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# The Origin of Life on the Earth

*Edited for the Academy of  
Sciences of the U.S.S.R. by*

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*Edited for the International  
Union of Biochemistry by*

**F. CLARK and  
R. L. M. SYNGE**

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PROCEEDINGS OF THE  
FIRST INTERNATIONAL SYMPOSIUM ON

# The Origin of Life on the Earth

HELD AT MOSCOW 19-24 AUGUST 1957

EDITED FOR THE ACADEMY OF SCIENCES OF  
THE U.S.S.R. BY

A. I. OPARIN    A. G. PASYNSKII  
A. E. BRAUNSHTEIN    T. E. PAVLOVSKAYA

*English-French-German Edition*

EDITED FOR THE INTERNATIONAL UNION OF BIOCHEMISTRY  
BY

F. CLARK and R. L. M. SYNGE



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## Foreword

THE QUESTION of the origin of life is one of the fundamental problems of science. However, for almost the whole of the first half of the present century this problem has occupied only an insignificant place in the world scientific literature. It is only in recent years that there has arisen a certain turning point in this respect and a great interest in the question of the origin of life has developed in wide circles of scientists.

In this connection it has been suggested that the time is ripe for drawing up an account of our knowledge of the problem of the origin of life and to point out ways in which it can be further studied.

In 1955 the General Assembly of the International Union of Biochemistry, gathered together in Brussels, put forward the desirability of calling a special International Symposium on the subject. It was suggested that the place of this Symposium should be the Soviet Union, the scientists of which had made a considerable contribution to the solution of the problem of the origin of life.

Following up the initiative of the International Union of Biochemistry, the Academy of Sciences of the U.S.S.R. organized a Symposium devoted to the problem of the origin of life on the Earth, which was held in Moscow in August 1957.

This Symposium attracted the attention of very wide circles of scientists. More than forty scientists, representing sixteen countries, took a direct, personal part in its work. Many of them were outstanding investigators in their own fields. Their names are known all over the world.

Among the participants in the Symposium were: E. Broda and O. Hoffmann-Ostenhof (Austria), I. Prigogine and M. Florkin (Belgium), Zh. Jordanov (Bulgaria), R. L. M. Synge, J. D. Bernal and N. W. Pirie (Great Britain), F. Straub (Hungary), K. Felix, G. Schramm and A. Wacker (Federal German Republic), K. Mothes and J. Böttger (German Democratic Republic), C. Reid (Canada), In-Khun-Chen (China), J. Heller, B. Skarzynski and W. Nemerko (Poland), S. Oeriu and E. Makovskii (Rumania), L. Pauling, M. Calvin, W. M. Stanley, N. Horowitz, H. L. Fraenkel-Conrat, S. Miller, A. Mirsky and E. Chargaff (U.S.A.), E. Aubel and M. Grunberg-Manago (France), I. Málek and F. Sorm (Czechoslovakia), S. Akabori, M. Ishimoto and Y. Oda (Japan).

In addition, many well-known scientists, such as H. Urey (U.S.A.), K. Bahadur (India), F. Cedrangolo (Italy), J. Brachet (Belgium) and others who could not, for one reason or another, come to Moscow themselves, sent the texts of their papers and contributions with the request that they be presented to a session of the Symposium or included in its printed works. Soviet scientific circles also took a great interest in the Symposium. A number of Soviet astronomers, physicists, geologists, chemists and biologists took part in it. About 500 visitors, in addition to the members, attended the sessions of the Symposium and they sometimes took part in the general discussions.

The very fact of there being such a representative gathering of scientists showed not only the great interest taken in the problem under consideration by the Symposium, but also that the previous negative attitude of scientists to the problem has now finally ceased to exist and the question of the origin of life has become a field of intensive experimental work.

At the basis of the programme for the work of the Symposium, which had previously been discussed and adopted unanimously, lay the principle of the evolutionary origin of life. This principle was shared by all the participants in the conference, a fact which greatly facilitated the extremely friendly and intensive work of the Symposium. It was very characteristic of this work that, in the process of discussing the different stages in the evolutionary development of matter in the Symposium, a number of new facts came to light, giving a foundation and experimental confirmation to a number of suggestions which had hitherto only been speculative in nature. Of course, although participants in the Symposium were all essentially in agreement about the evolutionary principle in the solution of the problem of the origin of life, nevertheless, on particular questions there were considerable differences between them which led to very heated and fruitful discussions.

However, the very nature of the discussions showed how far we have progressed along the path of scientific elucidation of the problem of the origin of life. For instance, even comparatively recently, the opinion was widely held among scientists that, under natural conditions and in inorganic Nature, even the simplest organic substances could not arise primarily. It was held that these substances could only be formed biogenically. In the Symposium it was shown to be completely possible that hydrocarbons and their derivatives could be formed on the surface of the Earth even before the emergence of life. This could have occurred in many different ways and the argument now was only concerned with which of these ways was the dominant one in the process of formation of our planet and in the earliest stages of its existence.

In just the same way, there was a time when it was considered that the asymmetry of organic materials, which is characteristic of protoplasm, was the exclusive prerogative of living things and it was maintained that it could not arise at any place or time in the inorganic world.

In the Symposium there were reported many asymmetrical syntheses under the influence of circularly-polarized ultraviolet light, by catalytic reactions occurring on the surface of quartz crystals, spontaneously by slow crystallization from solutions etc. The argument is now not concerned with whether or not the asymmetry of the first organic substances could have arisen abiogenically, but with which of the numerous possible ways was actually used on the surface of our planet, even long before the appearance of living materials on it.

Similarly, there lay before the Symposium the question of the possible means of abiogenic formation of amino acids, porphyrins, protein-like polymers, polynucleotides and other high-molecular organic compounds.

The large amount of experimental material put before the Symposium was a clear demonstration of the complete possibility of the primary formation of these compounds on the surface of the Earth even before life was present on it. An



extremely large amount of attention was given, at the Symposium, to nucleic acids, nucleoproteins and viruses.

The question of what stage of the evolutionary elaboration of organic material we should associate with the beginning of life is one which has aroused much argument. Can life be attributed to individual molecules, even if they are very complex, or only to the multimolecular systems which served as a basis for the emergence of life?

Numerous facts were laid before the Symposium, showing ways in which complex organic molecules could combine into multimolecular systems, the development of which could give rise to the emergence of the most primitive organisms.

The last sessions of the Symposium were devoted to general biochemical problems connected with the further development of metabolism. Although, at first glance, such problems might seem to be outside the scope of the problem of the origin of life, yet the comparative study of metabolism will certainly contribute a very great deal to our understanding of the laws which governed the emergence of metabolism, i.e. the emergence of the form of the motion of matter which is essentially characteristic of life.

One very valuable result of the Symposium was that it presented, to any scientist in the world, an extensive front of questions in the solution of which physicists, astronomers, geologists, chemists and biologists of all specialities can play a part. Each of these, if he is seriously interested in the solution of the problem of the origin of life, will find his part in the work, in which progress will contribute to a general scientific solution of the problem which concerns us all.

Furthermore, the Symposium was important, not only on account of its scientific results, but also because this gathering was a new and successful step in fruitful international co-operation between scientists of many countries.

The present collected volume is intended to bring the results of the work of the Symposium before wider circles of scientists and to enable more rapid progress to be made in the solution of the problem of the origin of life on the Earth.

A. I. OPARIN

# Introductory Note from the International Union of Biochemistry

THE appearance of this book in both Russian and English marks the occasion of the first international symposium organized under the auspices of the International Union of Biochemistry. The arrangements for the Symposium were made by the Academy of Sciences of the U.S.S.R. and the meeting was held in Moscow from 19 to 24 August 1957.

The topic which was chosen, 'The Origin of Life on the Earth', covers one of the basic questions of natural science, and the participation of a large group of biochemists in this Conference indicates both the interest that is now taken by biochemists in this biological question and also the progress that is being made in an approach to its solution in terms of the formation and origin of the structural components and metabolic systems of living matter.

We are indebted to Mrs. Ann Synge for undertaking the translation of the Russian contributions to the Symposium, and to Dr. R. L. M. Synge, F.R.S., and Mr. F. Clark for editing the English edition. Finally, our thanks are due to the Pergamon Press, who have undertaken to publish this book as the first of a numbered series of publications from the International Union of Biochemistry.

M. FLORKIN

E. H. STOTZ

R. H. S. THOMPSON

## Editors' Preface

THE INTERNATIONAL UNION OF BIOCHEMISTRY asked us to act as Editors of this English-French-German Edition of the entire Proceedings of the Symposium, which is being published in parallel with a Russian Edition. The Committee acting for the Academy of Sciences of the U.S.S.R. as Editors of the latter have supplied us with texts, which are here published with minor editorial changes for the sake of uniformity. Texts received in Russian have been translated into English by Mrs. Ann Syngé, and these are indicated by asterisks in the Contents List.

Some of the contributions to the Symposium were preprinted as uncorrected proofs in English, French and German for the use of participants in the Symposium. As these contributions were bound, they could be confused with the present definitive publication. Unfortunately, they received notice in *Chemical Abstracts* (52, 1331, 1958).

A multilingual publication presents special difficulties in the transliteration of Russian names. We have followed as far as possible the system used in *Chemical Abstracts*, but this could not be done rigorously, especially in the French and German papers. To restore non-Russian proper names from Russian texts to their original spellings demands superhuman qualities, and mistakes are certainly present. For these and other errors we apologize.

Abbreviations for periodicals are as far as possible those used in the *World List of Scientific Periodicals published in the Years 1900-1950* (Butterworths Scientific Publications, London, 1952) or in *Chemical Abstracts*. Other abbreviations follow in general the practice of the *Biochemical Journal*. The Indexes have been compiled by Mr. W. Hill.

F. CLARK  
R. L. M. SYNGE



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# Introductory Address

A. I. OPARIN

*Academy of Sciences of the U.S.S.R., Moscow*

Esteemed colleagues, dear friends,

In opening the International Symposium which is to consider the problems of the origin of life on the Earth, I wish, first of all, to extend a warm welcome to our visitors, outstanding scientists of various specialities, who have come to Moscow from seventeen countries to take part in the work of the Symposium.

The very fact that the company, which is gathered here to discuss the problems of the origin of life, is so widely representative in its composition is, in itself, most significant and encouraging.

A few years ago our friend Mr Pirie, who is present to-day, asked me what really new and significant facts have been found out in the field of the discovery of the origin of life since the time of Huxley and Tyndall. It seems to me that our Symposium is a very important event in the field of enquiry in which we are interested.

Nevertheless, twenty or thirty years ago, even the calling of such a Symposium would have been completely impossible in that, until quite recently, experimental scientists had not paid sufficient attention to this problem.

During almost the whole of the first half of this century it was only possible to find, in the world literature, a very few isolated attempts to advance towards a scientific solution of the question of the origin of life.

This state of affairs was by no means fortuitous. It arose from the fact that, until the end of last century and the beginning of this one, the ideas of most scientists were governed, almost exclusively, by the principle of spontaneous generation, the conviction that living things (though only the most primitive ones) could arise directly from the inorganic materials of the natural world. However, very carefully conducted experiments showed convincingly that, in every case where spontaneous generation was stated to have been observed, the findings were the results of faults in the experimental methods. This took away the ground from under the feet of those scientists who saw, in spontaneous generation, a scientifically credible way in which life could have originated. They were, thus, without any possibility of an experimental approach to the problem, which led them to a very pessimistic conclusion, namely, to the belief that the problem of the origin of life was 'proscribed', that it was an insoluble problem and that to work on it was unworthy of any serious investigator and was a pure waste of time.

It is now quite obvious that the reason for this negative attitude towards the problem under consideration lay, not in the nature of the problem itself, but in an incorrect approach to its solution.

The problem of the origin of life cannot be solved in isolation from a study of

the whole course of the development of matter which preceded this origin. Life is not separated from the inorganic world by an impassable gulf—it arose as a new quality during the process of the development of that world. An evolutionary approach to the study of our problem will, therefore, open up a wider vista of possibilities for its solution.

The advances in present-day science, the rich store of facts which are now at the disposal of astronomers, physicists, geologists, chemists and biologists, enable us to draw, with some degree of verisimilitude, a picture of the evolutionary development of matter which took place at some time on our planet, and to point out the possible stages through which this development could have passed on the way to the emergence of life.

We must suppose that, as the first stage, there were present, on the still lifeless Earth, the simplest organic compounds, the hydrocarbons and their closest derivatives. The succeeding increase in complexity of these compounds, which occurred abiogenically in the lithosphere, atmosphere and hydrosphere of our planet, in accordance with the general laws of physics and chemistry, may be regarded as the second stage in this development. This process resulted in the appearance of very complicated organic substances of high molecular weight, in particular, substances resembling proteins, nucleic acids and other compounds characteristic of contemporary protoplasm. Further, one may postulate the emergence of some sort of primary systems, based on these substances, which changed under the influence of the external medium and which could undergo selection. The evolutionary development of these systems may be regarded as the third stage which led, finally, to the emergence of the simplest primary organisms.

It is, of course, a very involved and extremely difficult undertaking, not only to give a theoretical explanation of the most important events which occurred in the past, but also to obtain proof of the correctness of this explanation.

We have, as yet, no single satisfactory account of the phenomena which occurred at some time on our planet. We want to verify our assumptions, either by observations of natural phenomena which are taking place at present, or by experimental reproduction of the separate stages of the development of matter which we have postulated.

This sort of approach to the question opens up wide possibilities for practical work by scientists on the problem of the origin of life. This work, however, does not consist in hopeless attempts to produce the sudden spontaneous generation of organisms (as was the case earlier), but in the study and experimental reproduction of phenomena which are not only quite possible, but which follow laws and which arise successively during the evolutionary development of matter.

It is quite obvious that an undertaking of this sort is not within the powers of any single investigator, or narrowly specialized scientific team, for the development of matter leading to the origin of life takes place by means of phenomena which are studied by workers in different scientific fields and requires, for its understanding, and even more for its reproduction, the mastery of many different techniques of investigation. Furthermore, it is essential that the investigations carried out should be made into a whole by the common acceptance



of certain general ideas, particularly as concerns the sequence and interdependence of the phenomena being studied.

Naturally the numerous facts which have recently been brought to light in various fields of science without any direct relation to the question of the origin of life are also of great importance for the solution of our problem. It may, however, be felt that the time has come for the undertaking of work directly aimed at the solution of our problem. I believe that our present gathering provides the opportunity for the methods of investigation employed in various branches of science to be used, not only to provide a general opinion on the problem in question, but also to indicate practical ways of working towards its solution.

Of course, even the ways of approaching the work may be very various. On the Organizing Committee which called this Symposium the question arose as to whether, in view of the large amount of material for presentation, the conference ought not to be split into specialized sections. However, we decided that it would be better to limit, to some extent, the number of papers read and to provide, throughout, possibilities of general discussion in which the representatives of the various sciences and branches of learning could participate.

In opening our Symposium, allow me to express the hope that it will really be a landmark in the history of the study of the problem with which we are concerned and that its work will serve as a great stimulus to the extension of studies in this field, enabling rapid advances to be made towards the solution of the problem of the origin of life.

I think I am voicing the general wish in proposing, as chairman of our present session, the esteemed President of the International Union of Biochemistry, Professor Florkin.



# Discours d'ouverture

M. FLORKIN

*Président de l'Union Internationale de Biochimie*

Mes chers collègues,

Je suis très reconnaissant à Messieurs les membres du Comité organisateurs de ce Symposium, de bien vouloir m'appeler à la présidence de cette séance d'ouverture.

Cet honneur, dont je sens tout le prix, ne s'adresse pas à ma modeste personne, mais à la fonction de Président de l'Union Internationale de Biochimie, à laquelle m'a appelé la confiance de mes collègues biochimistes, et que j'ai essayé d'accomplir dans la mesure de mes capacités depuis plusieurs années.

Lors de la première réunion du Conseil de l'Union, tenue à Londres à 1954, mes collègues Engel'gardt et Oparine ont bien voulu proposer l'organisation à Moscou par les soins de l'Académie des Sciences de l'URSS et sous l'égide de l'Union Internationale de Biochimie, d'un Colloque International sur l'origine de la vie.

A cette époque l'Union Internationale de Biochimie était encore dans les difficultés de la petite enfance.

Elle n'avait pas reçu la consécration de l'admission au sein du Conseil International des Unions Scientifiques et il faut bien dire qu'elle avait plus d'ennemis que d'amis.

La proposition de nos collègues de l'URSS était une précieuse marque de confiance et d'amitié, qui a été accueillie avec gratitude par le Conseil de l'Union Internationale de Biochimie.

Cette proposition venait au moment où les études sur les origines des mécanismes de la vie qui sont des objets des études biochimiques, entraient dans la phase expérimentale.

Il était particulièrement indiqué de réunir ce Symposium dans la ville même du pionnier incontesté des études sur l'origine de la vie—le professeur Aleksander Ivanovitch Oparine.

La brillante participation d'une pléiade de savants de premier plan est le gage du succès de ce Symposium de caractère véritablement et authentiquement international. Aussi ne voudrais-je pas retarder d'avantage le plaisir que nous désirons tout prendre à leurs exposés.