matter which, in my opinion, led up to the emergence of life on our planet.

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CHAPTER I

THEORIES OF THE SPONTANEOUS GENERATION OF LIFE

Ancient and mediaeval beliefs.

For many centuries people considered that the Earth was flat and immovable and that the Sun circled round it, rising in the east and hiding itself behind the sea or the mountains in the west. This false belief rested on direct uncritical observation of surrounding nature. Observations of this kind often suggested that living things, for example insects, worms, and sometimes even fish, birds and mice could not only be born from things like themselves but could also arise fully formed by spontaneous generation, out of mud, dung, earth or other inanimate substances.

We may find a belief in the possibility of the spontaneous generation of living things amongst all peoples and at all times; beginning in remote antiquity and finishing in our own days. Even now, in the period of the blossoming of exact science in the culturally advanced nations, it is common for their ordinary inhabitants to be convinced that maggots arise from dung and rotting meat and that various domestic pests arise of their own accord out of rubbish, mud and dirt. These superficial observations miss the fact that dung and filth are to be found in those places where pests lay their eggs from which the new generation of living things develops.

Tremendous significance was attached to these everyday, uncritical observations of creation characteristic of ancient peoples, at a time when nature was still not studied in detail, nor submitted to analysis and dissection but was accepted in its entirety as the immediate perception of the intuition. In his book *Urzeugung und Lebenskraft,* E. O. v. Lippmann[1] gives a wide range of material to show how extensively such

beliefs were held. For example, in China in remote times people believed that aphids would grow by spontaneous generation on bamboos if the young shoots were planted out in warm moist weather. In the Indian holy books there are also references to the sudden appearance of various parasites, flies and beetles from sweat and dung. In the cuneiform writings of Babylon one may read that the mud of canals forms worms and other animals from its substance.[2]

In ancient Egypt the view prevailed that the layer of silt left behind after the flooding of the Nile could give rise to living creatures when it was warmed a little by the sun. Frogs, toads, snakes and mice could originate in this way. In this case one might easily convince oneself by direct observation that the front part seemed already finished and alive while the hind part still consisted of undifferentiated damp earth.

We also find a repetition of these tales among the ancient Greeks (e.g. Diogenes Apolloniates) and in the writings of the famous Roman sage, Pliny. Such stories were widely current both in the East and the West, in the Middle Ages and far more recently. Shakespeare's audiences were not surprised when Lepidus, in *Antony and Cleopatra*, asserted that in Egypt crocodiles are produced from the mud of the Nile under the influence of the warm southern sun.[3]

In general, it appears to be highly characteristic of the history of spontaneous generation that among diverse peoples living at different times and at different cultural stages, we almost always find stories of the spontaneous development of organisms of one kind or another. Here maggots arise from dung and rotting meat, here lice form themselves from human sweat, here fireflies are born from the sparks of a funeral pyre, and finally, frogs and mice originate from dew and damp earth. Wherever man has met with the unexpected and exuberant appearance of living things he has regarded it as an instance of the spontaneous generation of life. Among the ancient peoples the belief in spontaneous generation did not arise as a consequence of any particular philosophy. For them spontaneous generation was simply an obvious, empirically established fact the theoretical basis of which was of secondary importance.

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