

Astrobiology and Society: Building an Interdisciplinary Research Community

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Abstract

This paper reports recent efforts to gather experts from the humanities and social sciences along with astrobiologists to consider the cultural, societal, and psychological implications of astrobiology research and exploration. We began by convening a workshop to draft a research roadmap on astrobiology's societal implications and later formed a Focus Group on Astrobiology and Society under the auspices of the NASA Astrobiology Institute (NAI). Just as the Astrobiology Science Roadmap and various astrobiology science focus groups have helped researchers orient and understand their work across disciplinary contexts, our intent was to apply the same approach to examine areas beyond the physical and life sciences and expand interdisciplinary interaction and scholarly understanding. These efforts continue as an experiment in progress, with an open invitation to interested researchers—astrobiologists as well as scholars in the humanities and social sciences—to become involved in research, analysis, and proactive discussions concerning the potential impacts of astrobiology on society as well as the possible impacts of society on progress in astrobiology. Key Words: Astrobiology—Extraterrestrial life—Life detection. *Astrobiology* 12, 958–965.

Introduction

SINCE THE DEVELOPMENT of astrobiology in the late 1990s, there has been increasing interest in the potential and realized impact of current and future astrobiological research on cultures, societies, and peoples. Authors from a wide range of disciplines have examined various issues—some near term, others focused on questions centuries in the future—but typically there is little communication across researchers and disciplines. Herein lies a challenge for astrobiologists: how can we develop a systematic research agenda that focuses on both the implications of *astrobiology on society* and the potential effects of *society on astrobiology*? As importantly, how can we proactively involve experts from other fields to collaborate in this effort and to communicate more widely about the issues?

Background: Astrobiology Science Roadmap

The field of astrobiology is centered on three fundamental questions: How does life begin and evolve? Is there life elsewhere in the Universe? And what is the future of life on

Earth and beyond? The overall focus is conveyed by an Astrobiology Roadmap, which provides an integrated set of science goals and objectives to strategically guide research and exploration across many disciplines and domains of investigation. Originally developed through a multidisciplinary conference in 1998, the Roadmap has been revised several times to reflect advances in scientific understanding and changes in research and exploration priorities (Des Marais *et al.*, 2008). As a product of a community-wide process, the Astrobiology Roadmap has helped maintain progress toward new multidisciplinary understanding of biological, planetary, and cosmic phenomena.

Integral to the Roadmap are four Implementation Principles, which acknowledge that astrobiology

- (1) Is multidisciplinary in content and interdisciplinary in implementation,
- (2) Encourages planetary stewardship and emphasizes planetary protection,
- (3) Recognizes a broad societal interest in its endeavors, and

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- (4) Has a strong emphasis upon education and public outreach.

There has been considerable progress on three of the four principles, while systematic attention to societal issues arguably has lagged since some interesting early efforts (*e.g.*, Connell *et al.*, 2000). In recent years, many researchers and conferences have considered questions arising from space exploration, the possible discovery of extraterrestrial life, and the future of life (*e.g.*, Davies *et al.*, 2008; Bertka, 2009; Codignola and Schrogl, 2009; ESF, 2009; Pontifical Academy of Sciences, 2009; AAAS, 2010; Denning and Race, 2010; AbSciCon2010, 2010; Landfester *et al.*, 2011; Stoeger *et al.*, 2011; The Royal Society, 2011; Rummel *et al.*, 2012), but there is still no systematic overview of issues nor any mechanism to guide collective research as the Astrobiology Roadmap has done for science. Clearly, no single field has all the answers, and multiple methodologies are needed to address the range of issues ahead. In an attempt to fill this gap, plans were made for a workshop to develop a research roadmap on astrobiology's societal issues.

Developing a Roadmap of Astrobiology Societal Issues

In February, 2009, 43 invitees attended a 2.5 day interdisciplinary workshop at the SETI Institute in Mountain View, California, to develop a draft roadmap for framing of astrobiology's societal issues.¹ The aim was to develop a roadmap similar to the Astrobiology Roadmap that could identify key questions and guide progress in areas beyond the sciences having importance and relevance to astrobiologists and the public. However, unlike the Astrobiology Science Roadmap, this activity was entirely community-based, not NASA-led. The draft Roadmap of Astrobiology Societal Issues² presented here is thus strictly a product of the authors of this paper and other attendees of the workshop, and has not been adopted in any manner by NASA.

The workshop agenda examined advances in astrobiology that raise questions and concerns in societal areas, and used subgroup deliberations to explore and categorize the issues. The draft societal roadmap deliberately paralleled the same three questions as the Astrobiology Science Roadmap, because questions about the origin and evolution of life, its distribution and fate, and life's future are central to almost all cultures and societies. These scientific issues also have implications for life's broad existential questions (*e.g.*, Harrison, 2007; Dick and Lupisella, 2009). After preliminary discussions we identified five goals for the roadmap, each offering multiple pathways for examination and research:

- (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
- (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

Further group discussions linked the five goals to research questions similar to the objectives of the Astrobiology Roadmap. Each subgroup viewed the goals and questions from one of three perspectives: Science and Religion; Philosophy and Ethics; and Social Sciences and Humanities. Subgroups deliberated issues, scenarios, controversies, and scholarly or research concerns that might arise in the context of pursuing each goal and addressed suggested questions that served as general discussion guidelines, including

- What societal issues or concerns are linked to that goal? What specific problems arise in the short term? Long term?
- Do certain disciplines, topics, or problem types predominate?
- Can specific research questions build on existing foundational bodies of scholarly work? If so, in what disciplines? Does astrobiology complement, extend, or challenge that work? Are there any disciplines or sectors that have little or no interest in the goal?
- Can astrobiology research or discovery change the question(s) or answer(s) in significant ways? How? What would be the societal ramifications of such change(s), and how great would the concern(s) be?
- Of the list of questions encompassed under a particular goal, identify those that are higher priority or more addressable in the near term through multidisciplinary efforts (and perhaps of greater concern to the public).

Discussions focused on any and all astrobiology science and exploration efforts that have direct or indirect implications for life on Earth and beyond—past, present, and future. At the end of the workshop, subgroup findings were discussed in a plenary session. After the workshop, subgroup recommendations were consolidated to form the draft Roadmap of Societal Issues (see Box 1).

Societal Roadmap Goals, Objectives, and Research Areas

The sections below briefly summarize the goals and objectives of the draft societal roadmap. Goals A, B, and C [related to origin and evolution (A); distribution and significance of life (B); and relationships of humans with life and environments (C)] are considered foundational and draw from extensive scholarship in many disciplines, sometimes over many generations. Before it is possible to address relationships with extraterrestrial life and environments (D), or the future of life (E), there is need to understand comprehensively how current knowledge and views have evolved over time, whether and how they are likely to respond to new science findings, and what the societal implications might be (see Fig. 1). Taken together, this draft roadmap provides an organized approach to the multiple pathways of research on societal issues and provides a preliminary step in thinking about how they may be coordinated and prioritized.³

¹Funds for the workshop were provided by the NASA Astrobiology Institute and logistical support by the SETI Institute.

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Box 1: Major Goals of the Astrobiology Roadmap of Societal Issues

A: Explore the range and complexity of societal issues related to how life begins and evolves.

Examine the kinds of religious, ethical, legal, cultural, and other concerns arising from scientific research on the origin, evolution, and nature of life.

B: Understand how astrobiology research relates to the significance and meaning of life.

Examine how astrobiology's search for extraterrestrial life and knowledge about its potential existence, distribution, and persistence relate to societal understanding of life's significance and meaning—scientifically and otherwise.

C: Explore the relations of humans with Earth, its life and environments.

Examine our diverse relationships with Earth's life and environments of varied types and consider our responsibilities toward them.

D: Explore the potential relationships of humans with “other” worlds and types of life.

Examine our possible interactions with other worlds—both with and without life—and consider the implications of our activities upon “other” worlds, life, and environments.

E: Consider life's collective future—for humans and other life, on Earth and beyond.

Understand the impacts on life and future evolutionary trajectories that may result from both natural events and human-directed activities in the short and long terms.

Goal A: Explore the range and complexity of societal issues related to how life begins and evolves. *Examine the kinds of religious, ethical, legal, cultural, and other concerns arising from scientific research on the origin, evolution, and nature of life.*

All three affinity groups focused on the need to clarify and compare definitions and understanding about life, its origins, and changes over time. They also emphasized the need to understand the different ways of “knowing”—and to anticipate how scientific discoveries will be translated and applied by scientists, nonscientists, and public groups, all from their different perspectives. The research objectives identified by each subgroup are summarized below.

The objectives identified by the **Philosophy and Ethics** group focused on examining the definitions of life, our varied and indeterminate understanding of the phenomenon, and the ways we value it. The group also highlighted the need to compare/contrast different methods of knowing, and the interpretations that follow from scientific versus other perspectives. In addition, the group noted the need to consider what ethical issues are associated with research aiming to “create” life in the lab.

The **Science and Religion** group emphasized the need to better understand the scientific versus nonscientific views of Creation/Origin and Evolution—addressing differences and similarities, and reconciling scientific views and different

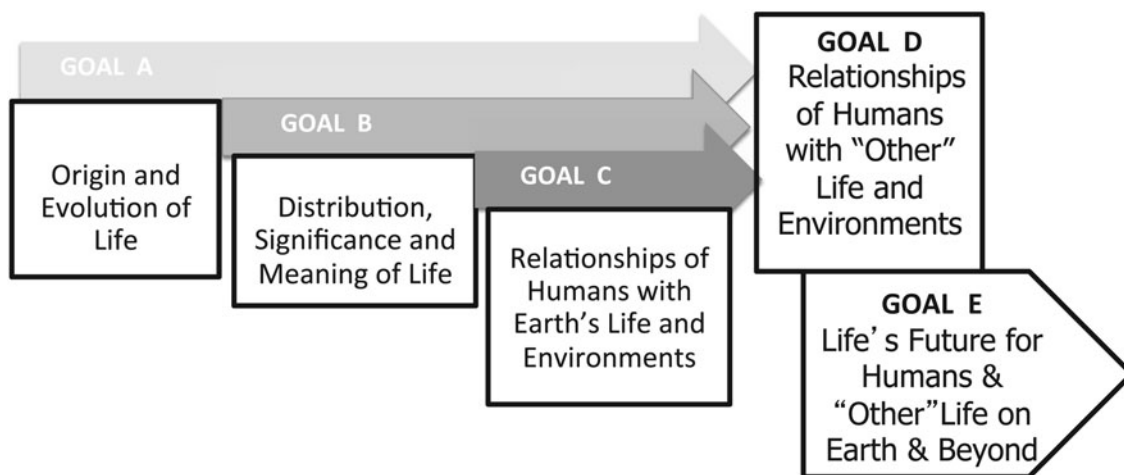


FIG. 1. Roadmap goals as building blocks. Information relevant to Goals A, B, and C draw upon current and historical research from many other disciplines. Before addressing relationships with extraterrestrial life and environments (D) or the future of life (E), there is a need to understand comprehensively how current knowledge and views have evolved over time, whether and how they might respond to new science findings, and what the societal implications might be, now and in the future.

religious and cultural narratives. Their objectives sought to understand the impact of new scientific findings about life's origin/evolution on worldviews and interpretations within different cultural, religious, or secular groups. As scientists seek to identify different biochemistries (a "second genesis"), synthesize life in the lab, and determine whether we live in a biological universe, it will be important to examine whether and how this new information could challenge religious and cultural views of Creation as purpose-driven and with special significance.

The **Social Sciences and Humanities** group focused on the need to compare and contrast definitions and understandings about life and evolution (physical, biological, and cultural evolution) as well as different views about life versus nonlife as interpreted through religious, cultural, historical, and scientific approaches. It is important to anticipate how changes in science explanations might translate to different interpretations and meaning about life, here and beyond. Understanding the different definitions, approaches, and interpretations about origin and evolution also has implications for how we make applied decisions about life in the legal, policy, and private sector spheres, from the individual to species and ecosystems levels.

Goal B: Understand how astrobiology research relates to questions about the significance and meaning of life. *Examine how astrobiology's search for extraterrestrial life and knowledge about its potential existence, distribution, and persistence relates to societal understanding of life's significance and meaning—scientifically and otherwise.*

All three subgroups focused on the continuing need to recalibrate thinking about life (*e.g.*, existence, distribution, persistence, involvement in global processes) and to proactively anticipate how an extraterrestrial discovery might alter our views or not. Considerations about significance and meaning must extend well beyond science *per se* and include dialogue with ethicists, theologians, and other disciplines/communities interested in broad cultural and societal implications.

The **Philosophy and Ethics** group identified three important areas of attention, two linked with environmental ethics and the third with social justice. Any discussions of possible extraterrestrial life must be linked with the extensive literature and research on human and environmental ethics. The existence of life beyond Earth would raise possible questions about "rights" and "personhood," similar to current debates over complex or intelligent nonhuman life on Earth. Likewise, the prospect of finding microbial extraterrestrial life in the Solar System raises questions of its moral standing and our obligations toward it. In addition, there are numerous questions about the morality and ethical implications of expanding life's range onto other celestial bodies, with or without indigenous life, either deliberately or by accident. The group also raised questions of social justice, suggesting the need to examine expenditures for astrobiology research and exploration in light of other pressing societal needs.

The **Science and Religion** group identified the need to examine comparative views about life's features such as significance, meaning, "specialness," rarity, naturalness, sustainability, and stewardship as explained by different

religious traditions, cultural groups, and scientists. Furthermore, there are numerous questions about whether and how religious frameworks map onto different moral landscapes, touching on issues such as our obligation to protect, to explore, to avoid alteration or interference, and so on.

The **Social Sciences and Humanities** group focused on applied questions relating to how individuals, private and public sector organizations, societies, and cultures would react to a discovery of extraterrestrial life. Analyzing the magnitude and types of reactions anticipated from different groups and under different contact scenarios will be useful for developing strategies to minimize the negative impacts of a discovery and for considering in advance the development of protocols or response plans for actual discoveries. Research on communication and education will be important for broad understanding of the realistic possibilities associated with astrobiology sciences and associated risks, in contrast to popular views of aliens, UFOs, and interaction mythologies. It is equally important to acknowledge that discoveries in astrobiology science will not necessarily eliminate the need or desire for examination and interpretation consistent with religious or cultural traditions.

Goal C: Explore the relations of humans with Earth, its life and environments. *Examine our diverse relationships with Earth's life and environments of varied types and consider our responsibilities toward them.*

It is appropriate to analyze the full range of relationships with life and environments on Earth and their foundational implications for questions about relationships with extraterrestrial or "other" life. While science information and legal/policy approaches guide how we treat living organisms as individuals or species, it is also important to understand how those fundamentals of relationships are linked with different cultural, religious, and political systems. Despite a preponderance of anecdotal evidence about how religious or cultural groups may react to astrobiology discoveries, we have yet to undertake a systematic and in-depth inquiry.

The **Philosophy and Ethics** group identified research questions in both ethical and non-ethical domains. The broadest ethical research questions aim at understanding moral constraints associated with historical exploration of various types (*e.g.*, imperialism, colonization, manifest destiny). Near-term, practical questions relate to how scientific samples with possible living entities should be used and whether frameworks developed for terran life automatically or naturally apply to extraterrestrial life. We also need to examine how scientific and ethical interests are balanced in decision-making about research and activities. Finally, various social justice questions arise regarding our relationships with life and research on it. Because of the implicit assumptions by the scientific community about the value of progress in astrobiology, it will be important to examine underlying assumptions in relation to what they mean for life on Earth.

The **Science and Religion** group focused on understanding the diversity of views about current relationships, responsibilities, and religious interpretations associated with life as we know it—and whether and how scientific advances about life might challenge or alter individual, cultural, or religious interpretations of relationships. It will be instructive

to examine the religious or cultural implications of acknowledging that life on Earth is temporary in a scientific sense and to consider our ability, and perhaps obligation, to intervene in human destiny against natural and manmade threats. Finally, astrobiology might raise questions about the nature of God, how views about deities are linked to life as we know it, and whether the discovery of extraterrestrial life would pose ideological challenges to some religious/cultural traditions.

The **Social Sciences and Humanities** group concentrated on the importance of engaging multiple disciplines—history, anthropology, law, economics, policy, social sciences, theology, art, and literature—to fully understand and characterize diverse views of life, relationships, and natural environments and how they have applied over time. They suggested the need to reexamine the basis for planetary protection policy under the Outer Space Treaty and how to incorporate ethical considerations within existing policy applicable during exploration for extraterrestrial life. They also noted the likely need for policy adjustments in response to possible conflicting uses or plans by different groups, including scientists, commercial and private sectors, the military, governmental bodies, and even future generations. Since both natural space phenomena and exploration activities may have effects on life and environments, it is advisable to explore planetwide decision-making and risk-management approaches in order to anticipate how to protect and sustain life. Finally, the group urged continued research on diverse analog living systems on Earth—past and present—to help reframe questions about evolution, intra- and interspecies communication, and our understanding of relationships across the diversity of Earth life and cultures.

The research objectives in Goals A–C aim to better organize and understand our current perspectives about life and relationships during the pre-discovery phase of astrobiology. Goals D and E are more forward-looking and consider alternative ways of responding to scenarios if and when extraterrestrial life is discovered.

Goal D: Explore the potential relationships of humans with “other” worlds and types of life. *Examine our possible interactions with other worlds—both with and without life—and consider the implications of our activities upon “other” worlds, life, and environments.*

Numerous questions are likely to arise in the months to years post-discovery, including what foundational approaches should be used in considering relationships with other worlds, with or without life, whether microbial or intelligent. Research under this goal addresses how the confirmed extraterrestrial life might impact our values and views, our social structures for guiding interactions, and our plans for continued space exploration. As we learn more about the nature of extraterrestrial life, we will be compelled to address questions about rights and obligations, how those might impact humans or “other” life and worlds, and whether we can or should undertake or expand activities on other celestial bodies. Since all ethical, legal, cultural, and theological systems are based on life as we know it on Earth, it will be instructive to consider whether and how existing policies and approaches to life and locations on Earth have utility for “other” worlds and life. Moreover, since our cur-

rent relationships with life are set largely in Western intellectual traditions, it is appropriate to consider whether framing relationships beyond Earth will require incremental adjustments or significant shifts in policies and approaches.

The **Philosophy and Ethics** group noted that discovery of life elsewhere would likely effect our view of self, our role and place in the Universe, our “rights” and obligations, societal structures, decision-making frameworks, and views of Earth and planetary stewardship. Certainty about extraterrestrial life is likely to prompt a reexamination of our approach to planetary protection for locations that are reachable by spacecraft. Plans for activities beyond Earth will be scrutinized and may be different depending on level of intelligence or other factors. Understanding the narrative or evolutionary history of the extraterrestrial life, its moral and theological value, and the overall significance of other worlds will be a challenge, especially in how they may impact human attitudes toward life, richness, diversity, and values.

The **Science and Religion** group noted that questions about the theological implications of verified extraterrestrial life will likely depend on whether it is microbial or intelligent and how the discovery is interpreted both across and within different religious traditions, both Eastern and Western. Each tradition will no doubt determine on its own whether a discovery undermines or strengthens individual faith and whether and how humans should interpret notions of stewardship and relationships. Questions may arise on the prospects of cross-proselytizing and impacts on the eventual fate of religion(s) as we know it. The involvement of diverse theologians and religious professionals can be anticipated during the communication and education process and will arguably be important during debates about any accommodation process.

The **Social Sciences and Humanities** group focused largely on institutional implications of a discovery of extraterrestrial life. Questions of many types arose about governance, jurisdiction, decision-making, management, protection, and control issues, particularly in light of planned future activities by different sectors and countries. Finally, the group discussed issues of information sharing and communication, including comparative multidisciplinary research on human historical analogues of relationships with “other” beings, from initial “contact” to subsequent exploration, migrations, expansions, or other activities on Earth. Such information may have applicability in thought experiments about “contact” and developing relationships with new “life” forms, and subsequent actions on Earth and beyond. In addition, there is need to consider broad communication about astrobiology discoveries and plans to reach diverse public and expert audiences worldwide.

Goal E: Consider life’s collective future—for humans and other life, on Earth and beyond. *Understand the impacts on life and future evolutionary trajectories that may result from both natural events and human-directed activities in the short and long terms.*

Thinking about life and its long-term future—decades or centuries hence—requires considering both diversity and locations, which translates into three separate scenarios: considering the fate of humanity and all life on Earth, the future of terrestrial life beyond Earth, and the fate of

extraterrestrial or “other” life in its native or transplanted locations. Each perspective immediately conjures up critical unknowns about natural evolution versus human-directed evolution and the implications of deliberate versus accidental actions. In addition, the realization of new taxonomic diversity in other solar systems may alter many of our current ideas about “life” and its future. Although we will not be able to direct or predict all outcomes of astrobiology research and exploration, we can evaluate “preferred” future(s) as compared with alternative trajectories and timeframes, just as we are attempting with global warming deliberations. Rather than wait for issues to arise and confront us, it is advisable to proactively contemplate the implications of astrobiology findings and life’s alternative futures from various perspectives—from the individual level to political and societal realms, and even planetary scales.

The **Philosophy and Ethics** group identified questions touching on the future of all life types and the need to rethink the nature of life, the implications of future migrations beyond Earth, possible transformations of humans, and impacts on Earth biota by extraterrestrial life and vice versa. Extended space exploration raises ethical questions about human experimentation, legal responsibilities, risks, and moral imperatives regarding life. The prospect of long-term changes in humans enters new conceptual territory, particularly with the possible engineering of new human, nonhuman, or hybrid forms. The implications of preempting “natural” evolutionary processes are many, raising questions about accidents, informed consent, control, oversight, and other ethically related questions. It is uncertain what principles and obligations should apply to migration, long-term settlements, and suggested planetwide resource exploitation and terraforming on other bodies. On Earth, there are questions about what ethical or moral obligations apply to protection of life from either technological or natural risks. Even in the long term, there are likely questions about social justice and the implications of one generation spending money on large-scale future extraterrestrial projects rather than directing efforts toward projects on Earth.

The **Science and Religion** group focused on three main questions related to life as we know it versus “other,” migration issues, and human knowledge about the end of life. Space exploration raises questions about how different faith traditions view the notion of interference with other worlds and how the existence of extraterrestrial intelligent life would be interpreted in theological terms. Demonstration of a new cosmological context would prompt reexamination of basic information associated with diverse religious traditions. Research questions also arise from our current knowledge of possible disasters and end-of-life scenarios, and what obligations might arise from them, if any. Finally, the group highlighted the apocalyptic beliefs of some cultures and religions—and suggested that special efforts may be needed to explain astrobiology findings and discuss steps for averting avoidable disasters rather than attributing predictable events to supernatural causes. Questions also arise about who should be involved in discussions within religious realms about the implications of astrobiology.

The **Social Sciences and Humanities** group concentrated on areas of deliberate actions, monitoring, and communications, as well as assorted questions related to proactively expanding beyond Earth. Given the significant questions

about survival of life as we know it, the group recommended the conscious preservation of human history and knowledge in the event of our collective demise—essentially development of an archive of human history that could survive beyond ourselves. The group also indicated the importance of monitoring other technological fields whose developments have the potential for causing evolutionary changes in bodies and minds. Continued research is needed to understand the range of natural and technological threats to the continuation of life on Earth. A future with certain knowledge about extraterrestrial life will require reanalysis of information and policies for planetary protection, as well as deliberations about the political sector, governance in a cosmic world, and effects of extraterrestrial life on humans and vice versa. In addition, it will raise new questions about international cooperation, legal and ethical frameworks, military roles, and use of resources during exploration and settlement. Even deliberations about who gets to leave Earth or settle elsewhere will involve unusual ethical considerations. It will be important to communicate widely about the potential for rapid changes that may cause impacts to life as we know it—and to consider legal, ethical, and social systems that may require modification. Because of the diversity of issues involved, no single area or topic should eclipse others in importance.

Formation of a Focus Group on Astrobiology and Society under the NASA Astrobiology Institute

While information on the draft Roadmap of Astrobiology Societal Issues has been presented at a number of seminars and meetings, communication about it has been limited largely to astrobiology audiences. Humanities and social science experts do not interact routinely with the astrobiology research community and are often unaware of the detailed issues. In addition, communication and engagement with the public on nonscience topics is not usually included with astrobiology science outreach. A group of us began considering ways to communicate more directly with other disciplines to seek external scholarly attention and invite cross-disciplinary collaboration that can help inform the public about important issues and deliberations ahead. Thus began the development of plans for a Focus Group on Astrobiology and Society with the aims of proactively identifying scholars who may be interested in astrobiology and issues about life from their perspectives in humanities, social sciences, and related fields; educating them about astrobiology sciences and anticipated issues; and enlisting their disciplinary expertise on individual or collaborative research projects addressing both astrobiology’s impact on society and society’s possible impact on astrobiology. Information about this research would also be shared with the public.

In early 2011, an interdisciplinary Focus Group on Astrobiology and Society was established under the NASA Astrobiology Institute (NAI). The main goals of the Focus Group are to (1) refine the draft Astrobiology Roadmap of Societal Issues through community input and discussions; (2) disseminate the information to both the astrobiology community and external researchers; and (3) provide an ongoing forum where researchers in the astrobiology community and those in relevant humanities and social science areas will be able to learn, interact, and possibly collaborate on research questions of interest. Because the draft societal roadmap

encompasses so many disciplinary topics, initial plans for the Focus Group are to examine selected priority issues, rather than tackling the entire societal roadmap at once. In particular, we plan first to examine the issues likely to arise if and when extraterrestrial life is discovered—and to consider what foundational or other information will be useful in preparing to respond to public questions.

Just as the societal issues roadmap borrowed from the format of the Astrobiology Science Roadmap, the Focus Group on Astrobiology and Society is likewise modeled on other focus groups formed under the NAI. Since it is impossible to predict how useful a focus group on societal issues might be, the group will be implemented as an experiment and evaluated at the end of 3 years to determine its effectiveness.

Tentative Focus Group Plans

As currently planned, the Focus Group efforts over the next several years will include activities aimed at building the community of researchers interested in the societal implications of astrobiology, encouraging interdisciplinary collaboration and research on priority issues, and proactively communicating about astrobiology and its societal implications to diverse academic and public audiences.

As currently planned, this Focus Group seeks to establish the foundation for an interdisciplinary research community by (1) developing a dedicated website under the auspices of the NAI, (2) compiling an online database of cross-disciplinary literature and resources for both astrobiology scientists and external experts in humanities and social science research; and (3) coordinating online and virtual communications in order to identify and include diverse scholars and prioritize key crossover research areas related to astrobiology's societal implications. In addition to soliciting comments and input about the draft roadmap, the Focus Group will also identify several key conferences in nonscience areas and propose special sessions or minisymposia for their annual meetings as a way to inform them about roadmap research areas needing interdisciplinary attention. If all goes as planned over the next several years, the Focus Group on Astrobiology and Society will have helped generate new scholarly attention and publication of research papers on important societal issues, which can then be communicated broadly to professional groups and the public. Finally, the experimental Focus Group effort itself will be evaluated for its effectiveness in expanding the community of interdisciplinary researchers and increasing research attention on questions about astrobiology's impacts on society as well as society's potential impacts on progress in astrobiology.

Conclusions

When explaining astrobiological findings and interpretations to diverse audiences, it is important to recognize areas of concordance and disagreement that may have implications for the understanding or acceptance of scientific findings and their significance. Continued support may well depend on having credible experts in diverse complementary fields who can put astrobiology findings and activities in broader contexts—across ethical, legal, psychological, historical, educational, theological, sociological, and cultural domains. Interestingly, the first workshop on the societal implications of astrobiology (Connell *et al.*, 2000, p 6) noted that

Interdisciplinary and multidisciplinary work is imperative. There must be close coordination between the scientists who conduct the research and those who can shed light on the social implications... Thoughtful and effective collaboration may break down the barriers that separate different intellectual fields and move us in the direction of consilience, or the unification of knowledge.

In short, the cross-disciplinary perspectives are equally important parts of the unfolding astrobiology story and must be communicated to the public and space communities alike.

The Roadmap of Astrobiology Societal Issues is intended as a vehicle to increase communications and collaborations between scientists and nonscientists—and to help proactively expand communication on ideas articulated in the Astrobiology Principles. It is our hope that, over time, the output of this cross-disciplinary experiment in research and communication will lead to better, more informed decision-making and actions for all.

In conclusion, these two efforts—development of a draft Roadmap of Astrobiology Societal Issues and establishment of a Focus Group on Astrobiology and Society—have initiated steps to gradually build a community of cross-disciplinary researchers interested in examining questions on the impact of astrobiology on society as well as the potential impact of society on astrobiology. We believe that this type of interdisciplinary scholarship will be useful in addressing questions with commonalities in other science and technology areas—from global change and sustainability to emerging technologies like synthetic biology or nanotechnology—all with the potential for varied impacts on human society and the environment in current and future generations. Systematic examination of cutting-edge science and technology is needed to understand all stages of progress and to address the diverse questions and perspectives that may arise. Our intention is to coordinate and expand inter- and cross-disciplinary studies of issues related to life, environments, emerging technologies, and human activities—just as astrobiology has done for the sciences.

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Postscript

To learn more about the Societal Roadmap and/or get involved in the Focus Group, go online to <https://astrobiology.nasa.gov/focus-groups/> or contact the authors at mrace@seti.org or kdenning@yorku.ca.

Abbreviation

NAI, NASA Astrobiology Institute.

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