Cambridge University Press & Assessment
978-1-107-10998-8 — The Impact of Discovering Life beyond Earth
Edited by Steven J. Dick
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Introduction: Astrobiology and society

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The search for life in the universe, once the stuff of science fiction, is now a robust research program with a well-defined roadmap and mind-bending critical issues (Des Marais *et al.*, 2008; Dick, 2012; Dick and Strick, 2004; Sullivan and Baross, 2007). The science of astrobiology – and there is no longer any doubt it is a science, simplistic slogans about "a science without a subject" notwithstanding – is funded by NASA and other institutions to the tune of tens of millions of dollars of ground-based research, not to mention the hundreds of millions spent on space-related missions. Biogeochemists study extremophile life on Earth, biologists study the origins of life, a bevy of spacecraft have orbited or landed on Mars, others have found potentially life-bearing oceans on Jovian and Saturnian moons as well as organic molecules on Titan, and the Kepler spacecraft has discovered thousands of planets beyond the solar system – all just a prelude to future studies. Recent US Congressional hearings on astrobiology indicate it is a hot topic in the policy arena (United States Congress, 2013 and 2014). And international interest is also strong, particularly within the European Space Agency. Although no life has yet been found beyond the Earth, the search for such life has arguably been a driver of the space program since its inception, has inspired multidisciplinary research on Earth, and is the subject of great popular interest that shows no signs of abating. As this volume illustrates, it is also a perennial theme in science fiction literature, igniting dreams of other worlds.

Given both scientific and popular interest in astrobiology it is important for scholars, practitioners, and policymakers to examine the societal implications of discovery in the event of success. Substantial studies have been undertaken on the societal impact of other scientific endeavors such as the Human Genome Project, biotechnology, nanotechnology, and spaceflight. Even closer to astrobiology's core interests are planetary protection protocols, which are certainly studies of potential impact since one of their goals is to prevent a catastrophic "Andromeda Strain" scenario, in the terminology of Michael Crichton's 1969 novel. We should be under no illusion that millions of dollars are going to be spent to study the implications of finding extraterrestrial life – not, that is, until it is discovered, in which case the floodgates may open as they did with the Human Genome Project, now in the form of a practical problem rather than a theoretical one.

But how to approach rationally such a "far out" problem as the societal impact of discovering life beyond Earth? That was the question posed at a symposium held at the Library of Congress in September, 2014, for which this volume is the elaborated and fully referenced record (Library of Congress, 2014). Entitled "Preparing for Discovery: A Rational Approach to the Impact of Finding Microbial, Complex, or Intelligent Life Beyond Earth," the Symposium was not the usual astrobiology meeting where technical aspects were discussed in minute detail. Rather it was a meeting about the *humanistic* aspects of astrobiology, particularly preparing for finding life, and the potential impact if we do. It was billed as a *rational* approach, because it was designed to be a systematic and scholarly (though hardly comprehensive) attempt at tackling the problem, making use of knowledge from a wide range of disciplines. In this spirit the program featured not only scientists, but also philosophers, theologians, historians, and anthropologists. Atypically, the discussion was intended to address not only the impact of the search for extraterrestrial intelligence (SETI), but also microbial and complex life. Indeed, many astrobiologists believe microbial life will be discovered first, certainly if it comes as a NASA discovery, since NASA's astrobiology focus at present is on microbes. Still, the discovery of even microbial life beyond Earth would be perhaps the greatest discovery in the history of science.

Some have asked why now: why not wait to discuss the societal impact of extraterrestrial life until it is actually found? Military planners have an answer for this – waiting for a problem to arise blindly in some part of the world would be considered dereliction of duty, if only because different scenarios require the deployment of different resources, sometimes quickly. Contingency plans are essential, whether an event is likely or not. And it is always better to think ahead, to have time to consider options in a thoughtful way rather than to react in the passion of the moment. Scientists also have an answer, which is why the Human Genome Project has from its beginning sponsored a robust program on the ethical, legal, and social implications of its work. The bottom line is that it is always better to be prepared for events, with the goal of minimizing risks to humanity. Protocols may not work perfectly (as evidenced in the 2014 ebola outbreak), but they work better than nothing at all. And while we can debate how likely any extraterrestrial life discovery scenario might be, in the last few decades the discovery of thousands of planets, some Earth-sized and in the habitable zone of their parent stars, have made the discovery of life beyond Earth more likely.

Given these developments in astrobiology, it is time that we look seriously and systematically at the problem of astrobiology and society. The stakes are high. More than 50 years ago the US National Academy of Sciences compared the impact of astrobiology to the impact of Copernicus and Darwin and concluded, "The scientific question at stake in exobiology is, in the opinion of many, the most exciting, challenging, and profound issue, not only of this century but of the whole naturalistic movement that has characterized the history of western thought for three hundred years. What is at stake is the chance to gain a new perspective on man's place in nature, a new level of discussion on the meaning and nature of life" (National Academy of Sciences, 1962). Ten years later science fiction pioneer and visionary Arthur C. Clarke wrote that, "The idea that *we* are the only intelligent creatures in a cosmos of a hundred million galaxies is so preposterous that there are very few astronomers today who would take it seriously. It is safest to assume, therefore, that *They* are out there and to consider the manner in which this fact may impinge upon human society" (Clarke, 1972). Even for those who consider the discovery of extraterrestrial life a low-probability event, the potentially high impact makes our endeavor prudent, if not essential.

A small interdisciplinary research group, largely under the auspices of the NASA Astrobiology Institute, has been addressing the issues of astrobiology and society over the last few years (Race *et al.*, 2012). It is a sign of astrobiological optimism that several other groups and individuals have also recently taken up the subject of the impact of discovering life (Bertka, 2009; Dick, 2000; Harrison, 1997; Impey *et al.*, 2013; Michaud, 2007; Vakoch, 2013). This volume is intended as a contribution to that effort, spurred on by the interest of NASA and the Library of Congress, as well as almost daily discoveries bearing on the subject. The volume begins in Part I by looking at frameworks for approaching the problems of discovery and impact. We are immediately faced with the problem of how we can transcend anthropocentrism when we talk about foundational concepts like life and intelligence, culture and civilization, and technology and communication. These problems are addressed in Part II. Part III tackles the potential philosophical, theological, moral, and cultural impacts of finding extraterrestrial life, while Part IV tackles the more practical aspects of preparing for discovery – or non-discovery. The questions we ask throughout the volume are foundational, examining the very roots of some of humanity's most cherished concepts. In the end they reflect on an age-old question that never loses relevance: what does it mean to be human? I maintain that even in the event that life is not discovered beyond Earth, the questions addressed in this volume will have been worthwhile because astrobiology forces us to look at ourselves from this foundational extraterrestrial perspective.

This Symposium was held during my tenure as the Baruch S. Blumberg NASA/Library of Congress Chair in Astrobiology, located in the Library's John

W. Kluge Center in the magnificent surroundings of the Thomas Jefferson Building, just across the street from the United States Capitol. I want to thank Congressman Lamar Smith, Chairman of the House Science Committee, whose remarks opened the Symposium; Mary Voytek, Director of the NASA Astrobiology program at NASA Headquarters; and Carl Pilcher and Ed Goolish, Director and Acting Director of the NASA Astrobiology Institute, for their support throughout the year. I also thank the staff of the John W. Kluge Center, especially its two directors during my tenure, Carolyn Brown and Jane McAuliffe, as well as JoAnne Kitching, Jason Steinhauer, and Danielle Turello for their important contributions to the symposium. They provided the congenial and resource-rich environment in which this volume was conceived and implemented. In addition at Cambridge University Press I wish to thank my editor Vince Higgs, as well as Karyn Bailey, Cassi Roberts, Rachel Cox, Jonathan Ratcliffe, and Zoë Lewin.

This book is dedicated to two pioneers: John Billingham, who led a series of workshops on this subject 25 years ago as the head of the NASA SETI program (Billingham *et al.*, 1999), and Baruch S. Blumberg, the 1976 Nobelist in medicine and founding director of the NASA Astrobiology Institute (Pilcher, 2015). Many of us remember Barry fondly for his passionate interest in the subject, not only for the science, but also for the societal aspects discussed here. He always liked to think of astrobiology as exploration in the tradition of Lewis and Clark. This volume should be considered in that light as well – exploration, pushing the envelope of knowledge into uncharted territory, wherever it may lead.

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Washington, DC
March, 2015

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Part I Motivations and approaches

How do we frame the problems of discovery and impact?

Introduction

For the most part in this volume we assume that life exists beyond Earth and ask what the implications are if a discovery is made. In other words, we begin where most scientific discussions of astrobiology end. Before we head down that path, however, it is prudent to ask why we should believe such life exists. A large literature exists on this subject, ranging from the optimistic (e.g. Davies, 2010; Shklovskii and Sagan, 1966) to the skeptical (Gonzalez and Richards, 2004; Ward and Brownlee, 2000). It is not the purpose of this section to adjudicate between the optimists and pessimists, only to see why studying the societal implications of finding life beyond Earth is a valid endeavor.

The first two chapters of Part I summarize the arguments of the optimists from the point of view of both science and philosophy. Seth Shostak, a radio astronomer and Director of the Center for SETI Research at the SETI Institute, discusses the three broad empirical approaches to the search for life: direct exploration by spacecraft, biosignatures in planetary atmospheres, and the search for signals of artificial origin. Should one of these searches prove successful, he believes the societal reaction might be less dramatic than often assumed. Others in this volume beg to differ. Iris Fry, a philosopher who has written extensively on the history of the origins of life controversy (Fry, 2000), examines our deep philosophical presuppositions in the search for life – the Copernican assumption that the Earth is not special, and the Darwinian assumption that life emerged and evolved on Earth by natural processes and might do so wherever biogenic conditions prevail. While these presuppositions are not proven, she argues that astrobiologists are continually testing them, and there are grounds for being optimistic that their assumptions are valid. She contrasts this with the presuppositions of the Intelligent Design movement, some of which implicitly or explicitly drive opposition to the search for life (as in Gonzalez and Richards, 2004). Those assumptions, she argues, are not testable. In other words, some presuppositions are better than others. This does not mean we are lacking good arguments against the existence of life beyond Earth, only that valid grounds exist to proceed with the search and to study potential societal implications.

While the first two chapters frame the likelihood of discovery of life beyond Earth, Chapters 3 and 4 frame the problem of the impact of discovery. In Chapter 3, I examine three approaches from the point of view of human experience: history, discovery, and analogy, laying out a variety of discovery scenarios. History offers lessons from the reaction to cases where life beyond Earth was thought to have been discovered; the nature of discovery teaches us that the event will be an extended affair; and analogy offers cautious but important lessons from the point of view of culture contacts, scientific advances, and changing worldviews. While we certainly cannot predict societal impact for any given scenario, these three approaches arguably can serve as solid guidelines to encounters with life. Taking a very different approach, the philosopher Clément Vidal greatly elaborates possible scenarios and argues that the discovery of extraterrestrial life will either be in the form of microbial life or intelligent life that does not communicate because it is inferior or superior to us. Vidal goes on to elaborate a multi-dimensional impact model from several perspectives, including those of the extraterrestrials. He argues that the extended nature of any discovery means that media and public interest may wane, also making it less impactful than one might predict. A smooth impact, he argues, is what we should seek in any case through proper preparation.

Taken together, these scientific, philosophical, and historical considerations of the problems of discovery and impact set the stage for the remainder of the volume.

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1 Current approaches to finding life beyond Earth, and what happens if we do

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Three broad approaches exist in the search for extraterrestrial biology: (1) discover life in the Solar System by direct exploration; (2) find chemical signatures for biology in the atmospheres of exoplanets; or (3) detect signals (radio or optical) transmitted by intelligent beings elsewhere. In this chapter I describe each of these approaches, and then elaborate the multiple ways that we might learn of technologically competent civilizations. I also discuss why society's immediate reaction to the discovery of extraterrestrial intelligence would be less dramatic than often assumed. In all three cases the search for life beyond Earth is the ultimate remote sensing project. With few exceptions (such as sample return missions) this is exploration at a distance. While some reconnaissance is done by spacecraft, the majority of the effort consists of sifting through information brought to us in a storm of photons, either optical or radio.

Introduction

The idea of extraterrestrial biology is hardly new, with written speculation on the subject dating back two millennia and more (Dick, 1982). The first scientific searches are more recent, beginning with Johannes Kepler who, observing the Moon in detail through an early telescope, thought he recognized features carved by rivers. These, he reasoned, were sure signs of biology. Kepler also believed that craters were the surface manifestations of underground cities constructed to protect the citizenry from the relentless sunshine of the two-week lunar day (Dick 1982, 75–77; Basalla 2006, 21).

These pioneering observations were plagued by naïve, anthropocentric assumptions and a lack of information on the true environments on these worlds. Such bugaboos continued to affect attempts to find cosmic company for centuries, extending to the enthusiastic study of Mars by astronomer Percival Lowell. In a series of books, lectures, and articles extending from 1894 until his death in 1916, Lowell proclaimed the existence of a vast, hydraulic civilization on the Red Planet (Crowe 1986; Dick 1996). Just as

Kepler had done, he appealed to morphological evidence – straight-line features that he interpreted as canals – to back up these assertions. Lowell's claims were spurious, although one could argue that the falsity of his discoveries was due more to poor observation than poor interpretation (the trap that had snared Kepler). If the linear features described by Lowell actually existed, they would have been compelling evidence for intelligent beings.

Our knowledge of possible cosmic habitats and their habitability has grown substantially since these early efforts. We've mapped most of our Solar System in detail and have found thousands of planets around other stars. Scrutiny of these worlds has likewise increased: the last half-century has seen the beginnings of radio and optical SETI (the search for extraterrestrial intelligence), robotic exploration of Mars, and spacecraft reconnaissance of moons around the giant planets. In addition, astronomical research has shown that planets are commonplace, and habitable worlds may be plentiful.

A recent analysis of data from NASA's Kepler mission indicates that roughly a fifth of all stars host at least one habitable world (Petigura 2013, 19273). We've also learned of the probable existence of massive liquid reservoirs on five nearby moons, and the likelihood of underground aquifers on Mars. Additionally, the discovery of terrestrial extremophiles able to survive conditions that a few decades ago might have seemed too daunting for life suggests that many worlds – even those with environments rather different from Earth – could be inhabited (Schulze-Makuch, Chapter 5, this volume). For all these reasons, the search for extraterrestrial life – always a subject of interest to the public – has become popular with the research community as well.

The three-way horse race

The various strategies being pursued in the hunt for extraterrestrial biology naturally fall into the three broad categories enumerated above (Shostak 2012). Of the three, direct exploration of the Solar System is the most costly, and requires sophisticated robotic spacecraft and rovers, and eventually manned expeditions. The spectroscopic search for biomarkers in the atmospheres of exoplanets or their moons is dependent upon telescopes that are mostly still unconstructed. The third strategy, SETI, is limited in scope due to very minimal funding. We consider each of these strategies in greater detail below.

Direct reconnaissance of the solar system

Of all the nearby worlds that have tempted scientists with the promise of extraterrestrial biology, none has been more seductive than Mars. Lowell's canals were chimeras, but despite careful research in the early twentieth century proving that the Martian surface was dry, cold, and layered by an atmosphere only 1 percent that of Earth's, many scientists were still convinced that the Red Planet wasn't a dead planet. Acting on that optimism, NASA sent two Viking landers to Mars in 1975. The craft bore sophisticated instruments designed to detect both macroscopic and microbial life, and were launched with both fanfare and high hopes. Carl Sagan, who helped design and manage the mission, ventured that, "The possibility of life, even large forms of life, is by no means out of the question."

The landers provided, at best, ambiguous results. They sampled and sniffed the Red Planet's dusty dirt, looking for microbial metabolism. They didn't find it, although one member of the experimental team maintains to this day that they did (Levin and Straat 1977). The Viking biology team consensus was that the barsoomian landscape is sterile, and is kept that way by stinging ultraviolet radiation from the Sun and oxidizing compounds in the soil. But the issue was reopened after the Phoenix lander discovered perchlorates on Mars in 2008, possibly causing a false positive from the biology experiments (Navarro-Gonzalez *et al.* 2010). And evidence both morphological and chemical has since suggested that liquid water once pooled and flowed on Mars, perhaps fed by underground aquifers that could still exist. The possibility of life remains, although the evidence could be difficult to reach.

Chastened by the experience with Viking, NASA today is taking a more cautious approach to looking for Red Planet residents, and in particular is using its orbiters and rovers to reconnoiter locations that may have been lakes or rivers billions of years ago. By eschewing extant life in favor of life that may have existed in the past, the agency reckons that it has upped its chances for success. The whole history of biology on Mars – assuming there is one – is made fair game for eventual discovery.

At least three moons of Jupiter (most notably, Europa) as well as two moons of Saturn show promise for extraterrestrial biology. Titan is the only other body in the solar system with liquids on its surface, but that surface is at –179 °C, and the lakes there are reservoirs of liquefied natural gas, not water. But Saturn has a second seductive moon – Enceladus – that also shows strong evidence of subsurface aquifers. Thanks to the periodic kneading of this moon as it orbits its host planet, some of the water is erupted into space, where it makes an attractive target for a flyby space mission to grab and analyze. Europa also squirts small amounts of frozen water into space – water that has managed to find its way through the 15 km of ice that separates this moon's surface from the vast oceans below (Figure 1.1). It too may contain evidence of microscopic biology.