Cultural Aspects of Astrobiology

Steven J. Dick
U.S. Naval Observatory
Washington, D.C.

ABSTRACT

Among the four operating principles of the NASA Astrobiology Roadmap, Principle 3 recognizes broad societal interest for the implications of astrobiology. Although several meetings have been convened in the past decade to discuss the implications of extraterrestrial intelligence, none has addressed the broader implications of astrobiology as now defined at NASA. Here we survey these societal questions, and argue that they deserve further serious study, in accordance with the National Aeronautics and Space Act of 1958. Astrobiology, already an interdisciplinary field in terms of the physical and biological sciences, should now embrace the humanities and the social and behavioral sciences in order to explore its cultural implications. Such study is part of the general need for better dialogue between science and society.

Justification for Study of Cultural Questions

Astrobiology, as defined within the NASA Astrobiology Roadmap (NASA, 1999), seeks to answer three fundamental questions: 1) How does life begin and evolve? 2) Does life exist elsewhere in the universe? and 3) What is life's future on Earth and beyond? Because the answers to these questions bear on fundamental human concerns, I argue here that NASA's Astrobiology Program, as well as exobiologists and bioastronomers in general, should address the cultural impact of their work. In doing so, they should encourage input from specialists in the humanities and the social and behavioral sciences.

It is important at the outset to define what we mean by "culture." For anthropologists, culture is "the total way of life of a discrete society—its religion, myths, art, technology, sports, and all the other systematic knowledge transmitted across generations." Put another way, "culture is a product; is historical; includes ideas, patterns, and values; is selective; is learned; is based upon symbols; and is an abstraction from behavior and the products of behavior" (Wilson, 1998, p. 130). According to Harvard biologist E. O. Wilson, each society creates culture, and is created by it. Our inquiry, then, is to determine the potential impact of astrobiology on this symbolic communal and evolving worldview that each society creates—a tall order indeed, but one that multidisciplinary study may systematically tackle in increments.

The study of the cultural impact of astrobiology is justified from many points of view. Primarily, it is an interesting and important problem that adds another dimension to astrobiology. It is well to remember that cosmic evolution does not end with astronomy or biology, but with culture; the evolution of human culture, and possibly cultures beyond the Earth, is not only part of cosmic evolution, but arguably the most interesting part. Such study is also entirely in keeping with the National Aeronautics and Space Act of 1958, in which one of the eight objectives of the U.S. space program is "the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes" (Logsdon, 1995). Though the Space Act has been amended many times, this objective has remained unchanged. It has also remained largely unfulfilled, aside from a NASA-sponsored Brookings Institution study (U. S. Congress, 1961), a NASA-sponsored study at Boston University (Berenzden, 1973), and a series of NASA workshops in 1991–1992 (Billingham et al., 1999). There is interest, however, both among the public

and at the highest levels of government, as evidenced by the Vice President's Space Science Symposium convened in December 1996 in the wake of the Mars rock, especially to discuss the cultural implications of that discovery (Lawler, 1996a, 1996b; Macilwain, 1996). We are thus faced with a golden opportunity. With the inauguration of NASA's Astrobiology Program, the time has come to focus on this objective once again.

One of the exciting aspects of astrobiology, and one of the features that distinguish it from the earlier exobiology program in NASA, is that the Astrobiology Roadmap recognizes the cultural dimensions of its work from the beginning. One of the groups at the Roadmap meeting formulated a "Question 7" in addition to the scientific questions: "How will astrobiology affect and interact with human societies and cultures?" The third of the four operating principles of the Roadmap "integral to the entire Astrobiology Program" states that "Astrobiology recognizes a broad societal interest in our subject, especially in areas such as the search for extraterrestrial life and the potential to engineer new life forms adapted to live on other worlds." This principle, as distinct from Principle 4 on education and public outreach, was presumably formulated with a view toward action, no less than the Roadmap's scientific aspects. In this paper we make a first reconnaissance of the scope of the cultural aspects of astrobiology as defined above, and issue a call for action.

Table I: Astrobiology Roadmap Questions and Their Cultural Implications

QUESTIONS	IMPLICATIONS				
Roadmap Scientific/ Representative Cultural	Philosophical	Ethical	Theological	General/Societal	
Q.1 Origin and Evolution of Life (Goals 1-4)					
Our Place in the History of Life	Schopf (1999)				
Nature of Life	Davies (1998)				
A Cosmic Imperative?	deDuve (1995)				
Chance and Necessity	Monod (1971)				
Q.2 Life in the Universe (Goals 5-8)					
A. Primitive					
B. Intelligent					
Contact	Davies (1995)	Ruse (1985)		Billingham et al (1999) Harrison (1997)	
Epistemology	Rescher (1985) Minsky (1985)				
Relation to God			McMullin (2000) Coyne (2000)		
Q.3 Future of Life on Earth and Beyond (Goals 9-10)					
Planetary Protection	Randolph, Race & McKay (1997)				
Environmental Change & Ecosystems					
Artificial Life/Bioengineering					
Terraforming		McKay (1990)			
Space Exploration				McCurdy (1997)	
Space Colonization					

POLICY

Astrobiology's Three Fundamental Questions and Their Implications

Although a good deal of thought has been given to the cultural impact of a successful SETI (Search for Extraterrestrial Intelligence) program, the impact of astrobiology, as encapsulated in its three fundamental questions, is much broader. In addition to intelligent life, we are interested in the quite different implications of microbial life and life that may be complex, but not intelligent. Moreover, astrobiology has a large historical dimension in that we are also interested in life's past, and it has a forward-looking dimension because we want to explore life's future—on Earth and beyond. These questions give astrobiology a breadth that exobiology never had, with correspondingly broader implications.

If we take each of the three questions in turn, and ask what the implications will be for society, we end up with an enormous two-dimensional matrix. Here we concentrate on only a small part of the matrix, the philosophical, ethical, and theological implications (Table I), which are also identified in the Table with each of the Astrobiology Roadmap Goals. These parts of the matrix, in my opinion, are particularly important because they form our worldview, and thus affect all other parts of society. Several aspects of this matrix merit emphasis: 1) The listing of representative studies indicates that some thought has been given to these issues; the point is that the entire problem has not been approached systematically. The study of the cultural implications of astrobiology is at a stage where exobiology was 40 years ago, with sporadic individual interest but little dialogue and thus little progress in the sense of systematic study. 2) We must recognize a third dimension to the matrix: different societies will be affected differently because they each have different cultures. Thus, the theological effects of contact with extraterrestrial intelligence would be very different for Chinese religions as contrasted with the Christianity embraced by much of the Western world. 3) An important feature of the matrix is the policy dimension: the study of cultural implications is not purely academic, but is undertaken with the idea of informing policy. For a national policy strategy, the matrix would be considerably smaller, but for global policy we can see the complexity involved. Thus we envision a very large three-dimensional matrix as the structure for our study, of which we address only a very small part in this paper.

Origin and Evolution of Life

Astrobiology's emphasis on the origin and evolution of life (Roadmap Goals 1-4) recalls the statement of T. H. Huxley in the context of Darwinism: "The question of questions for mankind—the problem which underlies all others, and is more deeply interesting than any other, is the ascertainment of the place which Man occupies in nature and of his relations to the universe of things" (Huxley, 1863). Surely one of the overarching results of origin and evolution of life studies will be a better understanding of our temporal place in the history of life on Earth. Surely, the discovery of the ancient origins of life some 3.8 billion years ago has already had an effect on human culture, as has the demonstration that bacteria ruled the Earth for the vast majority of that period. The relatively recent rise of the genus *Homo*, much less *Homo sapiens*, surely has lessons for our worldview. Exactly what they are should be the subject of further research.

Aside from illuminating our place in nature, origin of life studies force us to ask further questions such as "What is life?" "Is there a cosmic imperative for life imbedded in the laws of Nature?" and "What is the role of chance and necessity in the origin and evolution of life?" Research on molecular biology has already produced considerable discussion on the latter (Monod, 1971), but the answer to this question and others will depend on which of the three or four theories of origin of life, or what combination of them, proves to be true (Davies, in press). Life arising from panspermia will have quite different implications than if it arose on Earth, whether in Darwin's warm pond, in hydrothermal vents, or in the hot deep biosphere (Gold, 1999). Scientists have been asking these questions for years; it is time to engage the broader scholarly world as well.

Life in the Universe

The question of life in the universe (Roadmap Goals 5-8) brings another set of concerns. In any discussion of the cultural implications of life in the universe, we immediately need to distinguish primitive from intelligent life. Given the history of life on Earth—ruled by bacteria for more than two billion years—we perhaps need to consider that the universe is full of bacteria. Anyone who thinks this has no implications for society should recall the reaction three years ago to the claim of Martian fossils. The media were full of speculations about their meaning; the Vice President specifically convened a seminar of experts

to discuss the societal implications, and funding was provided in no small part leading to the Origins and Astrobiology programs we have today. Undoubtedly part of the excitement had to do with the implications for the abundance of extraterrestrial intelligence, but the existence of extraterrestrial bacteria, possibly with their own biochemistries, would have its own set of implications. The cultural impact of primitive life, however, has received no serious study.

The impact of intelligent life, by contrast, has been the subject of much speculation, and some serious study. Different approaches to the long-term problems of contact have been explored by Almar (1995), Billingham et al. (1999), Dick (1995), Harrison (1997), and Tough (1991), among others. The short-term reaction in the event of contact has been discussed in considerable detail (Tarter and Michaud, 1990), and policy issues regarding a response to an extraterrestrial communication are under consideration (Michaud, 1998). The problem of objective knowledge, or "extraterrestrial epistemology," has been broached by Rescher (1985) and Minsky (1985), while Ruse (1985) and Randolph, Race, and McKay (1997) have outlined ethical considerations. Theological issues are coming more to the fore, and are discussed in Dick (1996, 1998, in press), Crowe (1986), Coyne (in press), McMullin (in press), and Peters (1994), among others. From this small sample, one can glimpse the scope of the problem of the cultural implications of extraterrestrial intelligence. Social scientists have only begun to think about how these problems might be addressed (Harrison, Billingham, Dick, et al., 1998).

One of the conclusions of the studies thus far is that the discovery of extraterrestrial intelligence will be very much scenario-dependent. Any serious study of the impact of extraterrestrial intelligence must categorize the types of contact; a very general categorization of scenarios as terrestrial or extraterrestrial, and direct or remote is given in Table II, together with examples from science fiction. Although terrestrial modes of contact are not currently in favor among most scientists, they are logical possibilities and the subject of both science (Bracewell, 1975; Tough, 1998) and science fiction. (There is also a considerable popular following in the case of UFOs and alien abductions). Direct extraterrestrial contact is also currently considered unlikely, but again the subject of much science fiction. Indirect contact by radio, optical, or other electromagnetic means is currently the favored scenario, and the one to which most attention has been given in terms of implications. But clearly each of the four types of contact would have its own set of implications for each of the elements in the cultural matrix. Even a brief consideration of the cultural implications of SETI demonstrates that the subject is complex, involving matrices embedded within matrices, but that these complexities may be approached systematically in discrete parts.

Table II: Modes of Contact with Extraterrestrial Intelligence (*and Some Representative Science Fiction Scenarios*)

	TERRESTRIAL	EXTRATERRESTRIAL
DIRECT	Wells, *War of the Worlds*	Clarke, *Rendevous with Rama**
	Clarke, *Childhood's End*	Bradbury, *Martian Chronicles*
	ET: The Extraterrestrial	Alien (and it's sequels)
INDIRECT	Clarke, *2001: A Space Odyssey**	Gunn, *The Listeners*
	McCollum, *Lifeprobe*	
	Hoyle, *The Black Cloud*	Sagan, *Contact**

* More than one mode of contact takes place

Future of Life on Earth and Beyond

The future of life on Earth and beyond, the subject of Roadmap Goals 9 and 10, has implications best known today in terms of planetary protection and the problems of contamination and back contamination. These indeed are important and have been given prominent attention because the problems are immediate, and the potential implications catastrophic. The ethical questions, however, have only begun to be explored (Randolph, Race, and McKay, 1997). Moreover, astrobiology's third question raises many other cultural issues. Moving beyond the planet may mean producing artificial life for bioengineering ecosystems, in its grandest vision known as *terraforming*. Probably in the lifetimes of our children, certainly in the 21st century, the issue of terraforming Mars will become real; it behooves us to begin to consider the philosophical, ethical, and broader cultural implications now. Similarly Goal 9's emphasis on the interplay of environmental change and ecosystems raises broad questions that society has already had to tackle. As McKay (1990, in press) points out, we may soon be faced with extending the principles of environmental ethics to Mars.

Movement off of planet Earth (Finney and Jones, 1984) also raises the entire spectrum of issues associated with space exploration, in terms of manned or unmanned, the problems and opportunities of space colonization, and societal spending priorities. Perhaps more than the other two questions, Question 3 raises the issue of where our species wants to go in its cultural evolution, and emphasizes that to a large extent human cultural evolution is in our own hands. I stress again that cultural evolution must be viewed as part of cosmic evolution; indeed it is indisputable that the pace of cultural evolution now rapidly outpaces biological evolution (though genetic engineering may change that in the future). An understanding of human cultural evolution is essential to understanding ourselves and our future, and it will be essential for mutual understanding in the event of extraterrestrial contact. Viewed as a part of cosmic evolution, cultural evolution fits squarely in the context of astrobiology and the famous "L" (lifetime of communicative civilizations) parameter of the Drake Equation. Indeed, many have pointed out that the number of communicative civilizations in our galaxy (N) approximates L; since L depends in large part on the success or failure of cultural evolution, an understanding of human cultural evolution is one of the few ways we have at present to study L and better determine N. The humanities and social sciences are in a position to make significant contributions to this study.

Approaches and Goals

Social scientists must ask how we can *systematically* approach these difficult questions, these questions of the "benefits, opportunities, and problems" of astrobiology, in the spirit of the National Aeronautics and Space Act of 1958 and in the interest of encouraging dialogue between science and society. Of course we cannot *predict* the short- or long-term implications of astrobiology. But is there any systematic way for at least discussing them? Given the fact that different scenarios imply different implications, let me suggest three approaches that might guide us in our thinking about implications.

First, we must make use of the humanities, for the humanities study the elements that drive cultural evolution. History may be seen as a vast set of social experiments, conducted under many conditions. Surely, the record of these experiments must be used in any assessment of the effect of astrobiology on human cultural evolution. As a start, we should ask what effect space exploration has had on human cultural evolution in the last 40 years (McCurdy, 1997). Next, we might ask how humans have reacted to particular ideas or events. The historical record of public reaction to past false alarms of extraterrestrial life, whether the canals of Mars, reaction to the Orson Welles broadcast of *War of the Worlds* in 1938, reaction to UFOs, the discovery of pulsars, and the now well-known history of extraterrestrial life debate (Crowe, 1986; Dick, 1982, 1996, 1998; Guthke, 1990), are among the events that should prove relevant. The idea of "life beyond Earth," whether termed exobiology, astrobiology, or bioastronomy, has exercised a peculiarly strong lure in American culture, a phenomenon that should itself be studied.

More generally the humanities provide us with analogues of possible futures. An analogue is no more than a model, a concept very successfully used in the natural sciences, less so in the humanities and social sciences. Astrobiologists do not hesitate to use, with caution, Antarctica and Lake Vostok as analogues to conditions on Mars and Europa, respectively. In the case of SETI, to take a well-known example of analogical reasoning, one hears a good deal about physical culture contacts on Earth. But most scientists in the SETI field think direct physical culture contacts are unlikely, though contact with an alien probe in the vicinity of Earth must be considered a logical possibility (Bracewell, 1975; Tough, 1998). In the typical radio SETI scenario, a simple "dial tone" would provide evidence of a technological civilization, while decoding a message would initiate intellectual contact. For the latter, a much better analogue in Earth history is the transmission of knowledge from the ancient Greeks to the Latin West via the Arabs in the 12th and 13th centuries (Dick, 1995), an event that led to the European Renaissance.

More generally still, I have argued elsewhere that the idea of a universe with abundant life constitutes a worldview, analogous to the Copernican and Darwinian worldviews. If one accepts the claim that the biological universe is very different from the physical universe, we can study what effect changing worldviews have had on society (Dick, 1995). Worldviews traverse various stages, from motivation to evidence to opposition and confirmation or rejection, and there are very rich studies in the history of science elaborating the short- and long-term implications of worldviews like Copernicanism or Darwinism. So the humanities offer a number of approaches to the cultural implications of astrobiology.

Secondly, aside from history and the humanities, one should use the tools of the social and behavioral sciences, which admittedly are not as robust as the natural sciences, but which should play a role in the multidisciplinary science that is astrobiology. If, as E. O. Wilson and others have argued, there is such a thing as gene-culture co-evolution, it offers a starting point for studying cultural evolution based on the natural sciences. If, as Dawkins (1976) has argued, the "meme" is the unit of cultural evolution equivalent to the gene in biology, human cultural evolution including movement off of planet Earth may be studied using this increasingly developed concept (Blackmore, 1999). Alternatively, Albert Harrison's recent book, *After Contact: The Human Response to Extraterrestrial Life* has led the way in showing how fields such as psychology, sociology, and anthropology can be used as an aid to thinking about implications of contact, an approach that may be generalized to astrobiology. In particular he advocates a kind of systems approach, called Living Systems Theory, in which what we know about organisms, societies, and supranational systems on Earth can be used to discuss the outer space analogues of aliens, alien civilizations, and the galactic club. Yet another approach envisions an "alien anthropologist," who could apply the tools of anthropology to the Earth from an alien perspective.

Third, in addition to the humanities and social sciences, human imagination, so colorfully rendered in science fiction literature, is a rich resource for studying the implications of astrobiology. Authors such as Arthur C. Clarke have given considerable thought to the consequences of contact in fictional form. *Childhood's End*, *Rendezvous with Rama*, and *2001: A Space Odyssey* all provide engaging explorations of different contact scenarios. Carl Sagan's *Contact* asks probing questions about the relation of science and religion. At the other extreme of extraterrestrial morality, we have the genre of H. G. Wells' *War of the Worlds*, *Aliens*, *Independence Day*, and *Starship Troopers*. Perhaps more realistically, Stanislaw Lem's *Solaris* is a haunting story of contact with intelligence beyond our understanding. On the issue of extraterrestrial contamination, Michael Crichton's *The Andromeda Strain* is a thought-provoking exercise. Other science fiction authors have explored extraterrestrial environmental ethics, terraforming, and the problems of space colonization. Although one can argue about which scenarios are more likely, there is an enormous database of thought in the best science fiction that should not be ignored.

Undoubtedly a group of interdisciplinary specialists would produce a more robust list of approaches to the cultural implications of astrobiology's three questions. Some may consider such study premature, since we do not yet know whether or not life exists beyond Earth, or when we will terraform planets or colonize outer space. But I think it fair to say the scientific consensus is that extraterrestrial life is likely, and that problems like terraforming and colonization will face us as real problems in the 21st century. As the anthropologist Ashley Montague said 25 years ago at the NASA-sponsored Symposium at Boston University, it is important that we think about the cultural impact of exobiology well in advance of the discovery of extraterrestrial life. With the increasing attention now given to astrobiology, that sentiment may be reiterated, and extended to all of astrobiology's broader implications.

Conclusions

In closing, I would argue that it is prudent and essential for the Astrobiology Program to support research on the implications of its work. The public supports NASA's Astrobiology Program with its tax dollars; it is interested in the implications of this research, which deserves nothing less than systematic study by experts from many fields. The need for study of the implications of science has been explicitly recognized, for example, in the Human Genome Project, which devotes 3-5% of its budget to ethical, legal, and social issues. While the genomic issues are admittedly more pressing, it may surely be argued that a small percentage of astrobiology funding should be allocated to studying cultural implications, in accordance with the National Aeronautics and Space Act of 1958.

The study of the cultural aspects of astrobiology, however, need not confine its hopes to the success of similar studies such as the Human Genome Project. As Finney argues in this volume, astrobiology is strategically placed at the boundaries between disciplines—whether of the natural sciences, the social sciences, or the humanities—and so is in a unique position to cultivate the unity of knowledge in the deep sense that E. O. Wilson has elaborated in his recent book *Consilience* (Wilson, 1998). Even if life is not discovered beyond the Earth, a fundamental role in bringing about the unity of knowledge would be a stunning success for astrobiology in the 21st century

and the third millennium. Exobiology has already brought together the physical and biological sciences in unprecedented cooperation. I urge NASA and the astrobiology/bioastronomy communities to broaden their interdisciplinary scope yet again, this time to the humanities and social sciences, and to take up the broader challenges sure to come as astrobiology moves forward with its scientific goals.

ACKNOWLEDGEMENTS

The author thanks members of the "Question 7" Group at the Astrobiology Roadmap meeting at NASA Ames in 1998, and particularly Lynn Harper, Kathleen Connell, and Ken Rose for active discussions on the subject since that time.

REFERENCES

Almar, I. 1995, "The Consequences of a Discovery: Different Scenarios," in **G. Seth Shostak**, ed., *Progress in the Search for Extraterrestrial Life*, 499-505.

Berenzden, R. 1973, *Life Beyond Earth and the Mind of Man* (NASA: Washington, D.C.).

Billingham, J. *et al.* 1999, *Social Implications of the Detection of an Extraterrestrial Civilization* (SETI Press; Mountain View, Ca).

Blackmore, S. 1999, *The Meme Machine* (Oxford University Press, Oxford).

Bracewell, R. 1975, *The Galactic Club* (San Francisco), 69-83.

Coyne, G. 2000, "The Evolution of Intelligent Life on Earth and Possibly Elsewhere: Reflections from a Religious Tradition," in **Steven J. Dick**, ed., *Many Worlds: The New Universe, Extraterrestrial Life and its Theological Implications* (Templeton Press).

Crowe, M. 1986, *The Extraterrestrial Life Debate, 1750-1900: The Idea of a Plurality of Worlds from Kant to Lowell* (Cambridge University Press, Cambridge).

Davies, P. 1995, *Are We Alone? Philosophical Implications of the Discovery of Extraterrestrial Life* (Basic Books, New York).

Davies, P. 1998, *The Fifth Miracle: The Search for the Origin of Life* (The Penguin Press, London).

Davies, P. 2000, "Biological Determinism, Information Theory and the Origin of Life" in **Steven J. Dick**, ed., *Many Worlds: The New Universe, Extraterrestrial Life and Its Theological Implications* (Templeton Press, Philadelphia).

Dawkins, R. 1976, *The Selfish Gene* (Oxford University Press, Oxford).

De Duve, C. 1995, *Vital Dust: Life as a Cosmic Imperative* (Basic Books, New York).

Dick, Steven J. 1982. *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant* (Cambridge University Press, Cambridge).

Dick, S. J. 1995, "Consequences of Success in SETI: Lessons from the History of Science," in **G. Seth Shostak**, ed., *Progress in the Search for Extraterrestrial Life* (Astronomical Society of the Pacific, San Francisco), 521-532.

Dick, S. J. 1996, *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge University Press, Cambridge).

Dick, S. J. 1998, *Life on Other Worlds: The Twentieth Century Extraterrestrial Life Debate* (Cambridge University Press, Cambridge).

Dick, S. J. 2000, "Cosmotheology", in **Steven J. Dick**, ed., *Many Worlds: The New Universe, Extraterrestrial Life and Its Theological Implications* (Templeton Press, Philadelphia).

Finney, B. and **E. M. Jones**, 1984, *Interstellar Migration and the Human Experience* (University of California Press, Berkeley).

Finney, B. This volume.

Gold, T. 1999, *The Hot Deep Biosphere* (Springer Verlag, New York).

Guthke, K. 1990, *The Last Frontier: Imagining Other Worlds from the Copernican Revolution to Modern Science Fiction* (Cornell University Press, Ithaca, N.Y.).

Harrison, A. 1997, *After Contact: The Human Response to Extraterrestrial Life* (Plenum, New York).

Harrison, A., **J. Billingham**, **S. J. Dick** *et al*. 1998, "The Role of Social Science in SETI." Paper prepared for the SETI Committee of the International Academy of Astronautics, Melbourne, published in this volume.

Huxley, T. H. 1863, *Man's Place in Nature* (London), 71.

Lawler, A. 1996a, "Building a Bridge Between the Big Bang and Biology," *Science*, 274 (8 November, 1996), 912.

Lawler, A. 1996b, "Origins Researchers Win Gore's Ear, Not Pocketbook," *Science*, 274 (20 December, 1996), 2003.

Logsdon, J. *et al*. 1995, *Exploring the Unknown: Selected Documents in the History of the U. S. Civil Space Program,* vol. I, "Organizing for Exploration," (NASA: Washington, DC).

Macilwain, C. 1996, "Goldin Wants More NASA Biologists as Gore is Briefed on Space Plans," *Nature*, 384 (19/26 December, 1996), 601.

McCurdy, H. 1997, *Space and the American Imagination* (Smithsonian Institution Press, Washington).

McKay, C. 1990, "Does Mars Have Rights? An Approach to the Environmental Ethics of Planetary Engineering," in *Moral Expertise*, ed. **D. MacNiven**, (Routledge: New York), 184-197.

McKay, C. 2000, "Astrobiology: The Search for Life Beyond the Earth," in **Steven J. Dick**, ed., *Many Worlds: The New Universe, Extraterrestrial Life and Its Theological Implications* (Templeton Press, Philadelphia).

McMullin, E. 2000, "Life and Intelligence Far from Earth: Formulating Theological Issues," in **Steven J. Dick**, ed., *Many Worlds: The New Universe, Extraterrestrial Life and Its Theological Implications* (Templeton Press, Philadelphia).

Michaud, M. A. G. 1998, "Policy Issues in Communicating with ETI," *Space Policy*, 14, 173-178.

Minksy, M. 1985, "Why Intelligent Aliens Will Be Intelligible," in **Edward Regis, Jr**. ed., *Extraterrestrials: Science and Alien Intelligence* (Cambridge University Press, Cambridge), 117-128.

Monod, J. 1971, *Chance and Necessity* (New York).

NASA, 1999, "Astrobiology Roadmap" (Ames Research Center, Moffet Field, CA).

Peters, T. 1994, "Exo-Theology: Speculations on Extra-Terrestrial Life," *Center for Theology and the Natural Sciences Bulletin*, vol. 14, no. 3, 1-9.

Randolph, R.; **M. Race**; and **C. McKay**, 1997, "Reconsidering the Theological and Ethical Implications of Extraterrestrial Life," *Center for Theology and Natural Sciences Bulletin*, vol. 17, no. 3, 1-8, Berkeley.

Rescher, N. 1985, "Extraterrestrial Science," in **Edward Regis, Jr.** ed., *Extraterrestrials: Science and Alien Intelligence* (Cambridge University Press, Cambridge), 83-116.

Ruse, M., 1985, "Is Rape Wrong on Andromeda?" in **Edward Regis, Jr.** ed., *Extraterrestrials: Science and Alien Intelligence* (Cambridge University Press, Cambridge), 43-78.

Schopf, J. W. 1999, *The Cradle of Life* (Princeton University Press, Princeton).

Tarter, J. C. and **M. A. G. Michaud**, eds., 1990. "SETI Post-Detection Protocol," *Acta Astronautica*, 21 (February, 1990), 69-154.

Tough, A. 1991, *Crucial Questions About the Future* (Lanham, MD).

Tough, A. 1998, "Small Smart Interstellar Probes," *Journal of the British Interplanetary Society*, 51 (May, 1998), 167-174.

U.S. Congress, 1961. *Proposed Studies on the Implications of Peaceful Space Activities for Human Affairs,* a Report of the Committee on Science and Astronautics, U. S. House of Representatives, 87th Congress, First Session, prepared for NASA by the Brookings Institution (Washington: Government Printing Office).

Wilson, E. O. 1998, *Consilience: The Unity of Knowledge* (Knopf, New York).

Courtesy of the Astronomical Society of the Pacific Conference Series. Published by the Foundation For the Future with permission from the author.