16 Is there anything new about astrobiology and society?

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At the intersections of biology and society, scholars have long explored ethical, legal, policy, economic, and other social issues, while also placing emerging science in the context of history and philosophy of science. One tradition has focused on the impact of scientific developments on society, reflecting on eugenics, recombinant DNA, reproductive technologies, human subjects experimentation, genetically modified foods, and other issues in largely reactive ways. Others are trying to anticipate where the science will be going and to outline issues that society is likely to face. Synthetic biology and technologies such as human reproductive cloning raise additional questions about whether we should forbid some science altogether. Stem-cell research or genetic engineering of food and people raise questions about appropriate regulatory responses. Experiments with pathogens and sequencing genes of dangerous organisms raise questions about control of knowledge. The National Science Foundation's Program on the Science of Science Policy explores issues of how science policy gets made and what factors influence the decisions.

Astrobiology falls into this complex world of biology and society, and here I ask: "Is there anything new under the Sun?" Or, more precisely, "Is there anything new under and beyond the Sun?" Have we already heard all the issues and are now just applying them to astrobiology in particular? Or are there special features of astrobiology that call for new thinking or raise new questions? Providing answers requires thinking about the presumed domain of astrobiology, then its implications, which in turn benefits from a look at the context of issues of biology and society more generally.

The domain of astrobiology

NASA defines astrobiology as "the study of the origin, evolution, distribution, and future of life in the universe." Further: "This multidisciplinary field encompasses the search for habitable environments in our Solar System and habitable planets outside our Solar System, the search for evidence of prebiotic chemistry and life on Mars and other bodies in our Solar System, laboratory and field research into the origins and early evolution of life on Earth, and

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studies of the potential for life to adapt to challenges on Earth and in space" (NASA 2014a). The "astro" is only part of the story, which includes the origins and evolution of all life.

Biology is the study of life, of living organisms and systems, their processes, and their interactions with the environment. In their excellent look at the history of astrobiology, Steven J. Dick and James E. Strick explain the evolution of approaches to astrobiology in particular and how it came to include the study of life on Earth. First there was exobiology, meant to focus on extraterrestrial life. Then, for a number of strategic reasons that they explain, NASA expanded to include origins and evolution more generally, with the initial 1998 articulated set of roadmap goals to (Dick and Strick 2005, p. 219):

1. Understand how life arose on Earth.
2. Determine the general principles governing the organization of matter into systems.
3. Explore how life evolves on the molecular, organism, and ecosystem level.
4. Determine how the terrestrial biosphere has coevolved with the Earth.
5. Establish limits for life in environments that provide analogues for conditions on other worlds.
6. Determine what makes a planet habitable and how common these worlds are in the universe.
7. Determine how to recognize the signature of life on other worlds.
8. Determine whether there is (or once was) life elsewhere in our Solar System, particular on Mars and Europa.
9. Determine how ecosystems respond to environmental changes on time scales relevant to human life on Earth.
10. Understand the response of terrestrial life to conditions in space or on other planets.

More recent versions of the roadmap have revised the goals somewhat, though the overall intent remains (Des Marais *et al.* 2008).

Goals 1–5 and 9 fall into the category of terrestrial biology and are not particularly "astro." Goals 6–8 turn outward, asking about the universe more generally – about habitable worlds, signature of life, and where life has existed. This is study about, though not study of, life that might exist extraterrestrially. Goal 10 takes terrestrial life into space and asks how it might fare. None asks about possible risks of bringing life forms from space to Earth – accidentally or on purpose.

Dick and Strick make clear that from the beginning of the space program concern about possible back contamination was nonetheless real. In 1960,

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Norman Horowitz wrote a memo to Joshua Lederberg and invoked Christopher Columbus proposing to set sail, and noted that the fear of encountering risk and in particular any foreknowledge of syphilis would have kept Columbus from leaving. "Suppose, however, that they had known also of the tremendous benefits that were to flow from the discovery of the New World. Can there be any doubt what their decision would have been then?" (Dick and Strick 2005, 59). Yet worries grew stronger for some during the Cold War, with fears that enemies might try to use astro-knowledge or astro-materials as weapons. It seems a bit surprising, therefore, that protection is not listed as one of the astrobiology program goals. Presumably this is because of the existence of NASA's separate Office of Planetary Protection (Meltzer 2012). Yet surely that office is worth acknowledging. An eleventh goal might be in order; something like: "11. Understand the response of terrestrial life to life and materials from space."

Implications of astrobiology

For now, let's set aside the general goals of studying life on Earth, its evolution, and environment, which do not raise new questions in themselves. Instead, let's ask about three areas where astrobiology seeks to do something different, namely: (1) how to study and manage extraterrestrial life that ends up on Earth (either imported through back contamination or travelling here on its own); (2) how to study life elsewhere in its own environment; (3) how terrestrial life is affected by travel in space. These are sufficiently different sets of questions that it's worth looking at each in turn. I ask here about the science and how to address these questions. Then I'll turn to the social implications in the next section.

(1) How to study and manage extraterrestrial life that ends up on Earth?

While historians of the extraterrestrial life debate have documented the broad range of possible beings described in science fiction, these remain hypothetical. The issue here is: if life really arrived here from outside the Earth, what impact might it have on terrestrial life? Might it, for example, infect us with microbial "diseases," and how would we know? The possible existence of such life implies that we should plan for studying it and its biological impact. How would we know, what would we do, and what might we learn? Without thinking ahead about how the science should work, it is easy to fall into ad hoc reactions that fuddle one's thinking and lead to non-scientific hypotheticals that are not epistemologically well-grounded.

The second issue about managing extraterrestrial life is more complicated and, as noted earlier, seems not to be part of the NASA astrobiology program. Yet there are obviously real issues related to "planetary protection," as NASA recognized in setting up a special office for the job (Meltzer 2012). Although a great deal of sensible regulatory planning, guided by realistic scientific assessments of risks and costs and benefits, already exists, more will be needed to anticipate and respond to new discoveries.

(2) How to study life elsewhere in its own environment

If there is life in places other than Earth and we can study it with some version of biology, then how? Let's imagine that we want to do astrobiological fieldwork, which ecosystems ecologists argue is the best way to understand organisms and their environmental interactions. Doing fieldwork means respecting the field, and it's a little hard to know how to do that. Surely when we send rovers to Mars to march around and collect and stir up the environment, we are looking for what *we* want to find. And we are also changing the conditions even as we look; we have not yet developed any way to study without intervening. The same questions arise as with experimental biology on Earth: to what extent might alternative experimental work allow us to understand life in its natural context? How might we be able to do reliable biological inquiry on, or about, other planets or other bodies in the universe? The vigorous debates surrounding what it is that we see in looking at Mars or Moon rocks, for example, show just how many assumptions get made in working with unfamiliar materials with limited, familiar methods.

Biology of multicellular organisms typically includes study of reproduction, heredity, growth, differentiation, morphogenesis, development of functional systems, evolution, ecological interaction with the environment, and other processes related to each of these. In addition, some sort of cellular living units exist, and heredity is carried through information packed into units called chromosomes and genes.

Yet perhaps life does not always have to work this way. Rather than being based on carbon, for example, life could have a silicon base, as has been hypothesized repeatedly. But how much like our current life does it need to be in order to be considered "life?" In other words, what is the object of our biological investigation in space? Which functions of living systems are essential for life; might it be possible to generate more individuals through some sort of copying that would not be considered biological reproduction, for example? We need criteria to demarcate life from non-life, yet generating those has remained a major challenge in the history of exobiological studies and now of astrobiology (see Dick and Strick 2005 for many examples).

We also need criteria for deciding what to count as doing biology. If there is no reproduction or no heredity through information units such as chromosomes or genes, and if the systems are based on elements other than carbon and rely on molecules other than nucleic acids, then what kind of science do we use to study these systems? Is it still "biology" if the science relies on quite different methods and approaches? Therefore, the domain and the actual work of doing astrobiology are not entirely clear for both metaphysical and epistemological reasons. Nonetheless, let's make the assumptions that NASA seems to make and assume that we are going to work on something close enough to life to count as the same kind of thing, using something close enough to current biology to count as the same kind of science.

(3) How to understand how terrestrial life is affected by travel in space

As NASA's history website explains, before sending humans into space, several countries, including the United States, sent animals to test the effects of gravity reduction and other factors (NASA 2014b). Already in 1948 and 1949, American rocket scientists tested monkeys and mice, many of which did not survive the landing impact. The Soviet Union experimented with mice, rats, and rabbits. Tests suggested that conditions could support life, including human life, and the challenges came more with controlling landing.

As humans began to travel in space, researchers kept a close watch on their physiological and mental reactions, focusing on such concerns as impacts of cosmic radiation or effects of reduced gravity. Then came other issues in the field of space medicine, including concerns about muscle atrophy, digestion, and whether neural impairment might result from conditions in space. Those studies for the first decades were mostly reactive and focused on keeping astronauts apparently healthy and productive.

With time, launches began to include a wider range of biological experiments to determine the effects of the microgravity on living tissues and cells as well as whole organisms. Most recently, researchers have sent stem cells into space. Since the hopes for regenerative biology rely on our ability to control differentiation of cells, and since biological research has suggested since the late nineteenth century that gravitational forces can influence differentiation, stem-cell research seems an obvious candidate for experimentation in space. In fact, a NASA press release of December 6, 2013 announced that the Center for Advancement of Science in Space (CASIS) was making it possible to do stem-cell experiments on the international space station (NASA CASIS 2013). Experiments on mouse culture lines are currently underway to assess tissue loss in space conditions (NASA 2014c).

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What issues arise for astrobiology and society?

If astrobiology is basically a form of biology, then we can start from issues of biology and society and build outward. Those issues include: how we understand assumptions and arguments in science, informed through history and philosophy of science; how we evaluate the field's impacts on society, including through ethics, law, policy, and other social lenses; and how we understand the relevant ecosystems, including through study of how living organismic systems interact with their environments. Let's look at the three sets of considerations laid out earlier with respect to these societal issues. In each case, the way that other fields have approached parallel problems suggests approaches for astrobiology.

(1) Societal impacts of extraterrestrial life that ends up on Earth

Steven Dick has shown that, historically, people have been fascinated by thinking about life elsewhere, imagining what might be possible and what that might mean. Such speculation throws light back on ourselves and on what we hope and what we fear. Dick has himself done some of the best thinking about where our imaginations can carry us. He shows that we can reason by analogy, drawing on history for help (Dick 2014). We can come to define ourselves more clearly in response to thinking about what is alien or "other" so that even if we do not find actual extraterrestrial life, the reflective process can be socially useful.

Then there are questions about what to do if extraterrestrial life were actually discovered. What if we find microbes or even more organized life forms? Presumably the usual ethical, legal, and social considerations hold. Standard biomedical ethical thinking, typically grounded on Thomas Beauchamp and James F. Childress's principles of respect for autonomy, non-maleficence, beneficence, and justice, would guide us to realize that we should respect this life (Beauchamp and Childress 2013). This would presumably also lead to invoking relevant animal care or human subjects protections. Would we want to respect the integrity of even microbial life or molecular components that might signal proto-life, on the reasoning that failing to do so violates ethical assumptions about what matters?

Perhaps we should think about extraterrestrial life as a special form of life. Genetically engineered organisms, chimeras, nano-enhanced organic parts, synthetically produced cells or organisms, cloning, and stem-cell research: all produce something new and raise new questions about how to understand the new, as well as how to control or manage it. They raise questions about how to contain risk and costs while enhancing benefits. In the United States, these questions have typically led to expert panels, often multiple expert panels, to weigh relevant factors. These panels then advise other organizations, and eventually either the issue goes away or some level of government does something. The United States has done nothing about stem-cell research at the federal level, much to the relief of many researchers. By the time all the deliberative panels had deliberated, new techniques had already begun to raise new and different questions. (National Academy of Sciences 2002a, 2002b, 2005).

In other cases, as for embryo research in the United Kingdom, the government called on a special committee, which in turn held a series of public consultations. The stimulus was the first "test-tube baby" born after an in vitro fertilization process. The result was the Human Fertilisation and Embryology Act (HFEC 1990), which has guided embryo research since its inception. Other governments and citizen groups have called for participatory democracy, inviting discussions of nanotechnology, genetically modified organisms, or other innovations. The goals have varied but have always assumed that if a wider public understands what is at issue, deliberation and resulting policy decisions will be wiser and more reflective. Perhaps astrobiology would benefit from public discussions of the science and its implications, as Steven Dick has suggested in organizing the public conference that led to this collection of essays.

Public discussion might address the complex of topics included as part of astrobiology and might make astrobiology seem less exotic. Whether the life being studied is truly alien, from outside Earth, or extremophiles in the deep ocean vents on Earth, perhaps the research involves something different and calls for unique approaches. Or perhaps not. Including a broader community in the discussions about what is going on and what is at issue might help make the research seem less alien. For example, the intense interest of visitors at Yellowstone listening to scientific lectures about extremophiles shows that people are fascinated by the possibilities and ask really sensible questions about costs and benefits. Perhaps it is only our history of feeling titillated by the possibilities of aliens that causes us to believe that astrobiology should cause public worry.

Issues of safety seem, more compellingly, to raise new questions. If we were to find new and different life forms that come from other environments than those on Earth, then we should not assume that we will know exactly how they will behave in this different environment. Perhaps we have an ethical obligation to build clearly and wisely thought-through regulatory protections against such "invasions" just in case? This would be true whether alien life forms

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arrived on Earth on their own or were brought back through space travel as back contamination. Questions about safety depend on an understanding of the science involved, and depend very much on expert explanations. This is true for such different topics as stem-cell research, nanotechnology, or invasive species: we rely on experts to tell us what is actually real rather than imagined. Then a larger community can help make decisions about what the risk assessments mean and what risks we are prepared as a society to take, since this is a social rather than a scientific question.

So far, this discussion has focused on our human perspective. Several of the papers here ask us to move beyond anthropocentrism. Why do we imagine life elsewhere as like us? And if it is not, how can we conceptualize it and respond to it? Life elsewhere might not be carbon-based, might not operate with DNA, and might be different in many other ways. It might, in other words, involve a different physics and metaphysics. But then, I would argue, to study it would probably not involve biology as such and would not be astro*biology*. We would need some other scientific field, beginning with different underlying assumptions and drawing on different methods. Whether this would require a different epistemological strategy is unclear, but epistemology does often follow metaphysics and suggests that we would need to think differently about how to carry out our study. In this case, we do not have good precedents upon which to draw, since we have assumed that we have one kind of science (and its epistemological approaches) and one kind of life (with the metaphysical assumptions about what life is).

There are also religious questions – both about what to believe and about how to feel. Those seem not to raise any really new questions. The question of whether to baptize an extraterrestrial (Chapter 15 in this volume) is not much about biology and remains a matter for conventional decision-making processes to work out. There isn't any fact of the matter, nor any clear set of guidelines except insofar as we make conventions and policies for such matters, separating scientific from social considerations. Eugenics had its biological roots, for example, but was driven by sets of social values and conventions that led to social impacts (Kevles 1985; Cold Spring Harbor Laboratory, n.d.).

Another factor concerns environmental impacts. If extraterrestrial life is actually living and close enough to earthly life to warrant biological study, then its environment matters. If we take these beings out of their "natural habitat" and move them or even allow them to travel to other locations, then they would be "invasive" species and thought by many environmentalists and conservationists to be undesirable. The same holds for terrestrial microbes found in the deep oceans and thought to be possibly similar to astro-life: we are potentially creating invasive species problems when we move them around. Again, assumptions abound. Again, we can start from our experience with invasive species, going back to early-twentieth-century worries about invading alien cherry trees from Japan (Pauly 1996; Chew and Laubichler 2003). Since studies of ecology and evolution show that context matters tremendously, taking an "astro" object and moving it could cause serious ecological questions. These include not just the usual concerns about impacts on the environment, but also questions about the impact on populations and therefore on evolution of Earth's biodiversity.

(2) Societal implications for studying life elsewhere in its own environment

Ecologists urge us to do field study of life in its own environment insofar as possible. Experimental work in the laboratory is fine for some purposes, but not for all aspects of complex natural systems. Research requires going to new places, whether to extreme environments of hydrothermal vents on Earth or more uniquely to space. Researchers might themselves travel to space, but we obviously have not yet developed human travel to those places thought most likely to prove habitable for life like Mars or Europa. Research is much more likely to be carried out by programmed machines and robots.

These machines will necessarily impact the field sites they are studying in their own ways. Perhaps they will contaminate sites with dust or microparticles. We have certainly done this in studies of the ocean floor or desert environments, with our eagerness to explore new worlds. Only gradually have we come to realize that we are impacting the nature we seek to study. Ecologists recently noticed, for example, that in studying why amphibians were dying off, they were themselves carrying pathogens and infecting populations that had previously been unaffected (Collins and Crump 2009).

With space travel, the vehicles will surely land on and impact the physical site. In effect, we are ourselves the invasive species in this case – acting remotely. Is satisfying our curiosity sufficient grounds for risking affecting the alien life we seek to study? Or can we, and ought we, to build in regulatory protections for any such research before we muck about? How do we think about how to weigh the risks, costs, and benefits? And who are the "we" who should do this weighing? These are all questions that have long been contemplated as part of NASA's planetary protection program (Meltzer 2012). Presumably, such reflection will benefit from scientists working with humanists and social scientists.

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(3) Societal implications for terrestrial life that is affected by travel in space

Here we ask not about whether we might bring something alien back with us, which is question 1, nor about whether we might impact the field sites we wish to study, which is question 2, but about the impact on the humans or animals doing the study. Traditional considerations about interactions of biology and society suggest that we should think about several issues. We can draw parallels with study of nuclear development or radiation, in which scientists and citizens served as sometimes voluntary and at other times unwitting test subjects (Creager 2013). How can we test innovations without testing it on some*body* or some *thing*? With space travellers: if astronauts are, in effect, experimental subjects, do they receive appropriate information to be able to give informed consent? Do we have a clear standard of care for astronauts before, during, and after space travel? Given concerns about cosmic radiation, have we thought sufficiently about and imposed appropriate regulatory guidelines to protect germ lines so that future generations are not negatively impacted?

Then there are questions related to studies of other species, animals or microbes: are we influencing evolution in any way with space travel? If the germ line were affected in some significant ways, we could impact populations. Bioethicists and biologists both become worried at the idea of impacting the germ line, whether through genetic engineering or some other ways that we cannot predict. This seems very unlikely, but let's extend the consideration beyond just those few individuals actually travelling in space. In the laboratory, as researchers seek to create microgravity situations to discover the impact on stem-cell differentiation, for example, what impact might that have? Might selective breeding over generations lead to evolutionary change in microbial communities? If stem-cell (or other tissue and cell) researchers are successful in generating reliable results and move into commercial production, what effects might that have?

These are evolutionary questions that have ethical implications, for which our traditional thinking is applicable and informative. Space travel just happens to be one kind of condition to consider. Is there anything new under the Sun with astrobiology?

Are there any special issues for astrobiology and society?

The easy answer is probably not really. Not if we assume that astro-life and the study of astro-life are close enough to terrestrial biology. Yet we should consider that life on Earth and life beyond Earth might not be close enough

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to warrant the same kind of study, and also that the study itself will reveal significant differences. Perhaps extraterrestrial life forms will be so different that we will not know how to recognize them (except perhaps as being something different), how to study them, or what to do about them. If so, we have an entirely different context. As future-studies researchers like to point out, there are good ways to study the future. Yet, it takes work to lay the groundwork of assumptions as well as goals for study and values about what risks are worth taking.

Steven Dick's testimony to Congress on 4 December 2013 shows why my suggestion that there is nothing very new here may miss at least one important point. Dick challenges us to think differently. As Dick noted in his remarks, it is the imagination that matters. The very idea of astrobiology and the discoveries of those exploring life elsewhere in the universe have evoked "that sense of awe and wonder." Dick spoke as an historian with perspective on centuries of both hypothetical and empirically driven thinking about life beyond Earth, and on decades of space exploration that have led to discoveries of other planets and suggestive environmental conditions. As Dick put it, "Astrobiology raises fundamental questions and evokes a sense of awe and wonder as we realize perhaps there is something new under our sun, and the suns of other worlds" (Dick 2013).

Is he right and there is something new? And if there is some*thing* new, does that mean that we can know what it is or how to understand it? In 2012, Margaret Race and others looked at issues of astrobiology and society and asked what it would take to identify and address those issues. They asked what it would take to build an interdisciplinary research community for such study (Race *et al.* 2012). From a workshop and following efforts, they noted, as Dick's testimony had also suggested, that a large part of the impact of astrobiology on society is psychological.

The authors describe themselves as a working group for thinking about and developing a roadmap for the study of implications of astrobiology on society and of society on astrobiology. They point to the four implementation principles of NASA's Astrobiology Roadmap (Des Marais *et al.* 2008) and feel that much less progress has been made toward the third principle, namely recognizing "a broad societal interest in astrobiology's endeavors." They organized a workshop with their own five goals, to (Race *et al.* 2012):

(A) Explore the range and complexity of societal issues related to how life begins and evolves.
(B) Understand how astrobiology research relates to questions about the significance and meaning of life.

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(C) Explore the relationships of humans with life and environments on Earth.
(D) Explore the potential relationships of humans with "other" worlds and types of life.
(E) Consider life's collective future – for humans and other life, on Earth and beyond.

To do all this, they maintain, involves consideration of religious, ethical, legal, cultural, and other concerns related to our current and future conditions. Philosophers and humanists should be part of addressing these issues, with the implication that they will also be informed about evolution and environmental sciences.

This effort has great attractions, including the potential for providing employment for humanists. Yet the process also requires that humanists and social scientists work closely with environmental and life scientists. It cannot be that the scientists do their science and hand the results over to others to assess the social impacts and implications. Too much of the Human Genome Project's ELSI (Ethical, Legal, and Social Implications) Program involved humanists talking to each other and thereafter not being heard by some of the scientists involved. Yet even when humanists and social scientists understand the details of the scientific work they are considering, they are often marginalized as working on "other" problems not central to the science. "Why do we need history when science is about the future?" is a common type of complaint, or "Why are we wasting money talking about bioethics when we scientists all intend to be ethical and don't need somebody telling us what to do?"

Race and others understand that, and call for interdisciplinary work including scientists. This is ideal. To have productive discussions, it cannot be that the humanists pronounce on what the social issues seem to be. The questions need to arise from mutual discussion. For example, scientists may well not think there are serious religious issues – or not anything new raised by astrobiological science or even its hoped-for discoveries. Or they may feel that ethical questions are the same as for other fields, and ask why we need more discussions about the topic. It will be important to discover what the questions are through mutual exploration, informed by contributions from all participants. Offering a list of issues already presumed to be the important ones may well put off otherwise willing collaborators. What could truly make astrobiology new under the Sun would be for humanists, social scientists, and leading scientists to work closely and collaboratively together with mutual respect on shared research problems and methods.

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