Donald Goldsmith / Tobias Owen

The Search for Life in the Universe

Foreword by Carl Sagan

The Search for Life in the Universe

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Halton Arp: Fig. 3-16.
Elso Barghoorn: Fig. 10-1.
Breitkopf & Haertel, Wiesbaden: p. 322, Excerpt from J. S. Bach, Brandenburg Concerto No. 2, PB 4302.
Burndy Library, Norwalk, CT: photograph, p. 228.
Stillman Drake: Fig. 1-3 (left).
David Dressler and John Wolfson: Fig. 8-6.
Editions Hermann: Fig. 1-2.
Sidney Fox: Fig. 9-11.
Robert M. Gottschalk: Fig. 1-3 (right). © 1946.
Hale Observatories: Figs. 2-5, 2-8, 3-3, 3-8, 3-10, 3-14, 3-15, 4-1, 5-4, 6-4, 11-6, 12-5, 16-4, 18-1, photograph, p. 14.
High Energy Astrophysics Division of the Harvard/Smithsonian Center for Astrophysics: Figs. 3-3, 6-8, 7-7.
Houghton Mifflin Company: p. 145, from *The Book of Nightmares*, "Lastness," by Galway Kinnell, copyright © 1971 by Galway Kinnell. Reprinted by permission of Houghton Mifflin Company.
Instituto Nacional de Antropologia e Historia de Mexico: Fig. 21-5.
International Planetary Patrol photographs furnished by Lowell Observatory: Figs. 13-1, 14-1.
Kitt Peak National Observatory: Figs. 3-1, 3-8, 17-1 (upper).
Philip Klass: Figs. 21-1, 21-2.
Lick Observatory: Figs. 2-5, 3-7, 3-12, 4-4, 4-10, 6-7, 6-9, 7-6, 12-10; photograph, facing p. 1.
Little, Brown & Company: p. 323, from *Poems*, "Argonauts," by George Seferis, English translation copyright © 1960 by Rex Warner. Reprinted by permission of Little, Brown, & Company.
Lowell Observatory: photograph p. 2.
Lund Observatory: Fig. 4-2.
Master and Fellows, Magdalene College, Cambridge: Fig. 1-3 (center).
Carter Mehl: Fig. 4-3.
Meteor Crater Enterprises, Inc.: Fig. 12-6.
National Aeronautics and Space Administration: Figs. 7-1, 12-9, 12-11, 12-12, 13-2, 13-4, 14-2, 14-3, 14-4, 14-7, 14-8, 14-9, 14-10, 14-11, 14-12, 14-13, 15-1, 15-5, 15-6, 16-1, 16-3, 16-4, 16-5, 16-6, 16-7, 16-8, 19-1, 19-3, 20-12; photographs, pp. 144, 226, 268.
National Astronomy and Ionosphere Center: Figs. 20-10, 20-11.
Allison Palmer: Fig. 10-4.
Allen Parker: Fig. 12-7.
Cyril Ponnamperuma: Fig. 12-8.
W. H. Robertson: Fig. 17-1 (lower).
Ben Rose: photograph, p. 228.
Arnold Rots: Fig. 4-6.
Martin Ryle and P. J. Hargrave: Fig. 13-3.
J. William Schopf: Fig. 9-4.
Veronica Schwartz: Fig. 21-3.
Scientific American: Fig. 20-14, from "The Search for Extraterrestrial Intelligence," by Carl Sagan and Frank Drake, copyright © 1975 by Scientific American. All rights reserved.
Frederick Seward: Figs. 3-3, 6-8, 7-7.
Stanford Linear Accelerator Center: Fig. 19-2.
Woodruff Sullivan III: Fig. 20-7.
Paul Trent: Fig. 21-4.
University of Chicago Press: Figs. 2-9, 5-5, 10-5.
United States Air Force: Figs. 21-1, 21-2.

Foreword

Human beings evolved a few million years ago as one species among millions of others. Our ancestors were not markedly faster or stronger or better camouflaged than their competitors: they were only smarter. This intelligence has led to the invention of tools—wave after wave of extraordinarily clever discoveries and inventions—which have given human beings speed and strength and other powers undreamt of by our ancestors, and has led to a very real, although perhaps brief, dominance of the planet Earth by this single species. As we became more intelligent and more contemplative we wondered about origins and destinies, about the mystery of our own beginnings and about whether, in some distant lands, there are other creatures more or less like us.

In the breathless pace of human discovery the planet Earth has now been all explored. Each culture has found that many other exotic societies also existed. But as our technology advanced, developments in transportation and communications whittled down human cultural diversity. Today we live on a planet which has almost no unexplored land areas and in which all human societies are in breakneck progression towards forming a single global culture. It is natural that our search for other beings and other cultures has transferred itself from the Earth to the stars.

Some set of events has occurred which led to the development of a technical civilization on the planet Earth. But what is the generality of these events? Are there other planetary systems suitable for life; with the early chemical events leading to the origin of life; an environment with a suitable balance between constancy and variability to permit further biological evolution; the emergence of intelligence and technology; a long lifetime for the technical civilization; and the wish to communicate with other beings? All of that has happened here. And if the Copernican and Darwinian traditions are relevant, similar events may well have occurred on countless other worlds through the Milky Way Galaxy.

The question of life and intelligence elsewhere excites our mythic instincts, our sense of wonder, our curiosity about nature, and our deep quest—exemplified in the myths and legends of human culture—for our own origins. To pursue the subject requires knowledge in cosmology, astrophysics, planetary science, organic chemistry, evolutionary biology, radiophysics, psychology, sociology, and politics. One of the virtues of the subject is that it provides an integrated framework for inquiring into, more or less, everything.

For all of human history until the last few decades the search for life elsewhere was exclusively a speculative endeavor, an exercise in fiction

or theology or romantic speculation. But lately, in the most recent instant of cosmic time, tool-using humans have for the first time invented the technology to pursue this subject seriously. We have built the first interplanetary space vehicles, which are now performing a preliminary reconnaissance of the solar system in which we live. We have set down on the planet Mars and performed the first tantalizing searches for microbial life there, sent our little probes past Mercury and Jupiter and Saturn, and into the broiling and corrosive atmosphere of Venus. We have discovered organic molecules in meteorites and comets, in the atmospheres of the outer solar system, and in the vast dark of the space between the stars. We have attached messages telling something about our planet and ourselves to four spacecraft, Pioneers 10 and 11 and Voyagers 1 and 2, which are at this moment on trajectories which will take them out of the solar system, the first human emissaries to the realm of the stars and whatever beings may live there. We have constructed giant radio telescopes which, in a halting and provisional way, have begun scanning the skies to see if there are intelligent creatures on planets of other stars beaming radio messages to likely abodes of life—among which, we hope, they will count Earth as one.

Our early efforts to find life elsewhere have not been successful, but we have barely begun the search. We are at the very earliest phase of this grand exploration, and major advances are likely to be made in the relatively near future. The present book, a happy collaboration between two distinguished astronomers with a flair for popularization, is an excellent modern introduction to the entire field of exobiology, with an understandable emphasis on the astronomical factors. Reading this book illustrates one of the delights of the search for life elsewhere: to pursue the subject seriously we are required to know a great many things which are themselves of enormous intrinsic interest.

If, after a long, systematic search, with spacecraft, of the planets and moons of our solar system and, with large radio telescopes, of the distant stars, we fail to find a sign of extraterrestrial life, then we will have calibrated something of the rarity and preciousness of what we take so much for granted on our exquisite home planet. And if we succeed in finding life elsewhere—even very simple life—we will have turned a corner in human history and we will never be the same again: our science, technology, philosophy, and view of ourselves will have made a stunning advance. The search for extraterrestrial life is inexpensive by the standards of modern technological societies. It brings with it many subsidiary benefits. If we have the wisdom to keep looking, it is hard to imagine another enterprise which holds so much promise, whether it succeeds or fails, for the future of the human species.

Carl Sagan
David Duncan Professor of Astronomy and Space Sciences
Director, Laboratory for Planetary Studies
Cornell University

Preface

In this book we ask how and where we might hope to find other beings in the universe similar to ourselves. Does our galaxy contain millions of civilizations far more advanced than ours? Or does it have at best only a few planets with relatively primitive forms of life?

Our book provides a survey of these problems for the educated layperson, and a text suitable for nonscience majors in the first or second year of a college curriculum. We have adopted a nonmathematical approach in describing the search for life in order to make the book accessible to a wider audience. Standard courses in biology, geology, and astronomy can benefit from the perspectives provided here, which include the presentation of fundamental concepts in a new context. But the main function of our book as a text is its use in a one-quarter or one-semester course on astronomy emphasizing the search for extraterrestrial life.

Since we must often attempt to interpret ideas, observations, and experiments from the frontiers of several sciences in this book, the reader must not expect to find established dogma. Instead, we hope to convey a sense of the excitement of trying to reach beyond what we know, while still attempting to stay within the bounds of scientific thought. The tension between rigorous proof and free-ranging speculation provides one of the most enjoyable aspects of scientific research; we hope that some of this pleasure can be found by considering the various riddles that permeate the search for life in the universe.

To answer the questions of the origin of life and its cosmic distribution, we must summarize our knowledge of the physical universe: of space and time, the origin of matter, and the environments and chemical processes that determine the prevalence of life. To answer the question, "What is life?" we have only a single example, life on Earth. We must imagine the variations on our life that might occur within the sun's family of planets and satellites—where we can test our predictions with detailed investigation—and among the myriad stars of the Milky Way galaxy and beyond.

A single theme underlies this effort: the attempt to know ourselves, who we are, where we came from, our future as potential members of a galactic community. As babies, we humans each felt unique, the center of the world; as we grew, we saw other children like ourselves, and acquired a new sense of identity. As adults, we must cope with the conflict between our desire to feel unique as persons and our commonality with other humans, as well as the totality of life on Earth.

In a manner analogous to the growth of infants, human beings have now moved from an ancient belief in the Earth as the center of the universe to a proper appreciation of our relatively insignificant place in the cosmos. We now turn to the question of whether human intelligence and self-consciousness are unique, or nearly so, or whether the events that developed intelligent beings from chemical interactions on Earth may have occurred over and over again throughout the universe.

Despite the "averageness" of our sun among stars, the human sense of uniqueness dies slowly. The lingering belief that we must be special appears in some of the UFO reports that we read, and in the phenomenal interest in the idea that we humans are descended from, or educated by, ancient astronauts, superhuman visitors from the great beyond.

To progress beyond arguments based on belief and desire, we must use the methods of science and rely on experiments to test our hypotheses. But with only a single example of life to examine, our generalizations cannot be unquestionable. Instead, we must stretch our knowledge and our theories as far as we can, to see what insights we can reach: certain possibilities appear more likely than others. The ultimate experiment would be an effort (and a successful one!) to contact extraterrestrial intelligent beings. And if such contact should render this book obsolete, no one would be more delighted than its authors.

No book on this subject can fail to be indebted to the pioneering work *Intelligent Life in the Universe,* by Josef Shklovskii and Carl Sagan. We are especially aware of this influence since we have admired the book ever since its appearance in 1966, and have used it repeatedly in our courses. The major discoveries since then in astronomy, biology, and geology have led us to write the present book, but the basic perspective of Shklovskii and Sagan's remarkable work remains intact.

We are grateful to Jon Arons, Elso Barghoorn, William Baum, Klaus Biemann, John Billingham, Victor Blanco, Geoffrey Briggs, Elof Carlson, Karl Kamper, James Lawless, Mikhail Marov, Allison Palmer, Michael Papagiannis, William Robertson, Tom Scattergood, J. William Schopf, Frank Shu, Michael Soulé, Jill Tarter, William Ward, James Warwick, Richard Young, Ben Zuckerman, and especially to Frank Drake and Lynn Margulis for their comments on various parts of the manuscript and assistance with its text and illustrations. Much of the planetary research described in this book was supported by NASA. Henry Marien helped greatly with the proofreading, and Patti Rosen provided essential research assistance. But any mistakes are our own; like Shakespeare's Cassius, we must admit that the faults lie "not in our stars but in ourselves."

Donald Goldsmith
Tobias Owen

Contents

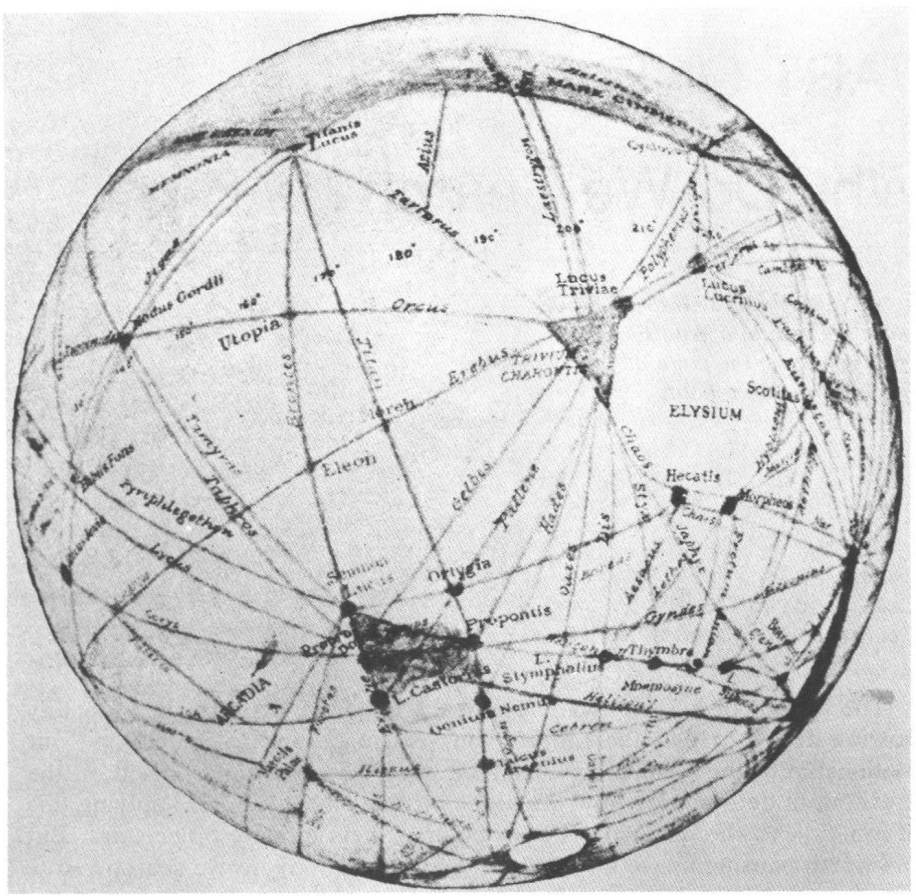
PART ONE

Why Do We Search?

To see a World in a Grain of Sand
And a Heaven in a Wild Flower,
Hold Infinity in the palm of your hand
And Eternity in an hour.

—WILLIAM BLAKE

The history of human awareness of the universe has brought a steadily growing desire to find the roots of our existence and to understand our relationship to the cosmos in which we live. We now stand poised on the threshold of determining how life arose on this planet, and of applying this information to the quest for life on other planets circling other stars. But it is worth pausing as we do so to ask ourselves: Why do we search? How has the search for our own origins and for evidence of our cosmic kin proceeded in the past? And what does the search for extraterrestrial life tell us about our attitude toward the universe around us?



This map of Mars, drawn by Percival Lowell during the early 1900s, shows some of the "canals" which Lowell imagined to cover the red planet.

CHAPTER 1

The Search from the Human Perspective

The Search for Life's Origins

Just over a hundred years ago, in May, 1876, Her Majesty's Ship *Challenger* returned to port at Sheerness on the Thames after more than three years away from England. During the ship's voyage around the world, scientists aboard the vessel had systematically dragged the ocean bottoms for the first time. Day after day, the ship's crew brought up samples of water and mud from the abyssal deeps, the bottom layers of the oceans of the world, which contained marvelous new sea creatures previously unknown to humanity. For the scientists on board the *Challenger,* the special fascination of the expedition had been the hope that they would find living fossils, early forms of life on Earth, happily ensconced in the great depths where conditions had barely changed since the time that life began. But there was still more to the scientists' expectations. When the first transatlantic telegraph cable had been laid ten years before, the ship's crew had discovered at the bottom of the ocean a gelatinous ooze, which, according to several leading scientists, was probably the primitive protoplasm from which all life had descended. A careful study of this *Urschleim* (original slime) would surely unlock the secret of how life began on Earth.

Alas! No living fossils were found by the *Challenger,* and the mysterious ooze turned out to be totally inanimate. Although the ooze appeared to undergo chemical changes reminiscent of life processes, these lifelike characteristics could be reproduced nicely by adding a strong solution of alcohol to ordinary sea water. Chemistry, not biology, rules the ocean floors.

A century after the *Challenger* expedition, we know much more about the Earth and its oceans, and have found that the history of primitive events

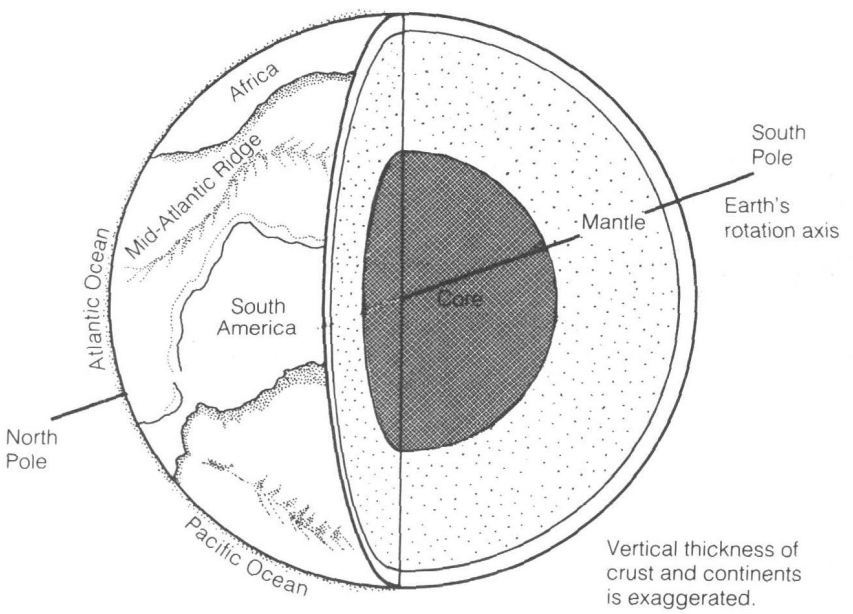


Fig. 1-1 The Earth's continental plates, which form the Earth's crust, slowly grind against one another, sometimes overlapping upon collision. These plate-tectonic encounters eventually carry what was once the crust down into the Earth's mantle, which fills about seven-eighths of the Earth's total volume, surrounding the iron-rich core.

on this planet has vanished forever. The geological records of the first billion years on Earth have been erased by erosion and the motions of the giant plates that form the Earth's crust. As the plates have moved, slowly but inexorably, they have dragged eroded material that once formed the Earth's surface down below the present crust of our planet (Figure 1-1). Thus, the most direct means of uncovering the earliest terrestrial history has been destroyed through 4.6 billion years of erosion and plate-tectonic activity. We do find around us an amazing variety of living organisms, and we can study the fossil record that extends over just 3 billion years. But we cannot reach back through this record to the point at which life differentiated itself from inanimate matter.

Despite our lack of definite information, no doubt exists concerning the *interest* of human beings in the origin of life. Every culture has creation myths, and even our own "sophisticated" civilization cares deeply about its origins. We find this pervasive interest at the root of diverse religious beliefs, and we find also that humanity has always been fascinated by the possibility that life may exist elsewhere in our solar system or somewhere farther out in space, among the myriad stars in the sky. The idea of visitors