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Douglas A. Vakoch
Editor

Astrobiology, History, and Society

Life Beyond Earth and the Impact of Discovery

Springer

Editor
Douglas A. Vakoch
SETI Institute
Mountain View
CA, USA

and

California Institute of Integral Studies
San Francisco
CA, USA

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To Tom Pierson,
for his steadfast leadership of research
and education
at the forefront of astrobiology

Foreword

The burgeoning field of astrobiology poses three basic questions: What is the origin and distribution of life in the universe? Are we alone? What is life's future on Earth and beyond? Astrobiology is remarkable not only for its scientific significance but also because of its relevance to longstanding philosophical and existential issues. Who has *not* at one time or another asked how did we get here, are we alone, and what will become of us? Astrobiology's human side, long evident in philosophy, history, and theology, is making inroads in the social sciences. Today it is safe to say it has two agendas: a science agenda and a societal agenda. The broad umbrella of astrobiology provides a common frame of reference and promotes dialogue among people whose backgrounds and interests give them different perspectives. Astrobiology stresses interdisciplinary and multidisciplinary collaboration at a time when research is becoming increasingly specialized, and, as the anthropologist Ben Finney pointed out long ago, may represent a step towards the unification of science.

Researchers pursuing the science agenda explore microcosm and macrocosm: their interests range from molecules to galaxies. In addition to peering through microscopes and telescopes they analyze samples of air, earth, and water; hunt for life that thrives under extreme conditions; track environmental changes including global warming; crack open meteorites to hunt for extraterrestrial fossils or biological specimens; search for signs of extraterrestrial intelligence; and identify and track asteroids that could collide with Earth. Researchers following the societal agenda also explore microcosm and macrocosm, ranging from individual cognition to the qualities of entire societies and cultures. They seek ways to minimize the roles of anthropocentrism and ethnocentrism in our thinking about extraterrestrial life, turn to history for analogies to possible astrobiological discoveries, look to cross-cultural data from societies ancient and modern to gain insights into human diversity and the outcomes of cross-cultural encounters, develop scenarios, sample public opinion, and conduct experiments.

The history sections of this book advance both the scientific and societal agendas, while the remaining chapters focus on the societal agenda. This book's focus on the detection of extraterrestrial life and its consequences has a direct bearing on astrobiology's first two great questions (What is the origin and distribution of life in the universe? Are we alone?) and a clear relationship to the third (What is the future of life on Earth and beyond)?

What a difference a few decades can make in a millennia-old quest to understand our place in the universe! Apart from some interest in flying saucers shared, no doubt, with many other adolescent American males in the 1950s, I recall no special interest in the search for life beyond Earth. More or less, I fell into astrobiology by accident. In the late 1970s, I began collaborating with Mary M. Connors of NASA Ames Research Center on human requirements for post-Apollo space missions. In the 1980s we were still hard at it, and by then, under the tutelage of John Billingham, Mary had become involved in the cultural aspects of the Search for Extraterrestrial Intelligence (SETI). An unsung SETI pioneer, Mary shared two of her white papers on the topic (duly referenced in my publications) and, as luck would have it, on one of our meeting days she introduced me to the psychologist Donald Norman whose report to Congress included a few paragraphs on SETI. My new interest was confirmed at a meeting of the Society for Applied Anthropology, where I became entranced with the ideas of Ben Finney.

When I began writing about SETI in the late 1980s there was very little for a psychologist to go on: Mary's papers, some history and philosophy books, two anthropology books, one psychology book, and musings on the part of bright people who were not trained in social science methodology. One figure that attests to progress in astrobiology is that whereas in 1990 not one exoplanet had been discovered, on 16 July 2012 the Extrasolar Planets Encyclopaedia proclaimed a veritable jackpot of confirmed planets: 777. Progress on the societal agenda is more difficult to prove, but suffice it to say that my original half shelf of books and single crate of reprints has now overflowed my home library and is taking up about half the floor in a garage-sized rented storage unit.

Astrobiology, *History*, *and Society* is a fresh and important addition to the literature. Within these pages we find breathtaking overviews and fine-grained analysis of specific episodes and events. We find chapters that shed new light on the earliest phases of the extraterrestrial life debate and bring the debate up to today. Writers with decades of experience are joined by newcomers who apply new talent and introduce new views. We find popular and contrarian ideas, consensus and controversy, old saws, and Facebook. Of particular importance we find substantial new material on the discovery of non-intelligent extraterrestrial life. For too long interest in extraterrestrial intelligence has obscured the many profound and practical implications of finding non-intelligent life within our solar system. Another powerful prevailing theme is the role and limitations of analogies.

Astrobiology, *History*, *and Society* deserves to make a mark on its debut and then earn a place in the reader's permanent library. Let us hope that the future will see the publication of many additional worthwhile books. Such is by no means assured. We live in an age of rapidly advancing science and technology. We also live in an age marked by the widespread denial of scientific findings (such as evolution and global warming), disdain for education (manifested in increasing class sizes and hopeless debt for college students), and political coalitions that seek to cut funding for science and suppress supposedly "liberal" scientific ideas.

The battle against enlightenment cannot be won in the arena of science, so it is fought in the courts, in election campaigns, on talk radio, and in blogs. The danger is real, and the outcome uncertain.

Albert A. Harrison
Professor Emeritus
Department of Psychology
University of California
Davis

Preface

Astrobiologists must continually struggle with the “N = 1 Problem.” Thus far, we know only one example of a planet that bears life: Earth. Consequently, we search for life beyond Earth by drawing analogies to “life as we know it.” Similarly, we can contemplate possible habitats for extraterrestrial life by examining the varied habitats of life on Earth, where “extremophiles” thrive in environments ranging from deep-sea hydrothermal vents to high altitude mountaintops, from frozen Antarctic polar deserts to the cores of nuclear reactors. This volume grapples with the challenges of discovering life beyond Earth on the basis of life *on* Earth, placing the contemporary search for extraterrestrial life in larger historical, cultural, and scientific contexts. *Astrobiology*, *History*, *and Society* examines the history of the idea of extraterrestrial life through a combination of broad overviews and in-depth case studies, while also exploring the varied societal dimensions of discovering life beyond Earth.

There has been a notable lack of consensus about the defining characteristics of good analogies for making inferences about extraterrestrial life. As we see repeatedly in this volume, even the most direct observations must be interpreted—sometimes leading different investigators to radically divergent conclusions. Consider, for example, late eighteenth and early nineteeth-century theories of the habitability of the Sun and the Moon, as seen through the work of William Herschel and Georg Wilhelm Friedrich Hegel. Both Herschel and Hegel allowed for other planets of our solar system to be inhabited due to their shared characteristics with the Earth, but they came to opposite conclusions about the habitability of the Sun and the Moon. Even when they agreed on important criteria for comparisons, they largely relied on different evidence and gave differing weight to disanalogies that contradicted their conclusions.

When Herschel looked at the Sun, he saw both clouds and landmasses. Seeing sunspots as patches of the Sun’s solid surface visible through its otherwise bright layer of clouds, Herschel argued the Sun has both solidity and atmosphere, providing a favorable environment for life. So too, Herschel reasoned, is the Moon much like the Earth. Both are massive bodies with mountains and valleys, whose inhabitants would experience environmental changes from season to season, as well as from day to night. The laws of gravity apply equally on these two bodies, Herschel noted, and the Moon has its own satellite in the sky above: the Earth.

The disanalogies Herschel saw between the Moon and Earth—the former lacking oceans, atmosphere, and rain-bearing cloud cover—did not dissuade him from imagining the Moon to be inhabited; the differences would merely yield selenites who are markedly different from humans.

In Hegel's cosmology, the Sun is made of light, while the Moon is made of fire. Only planets have solid cores, he reasoned. Moreover, neither the Sun nor the Moon has clouds, argued Hegel, indicating they contain no air or water. This lack of meteorological processes for Hegel indicated the absence of a dynamic system capable of supporting life on either the Sun or Moon. In contrast, the Earth and other planets are solid bodies with atmospheres, which are also alike in their motions, rotating around their own axes while also revolving around the Sun. This reflects a complex combination of motions fitting for an inhabited world, in Hegel's view. The Sun merely rotates about its own axis, but revolves around nothing else—making it unlike the Earth, and thus uninhabited.

While modern astrobiologists do not count on finding life on either the Sun or the Moon, the case for other planetary bodies is less clear-cut. Consider, for example, the history of efforts to determine whether Mars is a life-bearing planet, as seen through the intricate interplay of advancing scientific understanding and increasing technological capabilities. Viewed as a "wandering star" by the ancients who observed the night sky with the naked eye, over the millennia Mars was reconceived as one of several planets circling the Sun, along with Earth. This heliocentric model of our solar system became widely accepted in the seventeenth century, supported by increasingly accurate measurements of the motions of heavenly bodies as well as concepts of physics that challenged the distinct division between celestial and terrestrial realms, as illustrations later in this book remind us (Figs. 1.2 and 2.1). At the turn of the twentieth century astronomers sketched quite divergent maps of the surface of the red planet, giving rise to a debate about whether the apparent lines were natural features, canals manifesting the work of Martian engineers, or merely optical illusions (Fig. 1.5). As the twentieth century progressed, larger telescopes brought the surface of Mars closer to our comprehension, while the same instruments allowed spectroscopic studies of the Martian atmosphere, leading to a better understanding of its chemical composition (Fig. 7.2).

Viewed as a twin planet to Earth, in recent centuries Mars has often been seen as the other planet in our solar system most likely to be habitable. Contemporary astrobiologists draw analogies between present-day Earth and the red planet in an earlier era, when water flowed freely, as these scientists note parallels between the riverbeds cut into the Martian surface and similar features in satellite photos of Earth's surface. NASA has "followed the water" in its exploration of Mars, hoping that the link between water and life we see on Earth today can provide a guide for finding extraterrestrial life. If some day scientists find conclusive evidence of life beyond Earth—even in the form of long extinct microbes on our neighboring planet—this discovery would profoundly affect our understanding of our place in the universe.

Prior to the advent of the Space Age, humankind made its most direct contact with Mars only by serendipitous discoveries of meteorites, ejected from their home world by impacts so powerful they could break free of Martian gravity and make their way to Earth across the distances of interplanetary space. In recent years, the most notable example has been meteorite ALH 84001, which was formed on Mars about four billion years ago, when liquid water may have flowed on the planet, and eventually arrived on Earth. An examination of its interior with electron microscopy showed structures that were reported in 1996 as potentially being fossilized microbes—a view now rejected by a majority of scientists (Fig. 7.4).

As humankind has begun exploring other planets via spacecraft, remote sensing of planetary features has been complemented in some missions by onboard laboratories. After NASA's two Viking landers reached the surface of Mars in 1976 and began sending data back to Earth (Fig. 7.3), results that initially seemed to indicate the presence of Martian biochemistry were later largely seen as being caused by inorganic chemical processes. In 2008, when the Phoenix lander discovered perchlorates on the Martian surface, once again a minority of scientists argued this discovery provided additional support that the Viking experiments had detected life; the Viking experiments that showed no evidence of organics when soil samples were heated might be due to their reactions with perchlorates, it was argued, not because the organics were absent. The spectroscopic analysis of Mars, once conducted solely from Earth-based observatories, entered a new phase in August 2012, when Curiosity, the Mars Science Laboratory Rover, began examining the composition of rocks by studying the spectra they emit upon being bombarded by a series of laser pulses (Fig. 1).

History provides important lessons about the need for astrobiologists to be open to reinterpreting data as more is learned. To return to the mid-twentieth-century spectroscopic analysis of Mars mentioned above, the data initially interpreted as evidence for Martian vegetation was explained a half dozen years later by the same experimenter as being due to a form of water (deuterated hydrogren) in the Earth's atmosphere. In other cases, beliefs once held are not so easily let go of—at least by the scientists initially making the claims. In another example from roughly the same time period, early efforts to use the astrometric method of planet detection led to claims that Barnard's star was accompanied by a planet 1.6 times the size of Jupiter (Fig. 7.5). It took decades before this claim was demonstrated conclusively to be spurious.

An examination of such episodes can provide insights into the nature of scientific discovery, and this book provides a series of in-depth case studies of interest to astrobiologists and historians of science alike. The episodes detailed in this volume also allow the broader public to appreciate better the incremental nature of scientific progress, where interpretations of data can reverse as new observations and insights become available. The more clearly scientists and other scholars can articulate the ambiguities and uncertainties involved in the normal course of doing science, the better we can help prepare people from all walks of life as they follow the latest reports about efforts to find life beyond Earth.

Throughout the history of the search for extraterrestrial life, we have seen tantalizing suggestions of the impact that its discovery might have. For several days in 1835, people around the world thought intelligence had been directly observed on the Moon's surface, as the New York *Sun* recounted the latest discoveries of

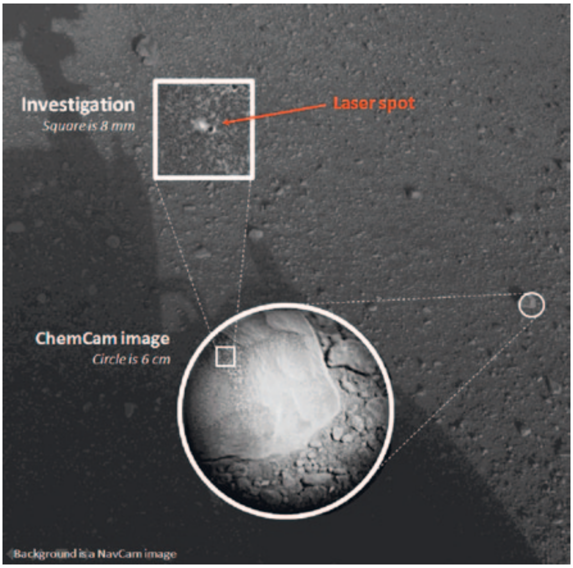

Fig. 1 Curiosity, NASA's Mars Science Laboratory, conducted the first spectroscopic laser test of a rock on an extraterrestrial planet on August 19, 2012, less than two weeks after this rover landed on the surface of Mars. The *widest* context view in this composite image was taken by Curiosity's Navigation Camera (NavCam). The *circular* inset, taken by the Chemistry and Camera instrument (ChemCam), shows a portion of the fist-sized rock named Coronation, which was hit by 30 laser pulses, each lasting five one-billionths of a second and delivering more than a million watts of power. By using ChemCam's three spectrometers to examine the glowing plasma from the laser-excited atoms in the rock, scientists were able to study Coronation's chemical composition. The *square* insert at the *top* of the image shows a higher magnification of the area repeatedly targeted by the laser. Image credit: NASA/JPL-Caltech/LANL/CNES/IRAP

renowned astronomer John Herschel using a 24-foot diameter telescope at the Cape of Good Hope in South Africa. Among the most astounding discoveries reported was the existence of lunar "bat people," or *Vespertilio-homo* (Fig. 1.4). In truth, this series in a daily newspaper was intended by its author as a satire about overly enthusiastic advocates of the plurality of worlds. As with Orson Welles' radio broadcast of *War of the Worlds* just over a century later, an unsuspecting public took these media accounts as true.

Might such historical incidents provide illuminating analogies for an actual detection of extraterrestrial life? As the chapters in this volume show, the analogies we might first think of are not necessarily the most useful. When historian Bruce Mazlish sought an appropriate analogy for understanding the development of the space program, he bypassed one obvious alternative—the Age of Exploration—and opted instead to draw an analogy to the development of the railroad (Yerxa and Mazlish 2009, 61). Similarly, scientists involved in the Search for Extraterrestrial Intelligence (SETI) have looked beyond voyages of exploration for analogies of contact with other civilizations, arguing that scenarios for contact at interstellar distances via radio transmissions are quite different from the direct physical contact involved in European expeditions to the New World. A more apt analogy, they argue, acknowledges the possibility of unidirectional transmission of knowledge across generations, akin to the transmission of ancient Greek writings through the ages, safeguarded and translated by medieval Islamic scholars, and eventually contributing knowledge critical for Europe's Renaissance (Finney and Bentley 1998).

Could such analogies help us anticipate the future? An early proponent of using encounters between *Homo sapiens* and Neanderthals as an analogue for human—extraterrestrial contact also suggested that the best analogies are discovered by starting with multiple analogies, then systematically eliminating the less favorable ones (Ascher 1961, 322–323; Ascher and Ascher 1963, 308). Indeed, forecasters have shown that experts who make judgments based on multiple analogies—identifying the single best analogy from the possibilities—can markedly improve their predictions (Green and Armstrong 2007). Some social scientists value prediction, not necessarily as a means to say with certainty what will happen in the future, but to identify some possibilities that are more likely to occur than others. For example, sociologists and psychologists have identified widespread patterns in people's attitudes about life beyond Earth, such as the tendency for more religious people to be more skeptical about the existence of extraterrestrial life (Bainbridge 2011; Pettinico 2011).

In contrast, historians have been loathe to attempt to predict the future through analogies with the past. Familiar with the vicissitudes of historical events and mindful of the multiple societal forces involved, historians warn against efforts to anticipate the future. As the chapters in the final section of this volume highlight, historians and anthropologists tend to be cautious about predicting the precise reactions of humankind to the possible discovery that we are not alone. The contingencies of historical circumstance and cultural context, as well as the difficulty of anticipating the precise nature of contact, make such anticipations inherently imprecise, they argue.

By definition, analogies make use of inexact comparisons, which necessarily limit our certitude about the conclusions we draw. Nevertheless, the use of analogies can be illuminating—often in unexpected ways. To return to Mazlish's *The Railroad and the Space Program*, while that project was limited in its ability to provide specific, concrete predictions about the impact of space exploration, the comparison proved especially fruitful in providing new perspectives on the development of railroads (Fischer 1970, 257). Similarly, in this volume we see ways that analogies involving extraterrestrial life can help us better understand life on Earth—even if we are left uncertain about whether life exists *beyond* Earth. For example, an examination of the analogies that have been drawn between terrestrial evolution and possible mechanisms of biological change on other worlds has highlighted key elements of evolutionary theory. By studying the history of the interrelationship of evolutionary theory and estimates of the likelihood of life beyond Earth, we can better chart the varied receptions of evolutionary theory within diverse scientific specialties in the twentieth century.

Other chapters in this volume argue that we may make significant advances by seeking relevant heuristics, rather than constructing grand theories of contact. Though we may not be able to predict the specific responses that people will have upon discovering life beyond Earth, analogies can provide us with insights into how we understand life and intelligence that is radically "other." Our views of "other life" are influenced not only by science, but also by science fiction and popular culture. We may not be able to anticipate the precise reactions of Earth's diverse religious traditions to discovering life beyond Earth, but even here, historical examinations of theological reflections on the plurality of worlds may help understand the range of possible responses within traditions (Vakoch 2000). The complete reactions of the populace may be impossible to anticipate with accuracy, but astrobiologists who understand how the news will be disseminated in a world of Twitter and Facebook will be better prepared to communicate clearly and effectively about scientific results that may not be as conclusive as the public would wish. And as we are reminded repeatedly in this book, we must be wary of anticipating the global response to the discovery of extraterrestrial life by relying solely on studies of Europeans and North Americans. Even the means we use to conduct a valid study may vary from nation to nation, with structured questionnaires asking about the participants' beliefs coming across as difficult to understand and complete in some cultures. Alternative approaches, such as ethnographic studies and in-depth interviews, provide critical opportunities for researchers to build trust, while yielding rich understandings of cultural context.

Astrobiology, *History*, *and Society* is divided into three parts, with each part beginning with an overview essay that includes a preview of the other chapters in that part. The first part covers the plurality of worlds debate from antiquity through the nineteenth century, while part II covers the extraterrestrial life debate from the twentieth century to the present. The final part examines the societal impact of discovering life beyond Earth. Throughout the book, authors draw links between their own chapters and those of other contributors, emphasizing the interconnections between the various strands of the history and societal impact of the search for extraterrestrial life.

Contemporary astrobiologists seek answers to questions previously asked, albeit in different form, by theologians and natural philosophers. As estimates of the prevalence of extraterrestrial life have swung like a pendulum through the ages, thoughtful individuals have contemplated the significance of competing alternatives: that life exists only on Earth, or that it is also found elsewhere in the universe. Astrobiologists search with increasingly sophisticated instruments, using the methods of modern science in place of pure reason or revelation, seeking evidence of both habitable environments and organisms that have evolved independently from life as we know it. By understanding the historical and social context of the modern search for life beyond Earth, we can better appreciate the cultural, ideological, and scientific factors that make it plausible at one time to imagine the universe brimming with life, and mere decades before or after, to see the cosmos as devoid of life, except for that found on Earth. By gaining a greater perspective on the nature and significance of this search as a whole, we are better prepared to sort through the many challenging and sometimes ambiguous questions facing today's astrobiologists.

Douglas A. Vakoch

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Douglas A. Vakoch

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