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Protecting and expanding the richness and diversity of life, an ethic for astrobiology research and space exploration

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Abstract: The ongoing search for life on other worlds and the prospects of eventual human exploration of the Moon and Mars indicate the need for new ethical guidelines to direct our actions as we search and how we respond if we discover microbial life on other worlds. Here we review how life on other worlds presents a novel question in environmental ethics. We propose a principle of protecting and expanding the richness and diversity of life as the basis of an ethic for astrobiology research and space exploration. There are immediate implications for the operational policies governing how we conduct the search for life on Mars and how we plan for human exploration throughout the Solar System.

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Introduction

Since the first space flights, the only ethical guidelines for space exploration have been the planetary protection policies based on Article IX of the 1967 Outer Space Treaty. Article IX states that exploration of the Moon and other celestial bodies shall be conducted in a way 'so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter.' The current interpretation of Article IX is the prevention of contamination that would adversely impact further scientific investigations; that is, the chief focus has been protecting the science investigations done by humans (COSPAR 2005).

This status quo was called into question by the National Academy of Science in its 2006 review of planetary protection procedures (NAS 2006). Their challenge could have a far-reaching regulatory impact on astrobiology research, and it is important that researchers are aware of these questions as they are debated and policy is developed. The National Academy recommended examining whether there are additional ethical considerations for space exploration. Specifically, the National Academy wrote: 'In light of new knowledge about Mars and the diversity and survivability of terrestrial microorganisms in extreme environments, NASA should work with COSPAR and other appropriate organizations to convene, at the earliest opportunity, an international workshop to consider whether planetary protection policies for Mars should be extended beyond protecting the science to include protecting the planet. This workshop should focus explicitly on (1) ethical implications and the responsibility to explore Mars in a manner that minimizes the harmful impacts of those activities on potential indigenous biospheres (whether suspected or known to be extant), (2) whether revisions to current planetary protection policies are necessary to address this concern, and (3) how to involve the public in such a dialogue about the ethical aspects of planetary protection.' A first step in this direction was a workshop held at Princeton University on June 8–10, 2010, 'to examine whether planetary protection measures and practices should be extended to protect planetary environments within an ethical framework that goes beyond 'science protection' *per se*.' (Rummel *et al*. 2012).

In 2010, COSPAR held an international workshop to begin studying these ethical issues and a second workshop is planned. Eventually, the basis of international Planetary Protection policy may shift from preserving future science to other operational policies. These new operational policies should be grounded in a clearly defined ethical foundation that has support among astrobiologists, government policy makers and the public.

By ethics, we mean a system of values and commitments that guide the formation and implementation of policies for space exploration as well as the day-to-day operations of astrobiologists. As noted, such a system of values and commitments must have a broad consensus among stakeholders in astrobiology. Science has always been guided by an ethical system of values and commitments, although usually this ethical system is assumed and not explicitly discussed. For example, the peer review process is grounded in an ethical commitment that values objective results rather than results based upon the subjective preferences of those funding the research. Ethics provides the values and commitments that guide policy and operations. At times, the ethical framework may be used to correct policy and operations, which have drifted away from the stakeholders' core values and commitments. To reiterate, all of science operates with an ethical framework, even if that framework is not explicitly discussed during policy implementation and operations.

Historically, there have been two major types of ethical systems: (1) a principles approach and (2) a goal approach. The first approach specifies a set of duties or principles that must be followed at all times. In the second approach, ethical decisions must be made based upon an over-riding goal, such as promoting the greatest amount of good. The principles approach has proven to be very effective for organizations seeking to establish a code of ethics, such as a code of professional ethics for some occupation. However, the principles approach has difficulty with inter-species (or environmental) ethics because the principles are not intended to apply equally to different species. In environmental ethics, for instance, we would apply a principle prohibiting harm differently to humans versus domestic animals that we consume as food. Some ethicists have proposed the second, goal approach as the best approach for an inter-species ethic (Singer 2009, 2011).

It is useful here to briefly review previous suggestions for how ethics can be expanded to all life forms and the ongoing discussions on how ethics can be applied to extraterrestrial settings.

In the context of life, and ecosystems, on Earth, Goodpaster (1978) suggested 'Neither rationality nor the capacity to experience pleasure and pain seem to me necessary (even though they may be sufficient) conditions on moral considerability. … Nothing short of the condition of being alive seems to me to be a plausible and nonarbitrary criterion.' [emphasis in the original]. Callicott (1986) applied this to extraterrestrial life suggesting a 'biocentric' ethic. He states: 'Let me therefore recommend an [biocentric] environmental ethic that is sufficiently inclusive and consistent to provide at once for the moral considerability of extraterrestrial as well as for terrestrial life without neglecting the practical primacy of human life, human needs, and human rights. … I can think of nothing so positively transforming of human consciousness as the discovery, study, and conservation of life somewhere off the Earth.'

Extending environmental ethics beyond the Earth has been discussed in terms of introducing life from Earth on a presumed lifeless Mars (e.g. McKay 1990; Kramer 2011). McKay (1990, 2001a, b) suggested that placing value on indigenous Martian life may motivate us to actively assist that life to expand into a global biosphere.

In 1996 there was considerable press and public attention to a claim of evidence of life in a Martian meteorite – a claim which has since been rejected by most scientists. But this report spurred consideration of the ethical issues of the discovery of even simple life forms on another world. Randolph *et al.* (1997) and Lupisella & Logsdon (1997) (see also Lupisella 1997) reviewed the need for a 'cosmocentric' ethic, and in that light the possible tension between indigenous life on Mars and human interests in Mars. Randolph *et al.* (1997) considered that Martian life may be related to Earth life or alternatively may represent a 'second genesis' and the ethical implications of the two cases may differ. Race & Randolph (2002) suggested the need for operating guidelines and a decision making framework for reporting, and reacting to, a discovery of non-intelligent extraterrestrial life.

Cockell (2005a, b, c) expanded on the notion of according microbes and microbial ecosystems moral consideration based not on the fact they are alive but based on their possession of 'interests'.

An ethic for space exploration must be broadly representative of the human species because space explorers represent the entire human species, regardless of what government or corporation sponsors their mission. Internationally, this is already recognized, implicitly, in the COSPAR planetary protection protocols as well as the Outer Space Treaty. An ethic for space exploration must be framed in a manner that resonates with a diversity of ethical viewpoints and grounds planetary protection policies that will guide national and transnational organizations, such as NASA and COSPAR, as well as private, commercial enterprises, such as Armadillo Aerospace, Space X, etc.

An ethic for astrobiology must necessarily be an inter-species ethic, similar to the work done in environmental ethics over the past 50 years. At the same time, an ethic for astrobiology will contain several key distinctions from conventional environmental ethics. First, the most likely discovery scenario involves finding a non-intelligent, non-sentient organism somewhere in the Solar System. Most likely this extraterrestrial life will be microbial. Therefore, a core challenge for astrobiology ethics concerns what duties and obligations are owed to microbes. By contrast, environmental ethics for Earth rarely reflects on microbes. As Cockell (2005a, b, c, 2008) has pointed out, we kill millions of microbes daily in order to live safe and healthy lives. In addition, microbes are so small that it is difficult to know whether our ethics should be on individual microbes or 'communities of microbes,' provided we could develop criteria for defining what counts as a microbial community (Cockell 2005c).

A second important difference from (terrestrial) environmental ethics could emerge if extraterrestrial life proves to be a 'second genesis' (McKay 2001a, b). That is, a second origin of life, completely independent and biochemically distinct from the unity of life that we know on Earth. In this scenario, an important ethical question arises whether the extraterrestrial's very distinctiveness confers a special ethical status that sets it apart for special respect and consideration. Should we ascribe extraordinary value to extraterrestrial life simply because it represents life with a separate origin from life as we know it on Earth, as suggested by McKay (2009a)?

A third and final distinction involves the problem of predation, a problem all inter-species ethics must address. Human predation extends beyond merely consuming other species for nourishment. For instance, the extermination of malaria-carrying mosquitoes is a necessary form of predation in order to avoid malaria outbreaks. Human predation may also occur in science, as when laboratory animals are killed in order to study the effect of disease. Predation of extraterrestrial organisms would inevitably occur during space exploration, both on human or robotic missions. Forms of extraterrestrial predation would include destruction of habitats, either accidently or intentionally, and the return of samples to Earth. However, there is a difference in the character of predation. Much of predation here on Earth is required for human survival and flourishing. By contrast, all of the predation on extraterrestrial bodies would be discretionary because it is not required for human survival and flourishing on Earth. Instead, we have freely chosen to leave our planet and visit extraterrestrial bodies that are not part of our home domain. As a species we freely choose to explore space and hence all predation of extraterrestrial organisms is discretionary. This does not mean that predation of extraterrestrial organisms is inherently unjustifiable. But, it is important to acknowledge this important distinction between mandatory predation on Earth and discretionary predation when we interact with life on other worlds.

Protecting and expanding the richness and diversity of life

We believe that new operational policies for space exploration and astrobiology research must be developed within an ethical framework that values sustaining and expanding the richness and diversity of life. In what follows, we will develop our proposal for an ethical framework for space exploration, explain our arguments in support of this framework, as well as consider and reply to a potential criticism. A new policy, if set at the international level has a good chance of succeeding. It is ironic that principles of environmental ethics established by international agreement are more effectively implemented for space exploration than environmental policies on Earth. This is because space exploration requires a large organized effort usually at the governmental level and will remain so for the foreseeable future. This makes implementation of policy – such as the current planetary protection policy – practical. A policy implemented by the current space-faring nations is likely to be accepted by other nations as they develop space capabilities as well as by private operators who may begin tourist operations in space or on other worlds. An example of this conformity to existing principles is the Antarctic Treaty System (Race 2010).

Our proposed ethics goal is that COSPAR operational policies should be designed to protect and expand the richness and diversity of life – both here on Earth and on extraterrestrial bodies that we explore. Similarly, astrobiology research projects should always be designed so as to protect or expand the richness and diversity of life. Our approach follows Goodpaster (1974) and Callicott (1986) in that we suggest that valuing life, *per se*, is the fundamental basis for a normative principle for guiding our exploration of other worlds. We recognize that our ethics proposal has implications for synthetic biology, which is also a means of expanding the diversity of life. However, in this article we will limit our consideration to extraterrestrial life because our focus is the development of new COSPAR operational policies.

How we value non-human organisms is a critical component of any inter-species ethic. There are two types of valuation that are important for our proposal: (1) intrinsic value and (2) instrumental value. Our ethics framework recognizes both intrinsic and instrumental values in all living organisms. Intrinsic value means that every organism has value in and of itself, regardless of what instrumental utility it may, or may not, have for humans. We believe that ascribing intrinsic value to all living organisms is warranted, given that all living organisms share life in common with humans. Acknowledging that all living organisms possess intrinsic value does not preclude predation in order to promote human flourishing, but it does create an important baseline of respect that provides a check against unjustified or excessive predation.

Whereas intrinsic value creates a needed baseline of respect, we also recognize the importance of instrumental value. Instrumental value emerges when something has utility. We usually think of instrumental value in terms of what has utility for humans, but our understanding of instrumental value needs to be expanded beyond what simply has utility for humans. In environmental ethics, for example, clean water has utility for humans because we depend upon it in order to live healthy, flourishing lives. Yet, clean water also has instrumental value for non-human organisms.

Our ethic attributes intrinsic value to all living organisms, while recognizing that many organisms may have important instrumental value, as well. In addition, some non-living ecological features, such as clean water in the illustration above, also have significant instrumental value. Although we do not attribute intrinsic value to objects or features that are not living, we do recognize that instrumental value may be attributed by humans to non-living objects.

The status of microbial organisms raises special challenges for ascribing intrinsic and instrumental value. As already noted, the most likely discovery scenario would involve detection of an extraterrestrial microbe. Should an astrobiology ethic attribute intrinsic and instrumental value even to microbes? Focusing only on microbial life here on Earth, Cockell (2005c, 2008) argues that we should attribute both intrinsic and instrumental value to all microbes, 'including viruses, bacteria, fungi, protozoa, and nematodes.' The instrumental value of microbes is relatively straightforward, according to Cockell: 'Microbes have become so pervasive that they are responsible for cycling all the major nutrients and elements in the biosphere and for creating the large-scale productivity needed for the 'complex' biosphere to exist. … Without nitrogen fixing and denitrifying bacteria, we and all other life could not exist.' In addition, microbes are critical in the fermentation of beer and wine, as well as the production of yogurt and antibiotics. It is reasonable to presume that microbes would contribute to extraterrestrial life processes in a similar manner and thus have obvious instrumental value.

Whereas the instrumental value of microbes is fairly straightforward, the question of their intrinsic value is more subtle. Even though microbes are unconscious, Cockell believes we can still discern their 'interests.' He observes that microbes 'reproduce, they grow in preferred places and directions (in the case of colonies), and many species are motile; they swim toward nutrients and away from chemicals that might damage

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them and prevent them from reproducing ('chemotaxis').' Cockell argues that in discerning the 'interests' of the microbe, we should experience a reverence or 'biorespect' for microbes. For Cockell, this 'biorespect implies intrinsic value for microbes from the individual to community scale.' Although we can recognize the intrinsic value of microbes, Cockell acknowledges that we cannot avoid destroying microbes on a practical level.

Cockell's argument parallels our understanding of the possibilities and limitations for an astrobiology ethic that attributes intrinsic value to all living organisms, even microbes. Recognizing this intrinsic value creates a baseline of respect for all of life, but it does not preclude the inevitable taking of non-human life for ethically informed reasons, such as predation. We would extend intrinsic value – with these qualifications – to all extraterrestrial life.

The 'precautionary principle' is an additional key axiom which requires discussion. Over the years, the 'precautionary principle' has been widely debated and writers have proposed multiple definitions. Based upon discussions at the 2010 COSPAR workshop on ethics in space exploration, we define the 'precautionary principle' as an axiom which calls for further investigation in cases of uncertainty before interference that is likely to be harmful to Earth and other extraterrestrial bodies, including life, ecosystems, and biotic and abiotic environments (COSPAR Workshop 2010). Space exploration in the future could frequently encounter new and unfamiliar living organisms and ecosystems. Given the value of life, we believe it is important that we act only after gathering enough information so that we can act in ways that will protect and expand the richness and diversity of life.

As a brief illustration of how our proposed ethic would apply, consider the question of contamination on the surface of Mars. Our ethics proposal would not require sterilization of spacecraft sent to the surface of Mars because it does not appear possible for life from Earth to grow on the surface because of the intense biocidal UV sunlight. Contamination from Earth exposed to the UV would be destroyed while contamination inside the spacecraft, shielded from the UV, would remain dormant. Unless there is a change in the environment, there is little chance that this dormant contamination would grow and interfere with any indigenous life. However, if indigenous life is discovered humans might choose to alter the Martian environment to enhance this life – consistent with our ethical principle. In this case it would be necessary to remove any dormant contamination. In environments where UV does not reach, such as caves and subsurface aquifers, a more thorough sterilization of spacecraft and equipment would be required since any contamination by Earth life would be irreversible and could interfere with the restoration of indigenous life. This would be counter to our overarching ethical goal of protecting and expanding the richness and diversity of life on Mars. Thus our principle mandates that the exploration of Mars be done in a way that is 'biologically reversible' – as already suggested by McKay (2009b).

Suppose that an ecosystem of diverse life were discovered in a Martian cave protected from UV radiation. As noted, our ethics framework would allow human predation of non-human organisms provided that the predation was proportionate and did not jeopardize the long-term viability of the species or ecosystem. The study and return of samples of extraterrestrial microbial life to Earth could be ethical in our proposal. However, given the lack of knowledge about newly discovered extraterrestrial life, our ethics proposal would require a period of non-contact observation and study of the extraterrestrial organisms *in situ* before interference with the ecosystem or the return of samples to Earth. During this preliminary period of study, astrobiologists should develop an understanding of what the extraterrestrial organisms require in order to flourish and how the eco-system promotes that flourishing. It would also be important to develop an understanding of potential threats of backward contamination posed by sample return and what protection protocols must be in place at the receiving laboratories on Earth.

Finally, suppose that this new Martian ecosystem contains organisms that represented a 'second genesis' or origin of life that was different than life found on Earth. In ethical reflection on this scenario, the perspective on 'second genesis' is important. From the human view, the Martian organisms are unique and different, hence a 'second genesis' of life. However, from the Martian perspective, it is humans and other organisms on Earth that constitute a 'second genesis.' Regardless of the frame of reference, our ethics proposal would affirm the intrinsic value of the Martian organisms because it recognizes intrinsic value in all of life and the diversity that is represented in a second genesis. This creates a baseline of 'biorespect.' We acknowledge that a 'second genesis' would have added instrumental value from a human point of view because of its promise for research and then perhaps other applications as well. Both the intrinsic and instrumental values are captured in our overarching goal to protect and expand the richness and diversity of life.

Considerations in favour of our proposal

There are two over-riding considerations that favour an ethics of protecting and expanding the richness and diversity of life. First, as noted above, an ethic for space exploration must be broadly representative of the human species. This is a daunting challenge. There is a broad and profound pluralism among human persons. Humans are shaped and informed by a plethora of religions and philosophies that create a rich diversity of ethical values. To establish a space ethic in the face of such overwhelming pluralism, we must find a common anchor-point; that is, a value that is common to this multitude of ethical perspectives around the world. We believe that this common anchor-point is actually very simple and straightforward – it is simply, life. Despite multiple differences in culture, religion, and custom, living is one reality that all persons share in common with one another as well as with non-human animals, plants and microbes here on Earth. If we discover extraterrestrial organisms, whether it is a humble microbe on Mars or a vastly superior space traveller from another planet, we will share life in common. Life is a key value in virtually every religion of the world, including Judaism, Christianity, Islam, Hinduism and Buddhism. Life is also a key value in most non-religious philosophies. A strength of our ethics framework is that it builds on this common anchor-point, by establishing the protection and maintenance of the richness and diversity of life as the over-riding ethical goal. We believe that our proposal holds the most promise for unifying the rich plurality of ethics perspectives into a consensus regarding operational policies for space exploration and astrobiology research.

A second consideration in support of our proposal is what we call the 'cosmic Golden Rule.' All of the Earth's global religions contain some version of the 'Golden Rule'. We prefer the Confucian version of the Golden Rule, which frames it as a prohibition: 'Never impose on others what you would not choose for yourself' (Confucius 1998). The most likely discovery scenarios for extraterrestrial life involve non-intelligent, non-sentient life. Clearly such extraterrestrial life discoveries would be inferior to humans in terms of intelligence, technology and power. As the vastly superior species, humans possess the capability to shape and change extraterrestrial ecosystems as we desire. Humans would essentially have god-like power over these forms of extraterrestrial life. However, it is clearly possible that elsewhere in this vast universe there are species with vastly superior intelligence and technology than that of humans; that is, these superior extraterrestrials would have god-like power over humans.

If a superior species visited Earth, we would hope that their expedition was guided by ethical principles that promoted the flourishing of Earth-life and a policy of no harm with the evolutionary process unfolding on Earth. We would want these superior extraterrestrials to carry-out their mission in a way that allowed the coexistence of terrestrial life, promoted the continued flourishing of that life, and sustained its diverse ecosystems. If this is an accurate description of human expectations for a superior, extraterrestrial visitor to Earth, then logically that should be the standard for our treatment of any inferior extraterrestrial life that we encounter in space missions.

Another way to think about the 'cosmic Golden Rule' is to shift our focus in time. Instead of imagining what our expectations would be for superior extraterrestrials visiting Earth in the present, imagine our expectations if these superior extraterrestrials had visited Earth several billion years ago, just as life was first emerging from the primordial soup of Earth. In this scenario, we can presume that these superior extraterrestrials would visit Earth for reasons similar to our current interests in space exploration, including scientific research, the search for minerals and other useful resources, and perhaps tourism. If these extraterrestrials were not guided by an adequate ethic and operational principles, then it is reasonable to posit that they could have interfered with life and emerging ecosystems, disrupting the evolutionary process so that life on Earth – including human life – would not evolve as we know it.

By contrast, if these superior extraterrestrials had followed our proposed ethic, with its goal of protecting and expanding the richness and diversity of life, then the evolutionary process would not have been disturbed. The 'cosmic Golden Rule' holds that we should not treat inferior extraterrestrials differently from the way in which we would want superior extraterrestrials to treat us. Our proposed ethic would uphold this 'cosmic Golden Rule,' and this is an important consideration in support of our proposal.

We recognize the challenge inherent in determining how to best assist alien life we might find on another planet so that it does flourish and contribute to the richness and diversity of life in the universe. This is a hard question with both ecological and evolutionary implications. However, a teleological ethic, such as we propose, sets out a direction and a goal, which practical decisions and actions should support. Of course, we may make mistakes along the way, especially when we first discover extraterrestrial life. But, practical mistakes in implementation do not undermine the overall validity of an ethical approach. Acknowledging these challenges of knowing how to best assist alien life, we still commend our ethic of protecting and expanding the richness and diversity of life.

A possible objection and our reply

Inevitably, there will be objections to any new ethics proposal. While there may be other challenges to our ethics framework, perhaps the most serious objection is against our claim that all living organisms have intrinsic value. To understand this objection's background, it is helpful to look at the discussion concerning intrinsic value in (terrestrial) environmental ethics. The question of whether non-human life has intrinsic value is extremely contentious – actually, something of a 'tug of war' – among environmental ethicists. Many environmental ethicists argue that non-human life does have intrinsic value, but they frequently disagree on what that means. For example, Taylor (1986) has argued that each individual organism is vested with intrinsic value, whereas others see intrinsic value only in ecological systems. Another philosopher, Rolston (1988), argues that organisms, species and ecosystems all have intrinsic value because they are 'projective'. He writes, '…systemic nature is valuable intrinsically as a projective system, with humans only one sort of its projects, though perhaps the highest. The system is of value for its capacity to throw forward (project) all the storied natural history.' For Rolston, this 'projective' characteristic grounds an argument for intrinsic value.

Other environmental ethicists deny that non-human life has intrinsic value. Among this group, Thompson (1990) has argued that any ethic which ascribes intrinsic value to non-human individuals, species or eco-systems 'is not properly ethics at all,' and she proposes an alternative environmental ethic. Thompson's critique of intrinsic value focuses on the 'demarcation problem.' As Thompson summarizes: 'The problem… is that how we view the world, how we divide it up into individuals and systems, what we regard as good or bad for an individual or a system is too arbitrary – i.e., too dependent on point of view, interest and convenience – to support an ethic that purports to be based on value in nature independent of our interests and concerns.' Since Thompson's

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article, several philosophers have proposed alternative theories of intrinsic value, which they believe can successfully overcome this 'demarcation problem.' Further, Samuelsson (2010a) has argued that Thompson's alternative proposal is itself vulnerable to the 'demarcation problem,' which she so powerfully used to criticize intrinsic value.

In a recent essay 'The Trouble with Intrinsic Value: An Ethical Primer for Astrobiology,' Smith (2009) provides the type of objection which we see as serious, yet unpersuasive, for our ethics proposal. Smith argues that intrinsic value must draw a clear 'line in the sand' to protect humans who are the 'fundamental units of ethical analysis.' He argues: 'The problem is that … the more entities are said to have intrinsic value, the more difficult it becomes to make any ethical decision, since instrumental tradeoffs are not allowed. Intrinsic value is a powerful ethical tool, but it must be used sparingly.' For Smith, the core ethics question is determining who is entitled to ethical consideration at all. Smith holds that only 'ratio-centric' beings can have intrinsic value because rationality is a prerequisite for social functioning.

We have a number of replies to Smith's position but we think one is sufficient to demonstrate why we find his critique unpersuasive. Whereas we see intrinsic value as establishing a baseline of respect in which to begin ethical reflection, Smith sees it as a means for demarcating what is worthy of ethical consideration and what is not worthy, and he seems to believe that this is a sufficient criterion for ethical analysis in astrobiology. We are sceptical of Smith's claim that the core ethical question for astrobiology resolves around determining what is in and what is out of ethical consideration – or that he successfully resolves these dilemmas by ascribing intrinsic value only to 'ratio-centric' humans. As argued above, we believe that ascribing intrinsic value establishes a baseline of respect for all of life. Further, intrinsic value provides an important check against humans intentionally or unintentionally skewing their analysis so that promoting human interests is always the most ethical option. Instead, we believe that promoting the goal of protecting and expanding the richness and diversity of life offers a stronger and more objective method for ethical analysis.

As we suggested above, the image of a philosophical 'tug of war' comes to mind when one begins reading all of the arguments and counter-arguments regarding intrinsic value. On the one hand, we believe that very significant issues are at stake in this debate concerning intrinsic value. On the other hand, this debate is now over 25 years old, with no prospect of resolution in the foreseeable future. In the meantime, the development of an ethic for space exploration needs immediate attention if it is to help inform new COSPAR guidelines and policies. How do we resolve this stalemate? We agree with a statement by Samuelsson (2010b), writing on environmental ethics: 'The question of whether or not, and in what sense, nature has intrinsic value does not stand in contrast to questions of finding workable solutions to environmental problems. To the contrary, such questions can often go hand in hand.' We believe this applies to the development of an ethic concerning space exploration as well. While continued debate on intrinsic value is important, we must simultaneously push forward on developing an ethic for space exploration.

Conclusion

In this article, we have tried to build a comprehensive argument for an astrobiology ethic that promotes the goal of protecting and expanding the richness and diversity of life. Three core axioms guide the implementation of this ethic within astrobiology and space exploration. First, all of life has intrinsic value. This axiom serves as a check to prevent biasing ethical analysis in favour of human interests instead of promoting healthy eco-systems. Second, the precautionary principle applies. We use the precautionary principle as defined at the 2010 COSPAR ethics workshop which calls for further investigation in cases of uncertainty before interference that is likely to be harmful to Earth and other extraterrestrial bodies (COSPAR Workshop 2010). Finally, our third axiom is the cosmic Golden Rule which holds that we should never treat inferior extraterrestrial life in a manner that we, ourselves, would not want to be treated by superior extraterrestrials, if they visited planet Earth.

Although we have tried to be comprehensive, we recognize that this is not the final word on an astrobiology ethic. Ultimately, a true ethic must come through discussion and eventual consensus of astrobiologists, policy-makers and the people who financially support astrobiology. A true ethic must also reflect what we discover about life on other worlds. Right now, we are beginning to develop an ethic from a position of ignorance concerning extraterrestrial life. It would be very surprising if what we conceive now is unaltered by the actual discovery of life on another world. As humans continue to explore space and as we begin to discover extraterrestrial life, then we will continually need to re-think and refine our ethic. Yet, even though astrobiology ethics will continually evolve, future generations of biotic life will be effected by the astrobiology ethics that we begin with now. So, what we hope to accomplish with this article is to establish a place to begin, to frame the ethical questions and provoke the discussion which must occur and must be informed by astrobiologists. This discussion must be ongoing, and it must shape the new operational policies adopted by COSPAR.

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