Praise for *Biocosm*

"A fascinating book, an eloquent and poetic synthesis of current ideas on the emergence of our biofriendly cosmos and its destiny. James Gardner's 'Selfish Biocosm' hypothesis envisions a novel perspective on humankind's role in the universe."

—Sir Martin Rees, Royal Society professor at Cambridge University; U.K. Astronomer Royal; author of *Just Six Numbers*, *Our Cosmic Habitat*, and *Our Final Hour*; and winner of the 2001 Gruber Prize in Cosmology

"James Gardner tackles the biggest of the Big Questions head on: Why is the universe bio-friendly? This stunning fact cannot be shrugged aside as an incidental quirk of nature, but deserves a deep and satisfying explanation. Gardner skillfully interweaves some of the most provocative ideas at the forefront of science to outline a possible explanation—and how extraordinary his explanation turns out to be!"

—Paul Davies, Professor of Natural Philosophy at the Australian Center for Astrobiology, author of *How to Build a Time Machine*, and winner of the Templeton Prize

"A magnificent one-stop account of the history of life. From the beginning of the universe to its end, Jim Gardner tells the entire story in a spell-binding account of how we got here and where we're going."

—John Casti, mathematician; author of *The Cambridge Quintet* and *The One, True, Platonic Heaven*; member of the External Faculty of the Santa Fe Institute; and former Executive Editor of *Complexity*, the journal of the Santa Fe Institute

"If there is no God—no outside transcendent being who designed and created the cosmos and life—from whence did it all come and how are we to find meaning in an apparently meaningless universe? The answer is derived from science, specifically the new sciences of chaos and complexity theory, that attempt to formulate natural explanations for these apparent supernatural phenomena. In this creative consilience of cosmology, evolutionary biology, and complexity theory, James Gardner courageously speculates about how it all could have come about and what it could possibly all mean using only the tools of science. *Biocosm* is breathtaking in its scope and its subject—the cosmos and everything in it—is far grander than the anthropocentric proscenium on which theistic world views play themselves out."

—Michael Shermer, Publisher of *Skeptic* magazine, monthly columnist for *Scientific American*, and author of *Why People Believe Weird Things*

BIOCOSM

BIOCOSM

THE NEW SCIENTIFIC THEORY OF EVOLUTION:
INTELLIGENT LIFE IS THE ARCHITECT OF THE UNIVERSE

JAMES N. GARDNER

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This book is dedicated to the millions of men and women from every nation and culture who selflessly dedicate countless hours of unpaid time and other personal resources to the advancement of science. Whether as teaching assistants in elementary classrooms, docents in natural-history museums, backyard stargazers, bird-watchers heedless of an early morning's predawn chill, uncompensated laborers on hot and dusty archaeological digs, or the more than four million SETI enthusiasts who happily link their home computers together to scan the random radio signals of the cosmos in hopes of finding the voice of ET, these volunteers are the unsung heroes and heroines of our scientific age. To them belongs the proud appellation derived from amator, *the Latin term for lover: "amateur."*

Nothing is too wonderful to be true
if it be consistent with the laws of nature.

—Michael Faraday (1791–1867)

Faraday was a British physicist and chemist who discovered electrolysis and invented both the transformer and the electric generator. The quoted statement was his response to ridicule expressed by his scientific contemporaries at his claim that he could generate an electric current simply by moving a magnet in a coil of wire.

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And, finally, to the great, beautiful, and mysterious cosmos itself, which stands before us like a vast open book, written in a language we are just now beginning to understand.

Foreword

Is intelligent life merely a bit player in the enormous pageant of the cosmos? Or is it destined to become something vastly more important: the architect of the universe, and of other universes to come?

That is the striking question addressed in *Biocosm*, by James Gardner. While the ancient Greeks could summon enough of their dreaded hubris to imagine that humankind was the center of the cosmos, centuries of science have encouraged us to have a more modest view. Ever since Galileo, astronomers have somberly charted a universe that is stupefyingly large, bitterly cold, and implacably hostile. As every schoolchild knows, we occupy a small planet around a common sort of star, itself just one of a hundred billion suns in a rather ordinary galaxy. Our cosmic situation is insignificant, and life, particularly intelligent life, might be only an accident of circumstance on one tiny, watery world. Indeed, we have yet to discover whether even a single other celestial body has managed to spawn the simplest biology.

In other words, we might be tempted to judge from current evidence that life is no more than an occasional consequence of nature's laws, a chance product of the chemistry that those laws allow. Intelligence, which has emerged only recently on our planet, might be even rarer. In this view, the appearance of life seems if not miraculous, then at least highly unlikely.

But there is something wrong with this picture. As our understanding of cosmology has deepened, we have been confronted with a disarming fact: it seems that the physical laws and constants of the universe have been finely tuned for life. For example, the energy states of atoms are such as to allow the easy formation of carbon in the searing

interiors of the stars, and to prevent this element from being quickly transmuted into yet heavier atoms. But there seems to be no compelling reason why these energy levels could not have been otherwise, resulting in a universe in which carbon—the key building block of complex molecules and therefore of life —was hard to find. The particulars of the Big Bang were also fortuitous. Had this initial event occurred with less force, the universe would have long ago collapsed on itself. With more force, it would have expanded too quickly to allow the formation of galaxies, stars, planets—and us. Again, it is hard to explain why, like Goldilocks's porridge, the Big Bang should have detonated with a force that was "just right." In the words of physicist Freeman Dyson, such apparent coincidences make it seem as if "the universe knew we were coming."

This is not a trivial observation, nor have there been broadly satisfactory explanations offered for why the cosmos is so hospitable, despite the best efforts of eminent scientists. One straightforward approach is to invoke a deity who deliberately engineered our universe in such a way that life could arise. But such an explanation seems difficult or impossible to prove. Perhaps the "fine tuning" that we perceive is only a temporary condition brought on by our incomplete knowledge of physics. With another century of research, this argument goes, we might understand that the universe had no choice in its construction: the energy levels that result in abundant carbon could not have had other values. Still another tack is to simply note that if the universe had not been tuned for life, we would not be here to write book forewords that ask *why*. Needless to say, this may be too tautologically trivial to appeal to many.

James Gardner carefully reviews all the best ideas on how to understand the cosmos's apparent biological imperative and then puts forth a new, and strikingly dramatic, suggestion of his own, one that makes use of the exciting field of complexity science. He is well qualified to do this, with training in theoretical biology and philosophy, and an impressive trail of published, scholarly work in complexity theory. His arguments are lucid, and his prose is elegant and engaging. But what

will most strike the reader of this book is the fact that Gardner is not going after small fish. The subject he is wrestling with is as large, as important, as they come: What is the purpose of our universe and the life it has spawned? He tells us how the fact that the universe was "made for life" can be ultimately understood by science and need not forever be the domain of theology or metaphysics.

As an astronomer engaged in the search for extraterrestrial intelligence (SETI), I had occasion to meet Gardner at an international conference several years ago. I watched as his proposals about a "selfish biocosm" caught the attention of my colleagues. I think their interest was principally piqued by the freshness of his thought and the broad sweep of his ideas. But there is more: one of the important tests of Gardner's hypothesis is the SETI enterprise. If we should soon find evidence of alien intelligence, that would be an important datum in Gardner's new way of assessing the universe.

Ever since Newton, scientists have tried to understand existence by discovering its underlying rules. The result has been a massive edifice of natural law, and biology has been seen as a consequence of the universe's construction, rather than an instigator. Only on Earth's surface, where life has molded the seas, the continents, and even the atmosphere, is biology thought to have had an important role in shaping physical conditions—the so-called Gaia hypothesis. But Gardner has taken Gaia to its furthest conceivable magnitude: extending the role and influence of life to the stars and beyond.

There is little doubt that his ideas will change yours.

Seth Shostak
Mountain View, California

Introduction

This book presents a new theory about the role of life and mind in shaping the origin and ultimate fate of the universe. In addition, it reflects on how that new theory might eventually influence religion, ethics, and our self-image as a species.

In important respects, my book is a riff on Charles Darwin's masterwork, *The Origin of Species*. Following Darwin's lead, I have endeavored to use the insights proffered by a wide range of gifted contemporary theorists—cosmologists, evolutionary biologists, computer scientists, and complexologists—to construct the foundation for a novel and somewhat startling synthesis. The essence of that synthesis is that life, mind, and the fate of the cosmos are intimately and indissolubly linked in a very special way. To echo the insightful phrase of Princeton astrophysicist Freeman Dyson, it is my contention that "mind and intelligence are woven into the fabric of our universe in a way that altogether surpasses our comprehension."[1]

The fundamental credo of science is that physical mysteries that presently elude human understanding will someday, if only in the far distant future, succumb to new explanatory paradigms that are capable of being either validated or discredited through falsifiable predictions. (Falsifiability of claims, which is scientific shorthand for the empirical testability of new hypotheses and their implications, is the hallmark of genuine science, sharply demarcating it from other arenas of human thought and experience like religion, mysticism, and metaphysics.) The basic claim of this book is that the oddly life-friendly character of the fundamental physical laws and constants that prevail in our universe can be explained as the predictable outcome of natural processes—

specifically the evolution of life and intelligence over tens of billions of years.

The explanation that I shall put forward to elucidate the linkage between biological evolution and the ultimate fate of the cosmos—a new theory called the "Selfish Biocosm" hypothesis—has been developed in papers and essays published in peer-reviewed scientific journals like *Complexity* (the journal of the Santa Fe Institute, the leading center for the study of the new sciences of complexity), *Acta Astronautica* (the journal of the International Academy of Astronautics), and the *Journal of the British Interplanetary Society*. These papers provide the foundation for a scientifically plausible version of the "strong anthropic principle"—the notion that the physical laws and constants of nature are cunningly structured in such a way as to coax the emergence of life and intelligence from inanimate matter.

The book is divided into six parts. The first part reviews the profound mysteries of an anthropic—or life-friendly—universe. Beginning with ancient Greek philosophy, continuing on through Renaissance thought, and concluding with contemporary speculations by a leading complexity theorist about a mysterious antichaotic force in nature, this section provides the foundation for theoretical speculations about possible reasons why the universe is life-friendly.

The second part of the book plunges deeper into the anthropic mystery and probes some of the novel ideas that contemporary scientists have advanced by way of explanation. These include the conjecture by a leading cosmologist that black holes are gateways to new universes.

The third part makes a risky foray into the dangerous territory that is the situs of the contemporary cultural war between ultraevolutionists and modern creationists, who call themselves "intelligent design theorists." In a proposed harmonization of these conflicting viewpoints, I suggest that the appearance of cosmic design could conceivably emerge from the operation of evolutionary forces operating at unexpectedly large scales.

The fourth part of the book puts forward my new Selfish Biocosm hypothesis: that the anthropic qualities that our universe exhibits can

be explained as incidental consequences of an enormously lengthy cosmic replication cycle in which a cosmologically extended biosphere provides the means by which our cosmos duplicates itself and propagates one or more "baby universes." The hypothesis suggests that the cosmos is "selfish" in the same metaphorical sense that evolutionary theorist and ultra-Darwinist Richard Dawkins proposed that genes are "selfish."[2] Under my theory, the cosmos is "selfishly" focused upon the overarching objective of achieving its own replication. To use the terminology favored by economists, self-reproduction is the hypothesized "utility function" of the universe.

An implication of the Selfish Biocosm hypothesis is that the emergence of life and ever more accomplished forms of intelligence is inextricably linked to the physical birth, evolution, and reproduction of the cosmos. This section also provides a set of falsifiable implications by means of which the new hypothesis may be tested.

The fifth part of the book enters a more speculative realm by considering methods by which a sufficiently evolved form of intelligence might replicate the life-friendly physical laws and constants that prevail in our universe. In addition, it advances the idea that if the space-time continuum (i.e., our cosmos in its entirety) constitutes a closed loop linking one gateway of time (the Big Bang) to another (the Big Crunch), then our anthropic universe could conceivably, in the words of Princeton astrophysicist J. Richard Gott III, be its own mother.[3]

The sixth and final section ponders the possible implications of the Selfish Biocosm hypothesis for fundamental evolutionary theory and for our self-image as a species. It also takes a brief look at possible religious and ethical implications of the hypothesis.

A major caveat is in order before we begin. This book is intentionally and forthrightly speculative. Following the example of Darwin, I have attempted to crudely frame a revolutionary explanatory paradigm well before all of the required building materials and construction tools are at hand. Darwin had not the slightest clue, for instance, that DNA is the molecular device used by all life-forms to accomplish the feat of what he called "inheritance." Indeed, as cell biologist Kenneth R. Miller

noted in *Finding Darwin's God*, "Charles Darwin worked in almost total ignorance of the fields we now call genetics, cell biology, molecular biology, and biochemistry."[4] Nonetheless, Darwin managed to put forward a plausible theoretical framework that succeeded magnificently despite the fact that it was utterly dependent on hypothesized but completely unknown mechanisms of genetic transmission.

As Darwin's example shows, plausible and deliberate speculation plays an essential role in the advancement of science. Speculation is the means by which new paradigms are initially constructed, to be either abandoned later as wrong-headed detours or vindicated as the seeds of scientific revolution.

Scientific speculation plays another equally important role, which is to shine the harsh light of skepticism on accepted verities. As the brilliant and controversial Cornell physicist Thomas Gold put it,

> New ideas in science are not right just because they are new. Nor are old ideas wrong just because they are old. A critical attitude is clearly required of every seeker of truth. But one must be *equally* critical of both the old ideas as of the new. Whenever the established ideas are accepted uncritically and conflicting new evidence is brushed aside or not even reported because it does not fit, that particular science is in deep trouble.[5]

Science is an inherently conservative discipline, and iconoclastic ideas like those entertained by Gold (the existence of a deep hot biosphere far beneath the planet's surface as well as the nonbiological origin of natural gas and oil) are legitimately relegated to what *Skeptic* magazine publisher Michael Shermer calls the borderlands of science.[6] But what must never be forgotten is that these dimly illuminated borderlands have frequently proven to be the breeding ground of revolutionary ideas.

Scientific revolutions differ profoundly in character from the normal practice of scientific investigation. Scientific historian Thomas Kuhn observed in his classic *The Structure of Scientific Revolutions* that normal

science consists of puzzle solving within the framework provided by prevailing scientific paradigms (like Newtonian mechanics or Darwinian theory), which are themselves the fruit of earlier revolutions. Revolutionary science, by contrast, is a hazardous but utterly exhilarating process of creative destruction—the erection of fundamental new paradigms to supplant or supplement a foundational structure that has become hopelessly flawed.[7] As science popularizer James Gleick put it in *Chaos: Making a New Science*,

> Then there are the revolutions. A new science arises out of one that has reached a dead end. Often a revolution has an interdisciplinary character—its central discoveries often come from people straying outside the normal bounds of their specialties. The problems that obsess these theorists are not recognized as legitimate lines of inquiry. Thesis proposals are turned down or articles are refused publication. The theorists themselves are not sure whether they would recognize an answer if they saw one. They accept risk to their careers. A few freethinkers working alone, unable to explain where they are heading, afraid even to tell their colleagues what they are doing—that romantic image lies at the heart of Kuhn's scheme, and it has occurred in real life, time and time again.[8]

The borderlands of science, in short, are the natural habitats of scientific revolutionaries—those free-spirited souls who cheerfully risk professional ridicule in return for the sublime privilege of attempting to pull one more veil from nature's deeply shrouded visage.

For me, the pathway to the particular scientific borderland that is the subject of this book has meandered through the novel intellectual landscape illuminated by the new sciences of complexity. These sciences, which explore phenomena like "emergence" (the generation of complicated phenomena such as consciousness from the interaction of relatively simple components like individual nerve cells), self-organization, and the operation of complex adaptive systems (like sets of coevolving species comprising a biosphere), have generated not only scholarly

excitement but a rapidly rising level of popular interest. The great appeal of these sciences is their inherently holistic quality, so different from the reductionist approach favored by practitioners of so-called hard physical sciences like physics and chemistry. These traditional sciences tend to foster a "silo" mentality that frowns on cross-disciplinary thinking. By contrast, scientists studying complexity deliberately seek out the recurrence of similar patterns of evolutionary development and emergence in a wide range of seemingly disconnected phenomena, from embryology to cultural evolution and from theoretical chemistry to the origin of life.

The key experimental tool utilized by complexologists is not physical measurement but computer simulation; the "experiments" of complexity scientists generally take place in what mathematician John Casti calls "would-be worlds" that exist only in the memory and logic chips of a computer.[9] As Casti puts it, "With our newfound ability to create worlds for all occasions inside the computer, we can play myriad sorts of what-if games with genuine complex systems. No longer do we have to break the system into simpler subsystems or avoid experimentation completely because the experiments are too costly, too impractical, or just plain too dangerous."[10]

The holistic philosophy embodied in the sciences of complexity is uniquely suited to the mission of the intellectual voyage on which we shall presently embark: to seek out and delineate, as precisely and exhaustively as possible, a specific theory concerning the linkage and "consilience" (in biologist Edward O. Wilson's resonant phrase)[11] between the basic laws and constants governing the behavior of inanimate nature and the role of life and mind in the universe. As we shall see, the very fact that such consilience and linkage should exist is itself a profound ontological commentary.

Now, why am I—an attorney, a complexity theorist, and a science essayist—qualified to serve as your guide on this daunting journey to the outer limits of cosmological theory? In part because, as an attorney, I am trained to search for faint and elusive patterns of evidence that a layperson might overlook—including evidence that crosses traditional

disciplinary lines demarcating the borders of disparate scientific fields.

I first began probing the mysteries of complexity theory in a scholarly paper that proposed an interpretation of the behavior of subnational geopolitical regions (like Flanders in Belgium and Catalonia in Spain) as the operation of complex adaptive systems.[12] After this essay was published in *Complexity*, I turned my attention to another set of complex phenomena: the probable future coevolution of "memes" (hypothetical units of cultural transmission) and genes in the context of the rapidly emerging technological capacity to engage in human germline genetic engineering. That essay—which is reproduced here in appendix 1—was likewise published in *Complexity*.[13]

With that foundation in place, I decided to use the approach of complexity theory to probe an odd feature of cosmology that has intrigued me ever since I began studying philosophy and theoretical biology as an undergraduate at Yale: the strangely life-friendly quality of the physical laws and constants that prevail in our universe. As a lawyer, I was goaded by the sense that the patterns of evidence seemed to be pointing in a direction that most mainstream scientists were unwilling to explore. As a student of philosophy and biology, I was convinced that issues of profound importance were being overlooked or deliberately shunned. And as a recent convert to the holistic philosophy represented by the sciences of complexity, I was becoming increasingly convinced that the pathway to genuine enlightenment about the import of an anthropic universe—a universe adapted to the needs of life just as thoroughly as life is adapted to the exigencies imposed by the universe—must surely pass through the strange and intriguing intellectual terrain revealed by these new sciences.

I explored that possibility in an essay published in *Complexity* entitled "The Selfish Biocosm: Complexity as Cosmology."[14] I was privileged to have as the chief reviewer for this paper an individual who is one of the most distinguished theoretical cosmologists in the world. And I was equally privileged to have the services of a courageous editor—John Casti—who was willing to take a chance on a relatively unknown theorist advancing a radically new hypothesis about the inti-

mate relationship of life and intelligence to fundamental cosmic forces and laws. That essay, of which this book is an expanded and augmented version, was my first attempt to crudely map out what is, for me at least, a singularly exciting new borderland of science.

Like a medieval European map maker piecing together the borders of an imagined America from travelers' tales and the misty recollections of ancient mariners, my role (at least as I perceive it) is not to serve as an explorer or experimentalist but rather to sketch the larger features of a vision of cosmic reality profoundly at odds with traditional wisdom. In medieval times, the orthodox view was that the surface of Earth was flat. In the contemporary era, the prevailing scientific mindset is captured curtly and elegantly by Nobelist Steven Weinberg's pithy epigram that "the more the universe seems comprehensible, the more it also seems pointless."[15] It is my fervent hope that those who consider seriously the speculative exercise in intellectual cartography presented in this book will conclude that Weinberg's assertion may eventually prove to be as mistaken as the flat-Earth orthodoxy espoused with such strenuous but utterly misplaced confidence in a bygone age.

With that preface, I invite you to enter what I believe to be the least tamed and most challenging scientific borderland of all: current theorizing about the ultimate nature and destiny of the vast cosmos that envelops our tiny speck of Earth like an endless sea. Perhaps you will find in the speculative discourse that follows some useful nugget of fact or some momentary flash of insight that helps pierce, to at least a minuscule degree, the perplexing darkness that surrounds the outer ramparts of twenty-first-century cosmological science. If so, I will have succeeded in communicating a faint echo of the sense of wonder and awe at the abiding mysteries of nature so perfectly captured by Isaac Newton three hundred years ago: "I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay undiscovered before me."[16]