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# Origins of Life

How did life on Earth originate? Did replication or metabolism come first in the history of life? In this extensively rewritten second edition, Freeman Dyson examines these questions and discusses the two main theories that try to explain how naturally occurring chemicals could organize themselves into living creatures.

The majority view is that life began with replicating molecules, the precursors of modern genes. The minority belief is that random populations of molecules evolved metabolic activities before exact replication existed and that natural selection drove the evolution of cells toward greater complexity for a long time without the benefit of genes. Dyson analyzes both of these theories with reference to recent important discoveries by geologists and biologists, aiming to stimulate new experiments that could help decide which theory is correct.

Since the first edition of this book was published in 1985, revolutionary discoveries have been made in biology, genetics, and geology, casting new light on the questions of the origins of life. Molecular biologists discovered ribozymes, enzymes made of RNA. Geneticists discovered that many of the most ancient creatures are thermophilic, living in hot environments. Geologists discovered evidence of life in the most ancient of all terrestrial rocks in Greenland.

This second edition covers the enormous advances that have been made in biology and geology in the past decade and a half and the impact they have had on our ideas about how life began. Freeman Dyson's clearly written, fascinating book will appeal to anyone interested in the origins of life.

Freeman Dyson, currently Emeritus Professor at the Institute for Advanced Study in Princeton, is a distinguished scientist and a gifted writer. He is a fellow of the Royal Society of London and a member of the U.S. National Academy of Sciences, as well as the holder of eighteen honorary degrees. His most recent books include *Imagined Worlds* (1997) and *From Eros to Gaia* (1992).

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Revised Edition

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*Institute for Advanced Study, Princeton*

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More information

# Contents





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Frontmatter
More information

# Preface

The delivery of my Tarner Lectures in Cambridge happened to coincide exactly with the two-hundredth anniversary of the first manned flight across the English Channel by Blanchard and Jeffries in January 1785. Like the intrepid balloonists, a public lecturer must carry supplies of hot air and of ballast to regulate his flight – hot air to be inserted when the text of the lecture is too short and ballast to be dropped when the text is too long. In preparing the lectures for publication I was able to retrieve some of the dropped ballast and to vent some of the inserted air. I am grateful to my hosts at Trinity College for their hospitality and to my audiences for their sharp questions and criticisms. In revising the book for this second edition in 1998, I have had the benefit of many additional criticisms from readers of the first edition. I am grateful to everyone who corrected my mistakes and told me about recent developments in evolutionary biology. I am especially grateful to Professor Cairns-Smith for reading and criticizing the new edition. The first edition was a lightly edited transcript of the lectures. The second edition is substantially enlarged and is no longer a transcript. Much has happened in the last thirteen years to deepen our understanding of early evolution. I have changed my story to take account of new discoveries. But the basic mystery of life's origin remains unsolved, and the central theme of the book remains unchanged.

The Tarner Lectures were established with the requirement that the lecturer speak "on the philosophy of the sciences and the relations or want of relations between the different departments of knowledge." I intended to ignore this requirement when I planned the lectures. I preferred to deal with concrete scientific problems rather than with philosophical generalities. I chose the origins of



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Frontmatter
More information



life as my theme because I judged the time to be ripe for a new experimental attack on the problem of origins. The main purpose of the lectures was to stimulate experiments. Nevertheless, it happens that the study of the origins of life touches many scientific disciplines and raises many philosophical questions. I therefore found myself, in spite of my pragmatic and unphilosophical intentions, fortuitously following Mr. Tarner's wishes. It was impossible to speak for four hours about the origins of life without encountering some ideas that connect widely separated branches of science and other ideas that stray over the border from science to philosophy.

The lectures were addressed to a general university audience. The readers of this book are likewise expected to be educated but not expert. The same thing can be said of the author. I do not pretend to be an expert in biology. I have not read systematically through the technical literature. In my survey of experiments and ideas, I made no attempt to be complete or even to be fair. I apologize in advance to all the people, living and dead, whose contributions to knowledge I have ignored, especially to J. B. S. Haldane, Desmond Bernal, Sidney Fox, Hyman Hartman, Pier Luisi, Julian Hiscox, Lee Smolin, and Stuart Kauffman. I apologize also to Paul Davies, whose excellent book (Davies, 1998) was published just as mine was going to press. I missed the chance to engage in a friendly debate with Davies, explaining where we agree and where we disagree.

I am grateful to Martin Rees and Sydney Brenner for inviting me to a meeting with the title "From Matter to Life," which was held at King's College, Cambridge, in September 1981. Biologists, chemists, physicists, and mathematicians came together to talk about the origins of life, and in three days I acquired the greater part of my education as an evolutionary biologist. That meeting led me to the point of view I am expressing in this book. I wish also to thank the Master and Fellows of Trinity College for inviting me to Cambridge as Tarner Lecturer in 1985.

The first two chapters of the book are historical. Chapter 1 introduces the six characters who contributed the most to my thinking about the origins of life. Chapter 2 describes in greater detail the leading theories and the experimental background from which they arose. Chapter 3 is the most technical chapter. It describes my own contribution to the subject, a mathematical model that is intended to represent in abstract form the transition from chaos to organized metabolic activity in a population of molecules. Chapter 4 discusses

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some of the questions the model leaves open and the implications of the model for the later stages of biological evolution. At the end of Chapter 4, I included, in deference to Mr. Tarner, an excursion into philosophy. My approach to the understanding of the origins of life emphasizes diversity and error tolerance as life's salient characteristics. This approach led me to draw analogies between the phenomena of cellular biology and the phenomena of ecology and cultural evolution, but the validity of these speculative analogies is in no way essential to our understanding of cellular biology.

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