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RESEARCH ARTICLE

Astrobiocentrism: reflections on challenges in the transition to a vision of life and humanity in space

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Abstract

Astrobiocentrism is a vision that places us in a scenario of confirmation of life in the universe, either as a second genesis or as an expansion of humanity in space. It manages to raise consistent arguments in relation to questions such as what would happen to knowledge if life were confirmed in the universe, how would this change the way we understand our place in the cosmos? Astrobiocentrism raises a series of reflections in the context of confirmed discovery, and it develops concepts that work directly with what would happen after irrefutable evidence has been obtained that we are not alone in space. Unlike biocentrism or ecocentrism, the astrobiocentric view is not limited to the Earth-centric perspective, and for it incorporates a multi-, inter- and transdisciplinary understanding. Therefore, the aim of this paper is to make a reflection on the astrobiocentric issues related to the challenges and problems of the discovery of life in the universe and the expansion of mankind into space. Here we explore some aspects of the transition from biogeocentrism to astrobiocentrism, astrobiosemiotics, *homo mensura*, moral community, planetary sustainability and astrotheology.

Contents

Introduction

Astrobiology is the science that studies the possibility of life in the universe, but it can also study the expansion of humanity to other habitable environments in the cosmos (Chon Torres, 2020). However, despite not having an empirical confirmation of a discovery of this magnitude, the research that is developed to try to detect extraterrestrial life allows the disciplines involved to acquire more and better knowledge, including astronomy, biology, chemistry, just to name a few (Kwon *et al*., 2018; Space Studies Board, 2019). That is to say, in the field of natural sciences, there is an important advantage. On the other hand, in the social sciences and humanities there is also an acquisition of knowledge, both at the level of law, politics and philosophy, among others. Thus, from an epistemological perspective, astrobiology brings together, but does not unify, the knowledge and methodologies of its component disciplines.

As astrobiology is an academic discipline closer to a transdisciplinary way of working (Santos *et al*., 2016; Chon-Torres, 2021), it allows the communication of knowledge acquired from different disciplines, resulting in an interconnected understanding, respecting methodological differences. That is, despite being the same study phenomenon, such as the possibility of life in the universe, or our expansion in it, it lets each discipline develop the knowledge it needs to be able to address the aspect that requires it, so that it finally manages to find a nexus with other disciplines involved that the researcher in charge needs. Let us imagine that in the study of the possibility of life in the universe, it is possible to determine the presence of life in an environment outside the Earth. First of all, to gain knowledge about which planets are suitable candidates requires knowledge of astronomy, specifically radio astronomy. However, to know what you need to look for, you must first have knowledge of the basics that enable life, for which you draw on biology, and more recently, also to systems chemistry. At some point in this investigation, knowledge of planetary geology may be relevant, as well as other disciplines. Each one offering information to complete the transdisciplinary puzzle that astrobiology is presenting us. However, these sciences would not be the only ones, since we also have the social sciences and humanities. The natural sciences, insofar as they investigate on the basis of evidence and scientific verification, have a greater impact on the discovery aspect. The empirical sciences discover, while the social sciences and humanities have a greater incidence in the creation of constructs or concepts to understand reality (Restrepo, 2020). This division is not absolute, because after all the natural sciences need to elaborate theories within a conceptual network at its own level of autonomy that can explain the laws that are discovered, just as the social sciences and humanities are based on a shared world, which ends up being observable, but which needs a narrative to be able to make sense of it. In the social sciences and humanities there is a greater degree of interpretation of the same phenomena (such as understanding the development of society from the right or left, as ideology), or sustaining an action from a utilitarian morality or one based on Kantian ethics. It is not the same to replicate an experiment in a laboratory – even when it is not completely attainable due to the challenges associated with subjectivity and interpretation, as in the fields of ecology and taxonomy – as to expect a psychotherapy to have the same result in all people. However, each academic discipline (such as natural sciences, social sciences and humanities) has a way of working that respects a procedure based on logical criteria, generally known as the scientific method.

It would be complicated to accept that cognitive processes, for example, can be reduced to laws of physics (Restrepo, 2020). What we could do is to establish a provisional division between disciplines that can be explained and derived from physics, and others whose dynamics cannot be reduced only to the former. Each discipline has its own *modus operandis*, respecting the disciplinary matrix (Kuhn, 2012) of its academic neighbours, although maintaining some connection as they develop in the same reality. In this scenario, astrobiology crosses a number of disciplines where not all are reduced to the dynamics of the laws of physics, such as philosophy, law, sociology and history, just to mention a few. In this sense, research on the presence of life in the universe, or our expansion in it represents a development in each area involved. However, only in the scenario where it is possible to confirm that extraterrestrial life exists, or that humanity has achieved considerable development as a multi-planetary

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being (Chon-Torres and Murga-Moreno, 2021), we could be talking about the emergence of a vision that is not limited to life on Earth: that is, astrobiocentrism.

Astrobiocentrism is the scenario where life outside the Earth manages to confirm itself, but also where humanity manages to become multiplanetary (Chon-Torres, 2022). In any case, it is a situation where life manages to take presence beyond the Earth. In this context, academic disciplines experience a change in relation to the discoveries made in their areas of knowledge. On the other hand, we currently live within biogeocentrism (Chela-Flores, 2022), that is, a vision of life in the universe conditioned to related knowledge we have on Earth. In the natural sciences, it is impossible to get out of this panorama as long as there is no evidence, because it depends on the discovery to be able to propose a basic theory that is adequate about life in the universe. On the other hand, in the spectrum of the social sciences and humanities, insofar as constructs are handled, we can pose scenarios in the form of mental experiments, or hypothetical situations where our ethics are faced with new challenges (e.g. what should we do if life is discovered in a space mining settlement; are we the guardians of life in the universe; etc.). Thus, at least as far as the reflection of the latter disciplines is concerned, it is possible to reflect what would happen in case both the discovery of life in the universe and the expansion of mankind in it would take place. Thus, we have the transition from biocentrism to astrobiocentrism; the approach of a moral community independently of the informational code that would come about due to changes in the process of multiplanetarity; a semiotics of life outside the Earth; a sustainable interplanetary development; astrotheology.

Astrobiocentrism beyond biocentrism

The new topic of astrobiocentrism discusses how our scientific and humanistic concepts would change, as soon as extraterrestrial life were to be firmly confirmed (Chon-Torres, 2022). Such an event would occur when we accept multiple data from either different missions for solar system exploration, or with reliable results from observatories, including radio telescopes. Anticipating such a step forward in our knowledge, it is timely to confine our discussion to what we mean by a 'second genesis' (McKay, 2001; Chela-Flores, 2009).

Astrobiology is an attempt that guides us to understand life in the universe in scientific terms. It is a tool for the search of an answer that science can provide, regarding the question of the fitness of the universe for the emergence and evolution of life. We can even attempt to formulate questions that are of interest beyond science, namely the humanities (Chela-Flores, 2005). We postpone the closely related consideration of the implications of the expansion of humanity into space (Chon-Torres and Murga-Moreno, 2021). The topic we will cover in this section is only biogeocentrism.

These are questions that would be simpler to understand with more than a single genesis in the universe (a 'second genesis'). Extrapolating elsewhere in the universe our present understanding for the emergence of life gives us an objective for astrobiology, since it allows us:

- To provide theoretical bases for the eventual detection of extraterrestrial life (Aretxaga-Burgos and Chela-Flores, 2012).
- To elaborate a strategy for obtaining reliable data of extant, or extinct life. An alternative option would be identifying biosignatures, with the payloads of forthcoming exploration of the Jovian system, from the point of view of biogeochemistry (Chela-Flores, 2022).

Consequently, astrobiology can be understood as the scientific exploration of the universe searching for life elsewhere. This new science maintains that it is not premature to discuss the implications of abandoning what some philosophers have called biocentrism: a scientific question that can be approached with specific missions supported by several national space agencies, or with the eventual success of the SETI Project (Drake and Sobel, 1992): it is remarkable that there are ways, through radio telescopes, to investigate whether our level of intelligence is not unique – the capacity of extraterrestrial civilizations to produce technological signatures that humans can detect (SETI, 2023) – eventually going beyond the restricted philosophical doctrine of biocentrism. Regarding the universe as being

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biocentric goes back in time for over a century: Lawrence Henderson added a significant step to Darwinism (Henderson, 1913).

Henderson's contribution is one of the earliest appearances of biocentrism in questions relevant to the emergence, evolution and distribution of life in the universe. However, Aretxaga (2004) has underlined that the term 'biocentrism' arises in at least, another two contexts, besides astrobiology: one of them is in the field of philosophy, the other is environmental science.

In the standard evolutionary theory, Darwin had argued in favour of the fitness of organisms for their environment. The contribution of Henderson to Darwinism was that, in addition to fitness of organisms to the environment, we should also consider profitably the fitness of the environment itself (Gingerich, 2008). The often-quoted citation from Henderson's (1913) article is the following:

> The properties of matter and the course of cosmic evolution are now seen to be intimately related to the structure of the living being and to its activities; they become, therefore, far more important in biology than has been previously suspected. For the whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric.

Henderson's suggestion refers to the relationship between the chemistry and environmental conditions that allow life to arise and evolve on Earth. In his book, fitness is not just limited to Earth. For clarity, within the astrobiological context, the word 'biogeocentrism' was coined (Chela-Flores, 2001) as a term that reflects a tendency observed in some contemporary scientists and philosophers, according to which life is only likely to have occurred on Earth.

Space mining in an astrobiological scenario

Practically, all exploration and research programmes, which are focused on the human and robotic study of space and the utilization of its geological resources, coincide with the need for applying a multidisciplinary approach to achieve the main scientific and technological goals. As Angel Abbud-Madrid, Director of the Center for Space Resources at the Colorado School of Mines in Golden, Colorado, has stated 'space mining has matured to the point where there are dozens of startup companies, even larger firms, addressing aspects of what's called the "space resources value chain"'. He also advanced several pertinent questions and standpoints on how this process would be developed (Abbud-Madrid, 2018).

However, there is an astrobiocentrist bias, whose implications are usually undervalued (or at least not considered in its whole dimension). Thus, it undermines the geoethical and astrobioethical principles (Martínez-Frías *et al*., 2010, 2011; Martínez-Frías, 2016; Chon-Torres, 2018), the way of thinking and acting, which should be also involved in the *In Situ* Resource Utilization (ISRU) concept, and its wide spectrum of socioeconomic and cultural considerations.

In order to take into account such astrobiocentrist bias, it would be relevant to establish a basic guideline, which could be used as a roadmap, depending on several factors. This guideline would also be useful at facing some key questions regarding the space mining of extraterrestrial natural resources, before developing any procedure. Here, some of these questions are put forward:

- ☐ Where will the space resources be mined, on the Moon or on the asteroids?
- ☐ Besides, in what area of the Moon (maria, terrae) will the mining take place or in what type of asteroids (e.g. carbonaceous, metallic, silicate-rich)?
- ☐ Is the space mining going to be part of the activities of a great private industrial company? If so, will they be developed under some special control or supervision?
- ☐ Will they be exclusively part of its corporate assets, or will they be widely and publicly used for the sustainability of humankind, particularly in the least developed countries?
- ☐ Are the ISRU only devoted to satisfy the needs of a small community of space astronauts or will it be a massive exploitation?

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☐ Will the investigation and exploration of space resources be exclusively characterized by a scientific interest (e.g. mineralogenetic and metallogenetic studies) to understand the origin and distribution of the mineralization processes, petrogenetic and geochemical distribution of the mineral concentrations, as part of the evolution of solar system bodies, such as asteroidal, lunar or planetary)?

All these questions, and probably many others, display a clear astrobiocentrist perspective (Garvin, 2005). In fact, all our activities in space follow this human-related guideline, and we can only to do our best to avoid our own human customs and preconceptions.

Anyway, it is clear that appropriate geoethical and astrobioethical protocols and codes of good practices are needed in any mining activity related to space resources, in order to (at least) palliate the astrobiocentrist bias. In spite of that, such protocols and codes are neither unambiguous nor standard. Therefore, they should be tailor-made considering, among others:

a) the type of natural resources to be mined;
b) their distribution and location in the asteroidal, lunar or planetary body;
c) the different, more or less, harmful extractive methodologies and their environmental consequences and
d) the type of utilization and profit and the general goals of their mining.

Carrying out previous assessments related to ISRU on selected outcrops at earth analogues (e.g. Lanzarote) (Martínez-Frías *et al*., 2017), and also using asteroidal, lunar and martian simulants, is of great importance to validate scientific models, test technological prototypes and potential extraction routines and their environmental damage. These efforts can provide information about the best methodological way to proceed and to uncover the strengths and weaknesses of the extractive procedures (also from the geoethical and astrobioethical perspectives).

As previously defined, the next space missions will be astrobiocentric (Garvin, 2005), and this affects almost all of our future activities beyond our planet. Space mining, in its whole dimension and polyhedral and inter- and transdisciplinary development and approach, is a perfect example of it. In addition, if, as it occurs in some mining areas of our planet, we'd also attempt to use microorganisms to help extracting some metals of interest (or in relation to any other biomining activity), the ethical issues would be still much more complex than using exclusively abiotic procedures.

Despite all these subjects arousing great interest and being tackled from different viewpoints in the framework of planetary protection, there is not a clear and appropriate legislation yet. Space mining incorporates many different industrial and scientific innovations and it can be, as any human activity, positive or negative depending on many variables. Ethics and the way of thinking and acting about their development are also key factors to be taken into account.

Astrobiosemiotics

The search for extraterrestrial life is more likely to yield indirect evidence, such as fossilized remains or chemical traces in exoplanet atmospheres, rather than live organisms for laboratory study. Much in the focus of astrobiological search is to look for those signs of life, biosignatures, that indicate certain biochemical processes that could have their origin in extraterrestrial biological activity (Lineweaver, 2008; Horneck *et al*., 2016; Cavalazzi and Westall, 2018). In other words, the astrobiologist (the interpreter) makes connections between the expression (the biosignature) and the content (the living organism). The astrobiologist is thus engaged in a meaning-making semiosis, where the sign (as expression) stands for something (its object). The sign does not include its meaning, rather the meaning is attributed through elaboration of an interpreter. So, for something to be meaningful, an interpreter is needed, a human being (or other meaning-making creatures) who endows the sign a meaning. In that perspective, the biosignatures are not solely 'out there', instead, they emerge in the interaction between our minds

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and the outer world. This astrobiosemiosis is thus triadic, it contains expression, object and interpreter – which in our case respond to 'biosignature', 'life' and 'astrobiologist'.

In astrobiology, biosignatures are a very diverse and inhomogeneous set of phenomena. Biosignatures can be of various kinds, such as fossils, molecules, traces, artefacts, structures, electromagnetic waves, etc. They can refer to chemical substances (such as elements or molecules), but also physical features (structures, sizes or morphology), and physical phenomena (electromagnetic radiation, or light and temperature). They can vary in scale from atomic to planetary magnitude, or perhaps even beyond. They can be searched for both by *in situ* investigations and through remote indirect sensing, e.g. atmospheric spectroscopy, chemical disequilibrium or isotope ratios (Hegde *et al*., 2015), on our nearest planets and moons as well as in other solar systems. These signatures are meant to be evidence for either living life or dead life, present or past life, distinctive from an abiogenic background.

We propose here that a semiotic analysis of the sign relations of biosignatures could bring some semiotic order in this seemingly chaotic variation of signs. It turns out that the semiotic function of these signs varies a lot, and each has its own epistemological problems and semiotic peculiarities. The problem of biosignatures is very much a semiotic problem: how can meaning be discovered, invented, deciphered and interpreted? Astrobiosemiotics, as we understand it focuses on how astrobiologists as interpreters, establish connections between things, between the expression (the biosignature) and the content (the living organism) in various forms of semiosis, as icons, indices and symbols of life. Through a sincere analysis of the sign relations of biosignatures, we can achieve a more well-grounded knowledge about the living Universe.

In order to uncover the meaning-making strategies in the search for biosignatures, we rest on cognitive semiotics and related fields of research (Sonesson, 2007, 2009; Zlatev, 2012, 2015; Dunér and Sonesson, 2016) that study meaning-making structured by the use of different sign vehicles, and the properties of meaningful interactions with the surrounding environment. A semiotic approach towards the semiosis of biosignatures have first been elaborated by Dunér (2018, 2019), however there are also a few earlier examples of studies that put forward the relevance of semiotics for the construction and decoding of interstellar messages (Vakoch, 1998a, 1998b; Dunér, 2011; Sonesson, 2013; Saint-Gelais, 2014).

The first problem that arises in a situation of interpreting a biosignature is realising that it really is a sign at all – that it contains an expression that refers to a content – leading to an interpretive process by the interpreter. Which signatures (phenomena) have meaning and which are just meaningless noise? The signifier (the biosignature) is directly given, but the signified (life) is however only indirectly present, through the link with the signifier. As interpreters, the astrobiologists determine the relation between the signifier and the signified by picking out those elements they assume to be relevant. Even though astrobiologists have good reasons to believe that the connection they infer between the expression and the content, between the biosignature and the living organism, is scientifically correct, they need to rule out other explanations of the sign relation. The 'biosignature' might not be a true biosignature at all, but instead it is caused by an unknown or known abiotic process.

Biosignatures are in semiotic terms very diverse phenomena. Depending on how the interpreter makes or interprets the connection between the expression and the object, there are basically three types of sign relations: icon, index and symbol. Based on Peirce (1932), three sign relations – icon, index and symbol – one could at least reveal some peculiarities of the semiosis of biosignatures. The meaning of the relation between expression and content, that the interpreter experiences, is based on either similarity (iconicity), proximity (indexicality), or habits, rules or conventions (symbolicity). Thus, we can detect three general kinds of biosignatures in semiotic sense: bioicons, bioindices and biosymbols.

Biosignatures that share a similarity with living organisms, for example, fossils, are in our terminology *bioicons*, namely a sign relation based on similarity, where the expression shares some of the object's properties. The most obvious examples of bioicons are body fossils, the imprints of the hard parts of animals and plants, where the imprints of skeletons or foliage allow us, based on morphologic similarity, to establish a link between the fossilized structure and the living thing. Bioicons

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are not just of visual nature, a similarity based on morphology or structure, they could exist in any sense modality. Based on chemical analyses, the researcher sees similarities between the expression and the content, not because of structural similarity, but because they share some chemical properties.

Bioindices are biosignatures that have a connection to their objects (the living organisms) by contiguity. In other words, the connection between the expression and the content is not based on similarity, but on indexicality. Perhaps the clearest examples of bioindices are atmospheric, chemical biosignatures that refer to biological processes, such as the metabolism of living organisms, discovered through spectroscopic methods (Arnold *et al*., 2002; Catling and Kasting, 2007; Arnold, 2008; Seager, 2014; Seager and Bains, 2015). The argument of spectroscopic analysis starts from the following premises: (P_1) that life produces certain gases as a by-product of metabolism; (P_2) some of these gases will accumulate in the atmosphere and (P_3) that these gases show a unique spectrum. From these premises – that are believed to be sufficient for detection – the astrobiologist concludes that life could, in theory, be detected. Bioindices call for a profound empirical knowledge of recurrent connections between object and expression. The challenge here is to distinguish those bioindices indicating existent life from features that are a result of known or unknown abiotic processes.

Searching for extraterrestrial intelligence by means of radio astronomy has been an exciting challenge ever since the start of Project Ozma in 1960 (Sagan, 1975; Weston, 1988; Tarter, 2001; Drake, 2011; Shuch, 2011; Dunér, 2015, 2017; Traphagan, 2015; Vakoch and Dowd, 2015; Cabrol, 2016). The problem of interstellar communication, however, lies not so much in the physical or technological constraints, even though they strongly challenge our scientific and technological skills, but in the cognitive and semiotic problems that an interstellar message decoding would provoke (Dunér, 2011, 2014; Dunér *et al*., 2013). The problem with symbolic messages, symbols, is that they are conventional, or arbitrary, as de Saussure (1995) called them. In contrast to icons and indices, the *biosymbols* are completely arbitrary, and depend on the socio-cultural context.

To conclude, the general epistemological problem of biosignatures is to recognize the signatures as meaningful, as signatures of life; that it is an expression that refers to a content (i.e. life). Second, one needs to establish the connection between the expression and the object, the biosignature and the biological process that we call life, and arrive at a certain degree of certainty, and to be able to rule out other explanations for the signatures that are not of biological nature.

Astrobiosemiotics is an emerging interdisciplinary field that delves into the interpretation of signs and symbols in the context of astrobiology. It seeks to understand and categorize biosignatures – indicators of life – as distinct from abiotic signatures that arise from non-living processes. The significance of this field to astrobiocentrism, which places the search for extraterrestrial life at the core of astrobiological studies, is profound. Astrobiosemiotics provides the philosophical and methodological frameworks necessary to discern meaningful patterns indicative of life in the cosmic tapestry, amidst the multitude of signals that the universe presents.

By developing a semiotic understanding of the cosmos, researchers can justify the search for life beyond Earth with a more nuanced approach. This involves not just the detection but also the interpretation of signals, which could potentially reveal the presence of extraterrestrial intelligence. It encourages us to explore the importance of meaning-making in a vast and seemingly indifferent universe, prompting us to ask not only if we are alone, but also how we might communicate and understand beings that are fundamentally different from ourselves. Astrobiosemiotics, therefore, not only supports astrobiocentrism but expands its vision by emphasizing the need for a deeper comprehension of life's signs across the cosmos.

Homo mensura?

The true meaning of the phrase '*homo mensura*' uttered by Protagoras is debated. It is often translated as 'humankind is the measure of all things' and is commonly interpreted as signifying that all meaning and all values are in some sense created by us humans. We do not know if this is a correct interpretation of Protagoras, but it seems nonetheless to say something about a deep-seated attitude among many

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humans. What does this attitude imply and how much sense does it make when discussing in the future interactions with extraterrestrial life?

When non-astrobiologists think about extraterrestrial life, they seem most of the time to think about complex life rather than microbial life (Offerdahl *et al*., 2002; Oreiro and Solbes, 2017). In many cases when talking to the public about astrobiology it becomes clear that what really interests people is the chance of finding life with a level of intelligence (to the extent that it makes sense to talk about intelligence in terms of levels of intelligence) similar to ours and with motivations, emotions, sense organs and perspectives similar to ours (Chon-Torres *et al*., 2020; Schwartz, 2020). This is not at all surprising. Grounding one's expectations in what is closest to oneself is quite natural. We can call this *epistemic anthropocentrism* on par with epistemic geobiocentrism. There is probably also an element of wishful thinking in here. We hope to meet other beings that we can communicate with and have some kind of meaningful exchange of knowledge and perspectives. Our focus on life with human-like properties is probably not only epistemic, however, but maybe to an even higher degree a matter of *axiological anthropocentrism*. That is, the more similar to humans another life form is, the more valuable it becomes (axiology = value theory). The most important and most troublesome form of anthropocentrism in this as well as other contexts seems to be *ethical anthropocentrism*, stating that only human beings have moral standing, or in other words, we have no moral obligation to care about the interests of non-humans.

It cannot be denied that the way we value others, and even the moral status we adjudge others is often strongly tainted by prejudice. We tend to value other humans, as well as non-humans, based on how close they are to us in some sense, socially, culturally, biologically and geographically. Traditionally, we also tend to assign moral standing only to members of our own species – and if we go further back in time, not always even to all members of our species, at least not to the same degree.

Ethical anthropocentrism can have different bases. It may be that we only accept humans as moral objects just because we are the same species, but it can also be that because we believe that humans have a certain property that only humans have and that is the proper basis for moral status.

Historically, it has been common to claim that only humans stand in a special relation to the god of one's choice. Descartes (1998) claimed for instance that only humans have moral standing because only humans have an immortal soul given to each of us individually by God. Until quite recently, it has been commonly believed that only humans are conscious or have feelings, commonly referred to as sentience. In more recent times, and even today, intelligence in a wide sense has been the property of choice for the defenders of anthropocentrism (Carruthers, 1992; Kant, 1998; Smith, 2009; Hart, 2010), either directly or indirectly under the assumption that it is a necessary prerequisite for some other property like the ability to express or defend one's own interests.

Anthropocentrism is under heavy fire today (Singer, 1979, 1993, 1995; Regan, 1986, 2001; DeGrazia, 1996; Jamieson, 1998), both because it is becoming increasingly clear that there is a considerable overlap between humans and non-humans when it comes to the properties referred to as necessary for moral status (like intelligence), and because it is increasingly questioned whether any other property than the ability to experience things in a positive, or negative way is even relevant for having morally relevant interests.

Even so, anthropocentrism is still the theory that, consciously or unconsciously, determines most policy as well as everyday behaviour among humans on planet Earth, so when we would be discussing our relations with extraterrestrial life, we still need to consider the implications of anthropocentrism.

If we use the property of belonging to our species as the basis for anthropocentrism, then there is no way any extraterrestrial life can have status as moral objects for us, no matter how intelligent they are and no matter how similar they are to us in other respects (Persson, 2012, 2019, 2021). They will not belong to our species and thus, according to this way of reasoning, we will not have any moral obligation to consider their interests. At first glance, this makes our life as explorers much easier, since we can do what we want on and with their worlds without having to care about what they think. In practice, however, it is more complicated than this. If we encounter extraterrestrial life forms with capabilities surpassing ours – which might be linked to higher intelligence but not necessarily – it could pose

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significant risks. Should these beings have advanced abilities, or if we can't dismiss the chance that they do, it becomes crucial for our safety to consider their perspectives. Moreover, since human actions in extraterrestrial realms could affect all of humanity, we arguably have an ethical obligation to be mindful of how these advanced aliens may perceive us, prioritizing human welfare.

What will happen if we base moral status on intelligence, directly or indirectly? If we encounter life with a less complex cognitive processes than ours, they will clearly not count. They may still have value for us, however, that would make us want to preserve them and their environments, for instance as study objects (Cockell, 2005, 2011b, 2011a; Persson, 2013, 2019). This kind of reasoning will in some cases motivate certain restrictions on our part, but it will still be on our terms and for our sake.

What if we ever encounter extraterrestrial life with cognitive processes as advanced as or more advanced than our own? Then they would need to be regarded as moral subjects, requiring us to consider their interests (Persson, 2012, 2013, 2021). This is a positive outcome for them, but the implications for us are uncertain. We cannot assume they reason as we do. If their cognitive capabilities are far beyond ours, to the extent that there is no common ground, we could find ourselves in a challenging situation (Persson, 2019).

Is there anything we can do (other than evolving) to increase the chances that an intelligent extraterrestrial life form will see us as having moral status, preferably on the same level as them? We could abandon anthropocentrism on Earth and hope that when they meet us, they will be inspired to do the same. At least it would be inconsistent for us to object if they act similarly. Most probably, however, this will not make a difference. If they really consider it necessary that someone has the same degree of cognitive awareness as they do or belonging to their species as being necessary to count morally, there is a small chance that they will change their mind because of us. Our only hope in this case is instead that an advanced degree of cognitive awareness is somehow connected with a more inclusive narrower perspective on what it takes to have moral standing, so that they might exhibit a more inclusive approach than we are.

An interesting complication that mixes epistemological anthropocentrism and ethical anthropocentrism is how to measure intelligence in a life form that is radically different from us and how to compare their intelligence with ours, and even whether we will be able at all to recognize an intelligent extraterrestrial life form as intelligent. These worries may seem improbable, but these complications are present already when measuring intelligence in other species on Earth, and even more so when trying to make inter-species comparisons of levels of intelligence. The problems will not be any smaller when dealing either with organisms that are even more different from us, or have a very different behaviour pattern or very different interests than we do. In principle, a highly intelligent extraterrestrial species should count as moral objects according to ethical anthropocentrism, but in practice this may not happen if we cannot even recognize them as being intelligent. One might say that epistemic anthropocentrism leads to a failure of ethical anthropocentrism. Correspondingly, and for the same reasons the extraterrestrials may not recognize us as being intelligent even if we are on the same 'level' of intelligence as they are, but that would clearly not be a case epistemic anthropocentrism, leading to the failure of ethical anthropocentrism but about epistemic extraterrestrial-ism leading to the failure of ethical extraterrestrial-ism.

Humanity as a shared moral community

But what becomes of our sense of humanity, and of the importance of humanity, if we acknowledge anthropocentrism as a prejudice or at least as a problematic bias? Might a concern about anthropocentrism require us to abandon our very identity as humans and begin to think of ourselves as something else? For example, as rational agents, or as part of the larger body of Earthlings (human and non-human), or as one particular group of sentient or rational beings out of many groups of such beings. A difficulty here is that such an attitude of indifference towards our humanity may not be advisable, even if it was psychologically available to us.

It might not be a good idea given that the recognition of a shared humanity has been pivotal to combatting discrimination and extreme forms of injustice. While identification as human is sometimes

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regarded as anthropocentric prejudice or, in discussions of animal ethics (Singer, 1993; Regan, 2004) 'speciesism' on a par with antisemitism and racism more generally, the recognition of a shared humanity, independent of perceptions of race, has historically played a crucial role in combatting both. Any notion of political equality depends upon an ability to answer the simple question: 'equally to what?' And while there may be a case for the inclusion of non-humans within our conception of the common good (Donaldson and Kymlicka, 2011), any workable way of doing so will have to acknowledge the typical differences between humans and non-humans, even if these differences collapse in marginal cases.

Doing so does not, however, even need to be seen as an appeal to species membership. If, for example, we were suddenly to discover that half of us belonged to one species while the other belonged to another species of hominids, it would not diminish the importance of having a shared overall conception of humanity. A conception which carries obligations to non-humans, as well as entitlements to certain kinds of equality. Indeed, such a conception of a shared humanity can be seen as a precondition of shared failures in our treatment of non-humans, either terrestrially or following contact with life elsewhere (Diamond, 1991). And shifting away from anthropocentrism and an overly Earth-focused way of thinking about life requires that some ways of acting should count as moral failures on our part, while other ways of acting count as morally praiseworthy.

What is at work in such an approach is a way of thinking about humanity as a moral community rather than primarily thinking about humanity as a species. This is an idea which has already been put forward in work on ethics in the tradition of Wittgenstein (Cockburn, 1990; Gaita, 2001, 2004), in the context of deliberation about outer space (Milligan, 2015a, 2015b) and in the context of deliberation about future generations (Wallace, 2021). Of course, there are various biological traits, or species traits, which make our shared human ways of living, experiencing, being vulnerable and responding to others, possible. But it is these things that we typically value and want to continue, through future generations of beings in many ways like ourselves who may or may not belong to the same species as ourselves. If our descendants really do survive for much longer than the *longue durée* in which we think about past human history, it is unlikely that they will continue to belong to the same species, given current technological trends and emerging technologies of genetic modification. They will still be our descendants, but their continuity with us may be best thought of as the continuity not of a species, but of a moral community, namely, a community with similarities and overlaps in our ways of living, experiencing, being vulnerable and responding to others. If our remote descendants were incapable of love, or compassion, or hope or fear, it would make more sense to say that our kind of moral community had been replaced by another and very different sort of moral community. And again, this would be the case irrespective of various similarities or changes at the level of DNA, biology and genetics.

Thinking of our humanity in this way, as a moral community, rather than thinking of it primarily in terms of species membership associated with distinctive biological characteristics, will better equip us for contact with other life forms and for change in the ways that we interact with other lifeforms here on Earth. It allows us a chance to recognize that a shared conception of humanity is a historic accomplishment, without trying to fix some set of biological traits as an everlasting ideal that other beings (terrestrial and otherwise) might then fail to meet. As a final qualification, none of this means that thinking about our moral community in terms of the concept of 'humanity' will itself go on forever. But even if the idea of humanity should at some point become outdated, there may be an ongoing need for a conception of moral community or of multiple moral communities, which plays many of the same unifying, differentiating and obligation-conferring roles.

Planetary sustainability in the context of a non-terrestrial life form scenario

Planetary sustainability was firstly coined by NASA and further developed by researchers at the University of Bern (NASA, 2014; Losch *et al*., 2019). In this sense, it is a consideration of all dimensions of sustainability on a planetary scale, including our space environment. Most of all, this means to

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consider aspects like the use of Earth orbits, the problem of space debris, the ambiguity of space tourism, eventual space mining and settlements on the Moon and beyond, whether they contribute to humankind's long-term survival. Sustainable development is a 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987), and survival is certainly a very essential need in this regard.

Our modern civilization is already largely dependent on satellites, and also the monitoring of the UN's Sustainable Development Goals is largely pursued by the use of those devices (United Nations, n.d.). If we take our society into space – which we need to do to survive in the long run, because time on Earth is limited by the slow expansion of the Sun – important ethical issues might arise when facing potential extraterrestrial life.

This is currently mainly discussed under the heading of planetary protection, 'the practice of protecting solar system bodies from contamination by Earth life and protecting Earth from possible life forms that may be returned from other solar system bodies' (NASA, n.d.). We do not want to bring our life to other celestial bodies in the first place, because this would obscure the possibility to find traces of extraterrestrial life on those bodies, and eventually create false positives. Yet there could indeed be ancient traces of extraterrestrial life on Mars, or microbial lifeforms in the under-surface oceans of icemoons like Europa is one. And planetary protection then means the protection of Earth against microbial contamination from those places. Thus, the commitment to create harmless systems for both groups of living beings is born, and given the advance of astrobotany and the very neglected *astrozoology*, it is necessary to understand and constantly monitor the role of plants and animals in the transport or transmission of unwanted microbes, so as not to endanger life in the places we intend to colonize, or our own biological diversity on Earth.

In the context of a non-terrestrial life form scenario, we would have to consider our ethical stance towards life, and particularly, towards extraterrestrial life. We pondered the ethical options elsewhere from a sustainability perspective (Losch, 2019b). There remain fundamental questions, like 'what is a (living) system? What and where are the fuzzy borders of living and not-living? Are there any limits, or how deep are we connected with our environment, where do feelings belong and what is mind?' (Losch, 2017, 2019a). Our ethics, however, is meant to guide us as beings who can make mindful decisions. That's why we promote a ratiocentrist framework which attempts at including all the other possible stances as complementary perspectives: because it is reasonable to consider their moment of truth.

We understand planetary sustainability to be a consideration of all dimensions of sustainability on a planetary scale, including our space environment. Now, our space environment is huge. We already discovered thousands of exoplanets and can expect that there are billions in the cosmos. Will we, one day, even encounter extraterrestrial intelligent life? Although even if such an encounter is not very likely, as the universe is expanding, and the distances grow, a ratiocentrist framework would be wide enough to allow for ethical exchange in such case. What sounds very futuristic is actually an old idea, already Immanuel Kant defined his philosophy to be ratiocentric, with ethical extraterrestrials in mind (Losch, 2016).

Astrotheology

Work at the frontier of the humanities, specifically theology, and the natural sciences often focuses on methodological concerns. It focuses on the 'and' of this intersection: the additive way in which two distinct fields inform one another while remaining methodologically distinct. Astrotheology does something slightly different, though, that is tune with the tendency in astrobiocentrism to consider where our concepts about life in the universe fundamentally change in the light of a future confirmation of life on other worlds. Astrotheology drives toward transdisciplinary possibilities, not only multidisciplinary or interdisciplinary approaches to the integration of different fields. In short, astrotheology is a form of theological reflection in which new answers must be developed to respond to fundamental shifts in the existential questions driving theological reflection: questions otherwise undeveloped in other theological approaches.

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The reason for this change is that most theological reflection is fundamentally geocentric. While ostensibly theologies address the nature of divine power expressed throughout the vastness of the cosmos, they most often remain tied to articulating the highly local ways in which the possibilities and conditions for life to emerge on Earth are significant for theology as a process of distinctly human meaning-making. If we take seriously our ever-developing understanding of the scope of the cosmos and its propensity for the occurrence of life, we must ask how this affects our language about God's self-communication such that we question our axiomatic assumptions about living things and the natural world and how we subsequently act responsibly in the light of this fecund cosmos.

John MacCarthy has helpfully described this in terms of the significance of the prefix 'astro-'. When this prefix is linked to a more traditional academic field of study, there is an amplification effect (MacCarthy, 2017). Astro- serves to link the current field of study 'with cosmic scales of time and space, with quantum physics, with planetary sciences, and the like'. Understanding 'astro-' as an amplicative prefix, we should expect to see (and are seeing) all sorts of new fields arise. These are not merely subdivisions of the hard sciences, like astrophysics, astrochemistry and astrobiology, but also fields imagining the wider social implications of space research, such as astrosociology, astroethics, astroanthropology and astroeconomics. By doing this, the prefix has an abductive effect on the field of study to which it is attached. 'Abductive' indicates two things about the quality of the resulting inferences that are drawn.

First, it indicates the body of observations from which inferences in the given field of study are drawn is inherently incomplete. Second, it indicates the rhetorical force of the inferences that can be made in an 'astro-' field is correspondingly broader. The breadth of possible yet unrealized observation has the effect of making the explanatory statements of astro-fields operate like a general rule from which subsequent deductive reasoning might proceed. In the case of astrotheology, there is an abductive shift on the intensely personal existential question driving much theological thinking, 'Why do I exist?' The assumed personal focus in this question is deemed inherently incomplete and significantly widened: 'Why do we (or any living things for that matter) exist?' Astro*theology fundamentally shifts* the existential quality of questions driving the theological reflection, and thus demands an astrobiocentric perspective from which to shape any theological effort at meaning-making.

Another way to describe this would be that astrotheology has to begin from the distinct existential questions that result from a self-understanding driven by the fundamental interdisciplinary insights of astrobiology regarding living systems. In astrobiology one cannot study *either* living systems *or* habitability; this is a complementary discussion since the living system and the habitable environment are co-constitutive. In turn, astrotheology needs language that captures the extent of this mutuality. The concept of 'intra-action' employed by Karen Barad's understanding of agential realism provides a helpful conceptual tool in this regard. *Inter*action assumes the prior existence of entities that relate to one another. *Intra*-action connotes the priority of the phenomenon as a holistic unit. As she variously describes it, intra-action indicates that '[r]eality is composed not of things-in-themsleves or things-behind-phenomena, but of things-in-phenomena' (Barad, 2007).

Rather than thinking about the intersection of a living system and the habitable conditions allowing such a system to arise as distinct phenomena *inter*acting (distinct parts of a greater whole), in astrobiology living systems and environmental habitability form an *intra*-active phenomenon itself that is *ontologically primordial*. The meaningfulness of a living system is not something that can be determined in contradistinction to its habitable environment: these concepts work in intra-active tandem – things-in-a-phenomenon – as a meaningful unit of existence that we cannot tear asunder without violating what constitutes a sufficient understanding of either part in itself. In so doing, life is better understood as a planetary or statistical quality of certain phenomena, *not a descriptor of specific organisms*. Bluntly put, the shift in our thinking would entail something like claiming it is not that a bacteria, bug, plant or human being is alive, it is that the *systems* in which those creatures appear are *living* in a way that we might contrast with systems in which such features could not or do not appear that would be non-living. The driving questions for an astrotheology would have to address the existential threats, questions and meaning-making processes of significance to these living-systems as they appear in

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all their distinctiveness. This requires a decentring of the human in theological reflection to account for the anthropocentric and geocentric biases that emerge in the more intensely personal reflections of traditional theological models.

Discussion

1. Astrobiocentrism expands the concept of biocentrism to consider the implications for science and humanity if extraterrestrial life is confirmed. This paradigm shift, anticipated by data from space missions and observatories, moves towards the idea of a 'second genesis' – the emergence of life elsewhere in the universe. This notion challenges biogeocentrism, the view that life is unique to Earth, and promotes the search for extraterrestrial biosignatures as part of astrobiology's goal. Henderson's early 20th-century biocentric view of the universe as inherently related to life's structure and evolution lays the foundation for this discussion, integrating Darwin's fitness concept with the environment's suitability for life, thus advocating for a universal application of biocentric principles beyond Earth.
2. Space mining represents a multidisciplinary challenge poised at the intersection of technological advancement and ethical consideration. As the industry matures, with startups and established companies joining the 'space resources value chain', questions arise about the astrobiocentric bias – often overlooked – that influences geoethical and astrobioethical principles. These questions extend to ISRU and its socio-economic and cultural impacts. To address this bias, tailored protocols considering resource types, extraction methods, environmental impacts and usage goals are necessary. Moreover, these practices must be informed by thorough scientific assessments and validations, reflecting the complexities of extraterrestrial mining and the ethical implications of using either abiotic or bio-mining techniques in space resource extraction. As space endeavours continue to be human-centric, the need for clear legislation and ethical guidelines becomes paramount to guide the industrial and scientific aspects of space mining, ensuring the sustainability and responsibility of off-world activities.
3. Astrobiosemiotics bridges astrobiology and semiotics, focusing on interpreting biosignatures as evidence of life. It's based on the premise that meaningful signs, or biosignatures, emerge from the interaction between our cognition and the cosmos. Biosignatures, such as molecular traces or fossils, are diverse, ranging from atomic to planetary scales and require an interpreter, the astrobiologist, to connect the sign with its life-related meaning. This interpretative process is a semiotic act involving icons, indices and symbols – each with unique epistemological and semiotic challenges. Astrobiosemiotics aims to bring order to the study of these biosignatures, enhancing our understanding of life in the universe through the structured interpretation of these signs. It underscores the importance of human cognition in ascribing meaning to potential evidence of extraterrestrial life, thereby enriching the search for life beyond Earth with a nuanced appreciation of universal semiosis.
4. The Protagorean maxim 'homo mensura' encapsulates a potentially anthropocentric outlook that has profound implications for the ethical consideration of extraterrestrial life. This perspective inherently values life forms with human-like intelligence or characteristics, often overlooking less complex organisms. Ethical anthropocentrism, which prioritizes human interests, is challenged by the possibility of encountering intelligent extraterrestrial beings. If such beings' cognitive capabilities are on par with or surpass ours, they could necessitate moral consideration, which would demand a reassessment of our anthropocentric ethics. Additionally, recognizing intelligence in radically different life forms poses epistemological and ethical dilemmas. The encounter with extraterrestrial intelligence would not only test our capacity to identify and value other forms of cognition but also force us to confront the limitations and biases of our anthropocentric worldview.
5. Reconceptualizing humanity as a moral community rather than a species addresses the problem of anthropocentrism. It acknowledges our shared human identity's role in fighting discrimination, suggesting that our commonality transcends species and includes ethical obligations to non-humans.

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This moral community perspective equips us to ethically engage with extraterrestrial life and adapt our interactions with terrestrial life. It emphasizes a continuity of values like compassion and vulnerability over mere biological traits, preparing us for a future where humanity may evolve beyond current definitions, yet maintain the essence of our moral and social bonds.

6. Planetary sustainability, as formulated by NASA and expanded by scholars, encompasses the stewardship of Earth and its extraterrestrial environs, including space debris, space tourism and off-world colonization. It underscores development that does not hinder future generations' needs, a principle integral to our survival as our civilization relies on satellites and contemplates space expansion due to the Sun's life cycle. The concept raises ethical questions, especially when considering extraterrestrial life, which is governed by planetary protection policies to avoid biological cross-contamination. A ratiocentric ethical framework suggests a comprehensive approach that acknowledges the value of all life, inviting a broad, inclusive dialogue on sustainability within the vastness of space.
7. Astrotheology, an emerging discipline at the intersection of theology and natural sciences, ventures beyond traditional multidisciplinary approaches, aiming for a transdisciplinary integration. It is distinct from conventional theology, which tends to be geocentric, focusing on human-centric interpretations of divine power. On the other hand, considers the implications of potential extraterrestrial life on theological concepts, thereby questioning our fundamental assumptions about life and the universe. This field emphasizes the need to expand our theological perspective to include astrobiocentric considerations, recognizing that our understanding of life and its existential questions should not be limited to Earth. The term 'astro-' as an amplifying prefix extends the scope of various fields, including theology, to cosmic scales, incorporating insights from astrophysics, quantum physics and planetary sciences. Astrotheology thus challenges and widens the scope of traditional theological inquiries, shifting from individual existential questions to broader considerations of life's existence in the universe. This approach necessitates new language and concepts, such as 'intra-action' as opposed to 'interaction', to better understand the co-constitutive nature of living systems and their environments. Ultimately, astrotheology calls for a decentring of human perspectives in theology, acknowledging the anthropocentric biases of traditional models and embracing a broader, more inclusive view of life's significance in the cosmos.

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References

Abbud-Madrid A (2018) Space and planetary resources. In Rossi AP and van Gasselt S (eds), *Planetary Geology*. Switzerland: Springer International Publishing, p. 441. https://doi.org/10.1007/978-3-319-65179-8

Aretxaga-Burgos R and Chela-Flores J (2012) Cultural implications of the search and eventual discovery of a second genesis. In Seckbach J (ed.), *Genesis – In the Beginning Precursors of Life, Chemical Models and Early Biological Evolution*. Netherlands: Springer, Vol. **22**, pp. 873–890.

Aretxaga R (2004) Astrobiology and biocentrism. In Seckbach J, Chela-Flores J, Owen T and Raulin F (eds), *Life in the Universe*. The Netherlands: Springer, Vol. **7**, pp. 345–348. https://doi.org/10.1007/978-94-007-1003-0_71

Arnold L (2008) Earthshine observation of vegetation and implication for life detection on other planets. *Space Science Reviews* **135**, 323–333.

Arnold L, Gillet S, Lardière O, Riaud P and Schneider J (2002) A test for the search for life on extrasolar planets. *Astronomy & Astrophysics* **392**, 231–237.

Barad K (2007) *Meeting the Universe Halfway*. Durham, USA: Duke University Press.

Cabrol NA (2016) Alien mindscapes – a perspective on the search for extraterrestrial intelligence. *Astrobiology* **16**, 661–676.

Carruthers P (1992) *The Animals Issue*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511597961

Catling D and Kasting JF (2007) Planetary atmospheres and life. In Sullivan W and Baross J (eds), *Planets and Life: The Emerging Science of Astrobiology*. Cambridge, UK: Cambridge University Press, pp. 91–116.

Cavalazzi B and Westall F (2018) Biosignatures for astrobiology. In Cavalazzi B and Westall F (eds), *Advances in Astrobiology and Biogeophysics*. Switzerland: Springer, p. 347.

Chela-Flores J (2001) *The New Science of Astrobiology*. Netherlands: Springer, https://doi.org/10.1007/978-94-010-0822-8

Chela-Flores J (2005) Fitness of the universe for a second genesis: is it compatible with science and Christianity? *Science and Christian Belief* **17**, 187–197.
Chela-Flores J (2009) *A Second Genesis: Stepping Stone Towards the Intelligibility of Nature*. Singapore: World Scientific Publishers.
Chela-Flores J (2022) Instrumentation for detecting sulphur isotopes as biosignatures on Europa and Ganymede by forthcoming missions. *Universe* **8**, 357.
Chon-Torres OA (2018) Astrobioethics. *International Journal of Astrobiology* **17**, 51–56.
Chon-Torres OA (2021) Disciplinary nature of astrobiology and astrobioethic's epistemic foundations. *International Journal of Astrobiology* **20**, 186–193.
Chon-Torres OA (2022) Teloempathy. In *Encyclopedia of Astrobiology*. Berlin Heidelberg: Springer, pp. 1–1, https://doi.org/10.1007/978-3-642-27833-4_5615-1
Chon-Torres OA and Murga-Moreno CA (2021) Conceptual discussion around the notion of the human being as an inter and multiplanetary species. *International Journal of Astrobiology* **20**, 327–331.
Chon-Torres OA, Ramos Ramírez JC, Hoyos Rengifo F, Choy Vessoni RA, Sergo Laura I, Ríos-Ruiz FGA, Murga-Moreno CA, Alvarado Pino JPL and Yance-Morales X (2020) Attitudes and perceptions towards the scientific search for extraterrestrial life among students of public and private universities in Peru. *International Journal of Astrobiology* **19**, 360–368.
Chon Torres OA (2020) Astrobiology and its influence on the renewal of the way we see the world from the teloempathic, educational and astrotheological perspective. *International Journal of Astrobiology* **19**, 330–334.
Cockburn D (1990) *Other Human Beings*. London, UK: Macmillan.
Cockell CS (2005) The value of microorganisms. *Environmental Ethics* **27**, 375–390.
Cockell CS (2011a) Microbial rights? *EMBO Reports* **12**, 181–181.
Cockell CS (2011b) Originism: ethics and extraterrestrial life. *Journal of the British Interplanetary Society* **60**, 147–153.
DeGrazia D (1996) *Taking Animals Seriously*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781139172967
De Saussure F (1995) *Cours de Linguistique Générale*. France: Payot.
Descartes R (1998) *Discourse on Method and Meditations on First Philosophy* (D. Cress, Ed.; 4th ed.). USA: Hackett Publishing Company.
Diamond C (1991) The importance of being human. *Royal Institute of Philosophy Supplement* **29**, 35–62.
Donaldson S and Kymlicka W (2011) *Zoopolis: A Political Theory of Animal Rights*. Oxford, UK: Oxford University Press.
Drake F (2011) The search for extra-terrestrial intelligence. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* **369**, 633–643. https://doi.org/10.1098/rsta.2010.0282
Drake F and Sobel D (1992) *Is Anyone out There? The Scientific Search for Extraterrestrial Intelligence*. NY, USA: Delacorte Press.
Dunér D (2011) Cognitive foundations of interstellar communication. In Vakoch D (ed.), *Communication with Extraterrestrial Intelligence*. NY, USA: SUNY Press, pp. 449–467.
Dunér D (2014) Interstellar intersubjectivity: the significance of shared cognition for communication, empathy, and altruism in space. In Vakoch DA (ed.), *Extraterrestrial Altruism: Evolution and Ethics in the Cosmos*. Berlin, Germany: Springer, pp. 141–167. https://doi.org/10.1007/978-3-642-37750-1_10
Dunér D (2015) Length of time such civilizations release detectable signals into space, L, pre-1961. In Vakoch DA and Dowd MF (eds), *The Drake Equation*. Cambridge, UK: Cambridge University Press, pp. 241–269. https://doi.org/10.1017/CBO9781139683593.016
Dunér D (2017) On the plausibility of intelligent life on other worlds. *Environmental Humanities* **9**, 433–453.
Dunér D (2018) Semiotics of biosignatures. *Southern Semiotic Review* **9**, 47–63.
Dunér D (2019) The history and philosophy of biosignatures. In Cavalazzi B and Westall F (eds), *Biosignatures for Astrobiology*. Switzerland: Springer, pp. 303–338. https://doi.org/10.1007/978-3-319-96175-0_15
Dunér D and Sonesson G (2016) *Human Lifeworlds: The Cognitive Semiotics of Cultural Evolution* (D. Dunér & G. Sonesson, Eds.). Peter Lang D. https://doi.org/10.3726/978-3-653-05486-6
Dunér D, Parthemore J, Persson E and Holmberg G (2013) *The History and Philosophy of Astrobiology: Perspectives on Extraterrestrial Life and the Human Mind* (D. Dunér, J. Parthemore, E. Persson, & G. Holmberg, Eds.). USA: Cambridge Scholars Publishing.
Gaita R (2001) *A Common Humanity: Thinking About Love and Truth and Justice*. UK: Routledge.
Gaita R (2004) *Good and Evil: An Absolute Conception*, 2nd Edn. UK: Routledge. https://doi.org/10.4324/9780203489123
Garvin J (2005) in Roth, N. E. 'New tools for finding life on Mars.' Geotimes.
Gingerich O (2008) Revisiting the fitness of the environment. In Barrow JD, Conway Morris S, Freeland SJ and Harper CL (eds), *Fitness of the Cosmos for Life: Biochemistry and Fine-Tuning*. Cambridge, UK: Cambridge University Press, pp. 20–30.
Hart J (2010) Cosmic commons: contact and community. *Theology and Science* **8**, 371–392.
Hegde S, Paulino-Lima IG, Kent R, Kaltenegger L and Rothschild L (2015) Surface biosignatures of exo-earths: remote detection of extraterrestrial life. *Proceedings of the National Academy of Sciences* **112**, 3886–3891.
Henderson LJ (1913) *The Fitness of the Environment; an Inquiry Into the Biological Significance of the Properties of Matter* (P. Smith, Ed.; Vol. 10, Issue 25). London, UK: Macmillan.

Horneck G, Walter N, Westall F, Grenfell JL, Martin WF, Gomez F, Leuko S, Lee N, Onofri S, Tsiganis K, Saladino R, Pilat-Lohinger E, Palomba E, Harrison J, Rull F, Muller C, Strazzulla G, Brucato JR, Rettberg P and Capria MT (2016) AstRoMap European astrobiology roadmap. *Astrobiology* **16**, 201–243.

Jamieson D (1998) Animal liberation is an environmental ethic. *Environmental Values* **7**, 41–57.

Kant I (1998) *Immanuel Kant: Groundwork of the Metaphysics of Morals* (M. Gregor, Ed.). Cambridge, UK: Cambridge University Press.

Kuhn TS (2012) *The Structure of Scientific Revolutions: 50th Anniversary Edition*, 4th Edn. USA: University of Chicago Press.

Kwon JY, Bercovici HL, Cunningham K and Varnum MEW (2018) How will we react to the discovery of extraterrestrial life? *Frontiers in Psychology* **8**, 1–8. https://doi.org/10.3389/fpsyg.2017.02308

Lineweaver CH (2008) *Planets and Life. The Emerging Science of Astrobiology* (W. T. Sullivan & J. A. Baross, Eds.; Vol. 145). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/S0016756808004792

Losch A (2016) Kant's wager: kant's strong belief in extra-terrestrial life, the history of this question and its challenge for theology today. *International Journal of Astrobiology* **15**, 261–270.

Losch A (2017) *What is Life? On Earth and Beyond* (A. Losch, Ed.). Cambridge, UK: Cambridge University Press.

Losch A (2019a) Interplanetary sustainability: Mars as a means of a long-term sustainable development of humankind in the Solar System? In Szocik K (ed.), *The Human Factor in A Mission to Mars: An Interdisciplinary Approach*. Switzerland: Springer, pp. 157–166. https://doi.org/10.1007/978-3-030-02059-0_9

Losch A (2019b) The need of an ethics of planetary sustainability. *International Journal of Astrobiology* **18**, 259–266.

Losch A, Galli A, Ullrich O and Jah M (2019) Space resources and planetary sustainability: challenges and opportunities. Available at https://www.frontiersin.org/research-topics/30181/space-resources-and-planetary-sustainability-challenges-and-opportunities

MacCarthy J (2017, April). Cultural traditions and astrobiology. Center of Theological Inquiry's Spring Symposium.

Martínez-Frías J (2016) Ethics and space exploration: from geoethics to astrobioethics. XII The Rencontes Du Vietnam. Available at https://www.youtube.com/watch?v=S3OI0C-AuGU

Martínez-Frías J, Horneck G, de La Torre Noetzel R and Rull F (2010) A geoethical approach to the geological and astrobiological exploration and research of the Moon and Mars. 38th COSPAR Scientific Assembly 2010. Available at https://www.cospar-assembly.org/abstractcd/OLD/COSPAR-10/abstracts/data/pdf/abstracts/PEX1-0007-10.pdf

Martínez-Frías J, González JL and Pérez FR (2011) Geoethics and deontology: from fundamentals to applications in planetary protection. *Episodes* **34**, 257–262.

Martínez-Frías J, Mederos EM and Lunar R (2017) The scientific and educational significance of geoparks as planetary analogues: the example of Lanzarote and Chinijo Islands UNESCO Global Geopark. *Episodes* **40**, 343–347.

McKay CP (2001) The search for a second genesis of life in our Solar System. In Chela-Flores J, Owen T and Raulin F (eds), *First Steps in the Origin of Life in the Universe*. Netherlands: Springer, pp. 269–277. https://doi.org/10.1007/978-94-010-1017-7_47

Milligan T (2015a) *Nobody Owns the Moon: The Ethics of Space Exploitation*. USA: McFarland & Company.

Milligan T (2015b) *Animal Ethics: The Basics*. UK: Routledge.

NASA (2014) Our vision for planetary sustainability. Available at http://www.nasa.gov/content/planetary-sustainability-our-vision/#.WBgtmiTBZsl

NASA (n.d.) *Planetary Protection*. USA: OSMA. Retrieved September 13, 2023, from Available at https://sma.nasa.gov/sma-disciplines/planetary-protection

Offerdahl EG, Prather EE and Slater TF (2002) Students' pre-instructional beliefs and reasoning strategies about astrobiology concepts. *Astronomy Education Review* **1**, 5–27.

Oreiro R and Solbes J (2017) Secondary school students' knowledge and opinions on astrobiology topics and related social issues. *Astrobiology* **17**, 91–99.

Peirce CS (1932) *Collected Papers 2: Elements of Logic* (C. Hartshorne, Ed.). USA: Belknap Press of Harvard University Press.

Persson E (2012) The moral status of extraterrestrial life. *Astrobiology* **12**, 976–984.

Persson E (2013) Philosophical aspects of astrobiology. In Dunér D, Pathermore J, Persson E and Holmberg G (eds), *The History and Philosophy of Astrobiology*. USA: Cambridge Scholars Press, pp. 29–48.

Persson E (2019) A philosophical outlook on potential conflicts between planetary protection, astrobiology and commercial use of space. In Lehmann-Imfeld Z and Losch A (eds), *Our Common Cosmos*. USA: Bloomsbury T&T Clark, pp. 141–160.

Persson E (2021) Astrobiologins filosofi – Några frågor rörande praktisk filosofi. *Filosofiska Notiser* **8**, 25–38.

Regan T (1986) A case for animal rights. In Fox MW and Mickley LD (eds), *Advances in Animal Welfare Science*. The Humane Society of the United States, pp. 179–189.

Regan T (2001) *Defending Animal Rights*. USA: University of Illinois Press. https://doi.org/10.1017/S0962728600025999

Regan T (2004) *The Case for Animal Rights* (P. Singer, Ed.). USA: University of California Press.

Restrepo JE (2020) Los límites epistemológicos de las neurociencias: la falacia de las neuro–lo que sea. *Revista de Psicología Universidad de Antioquia* **11**, 201–224.

Sagan C (1975) *Communication with Extraterrestrial Intelligence* (C. Sagan, Ed.). USA: The MIT Press.

Saint-Gelais R (2014) Beyond linear B: the metasemiotic challenge of communication with extraterrestrial intelligence. In Vakoch DA (ed.), *Archaeology, Anthropology, and Interstellar Communication*. USA: NASA, pp. 79–93.

Santos CMD, Alabi LP, Friaça ACS and Galante D (2016) On the parallels between cosmology and astrobiology: a transdisciplinary approach to the search for extraterrestrial life. *International Journal of Astrobiology* **15**, 251–260.
Schwartz JSJ (2020) Myth-free space advocacy part IV: the myth of public support for astrobiology. In Smith KC and Mariscal C (eds), *Social and Conceptual Issues in Astrobiology*. Oxford, UK: Oxford University Press, pp. 263–287. https://doi.org/10.1093/oso/9780190915650.003.0015
Seager S (2014) The future of spectroscopic life detection on exoplanets. *Proceedings of the National Academy of Sciences* **111**, 12634–12640.
Seager S and Bains W (2015) The search for signs of life on exoplanets at the interface of chemistry and planetary science. *Science Advances* **1**, 1–11. https://doi.org/10.1126/sciadv.1500047
SETI (2023) The SETI Institute. Available at https://www.seti.org/about
Shuch HP (2011) Project Ozma: the birth of observational SETI. In Schuch HP (ed.), *Searching for Extraterrestrial Intelligence: SETI Past, Present, and Future*. Switzerland: Springer, pp. 13–18. https://doi.org/10.1007/978-3-642-13196-7_2
Singer P (1979) Not for humans only: the place of nonhumans in environmental ethics. In Goodpaster KE and Sayre KM (eds), *Ethics Problems of the 21st Century*. USA: University of Notre Dame Press, pp. 191–206.
Singer P 1993 *Practical Ethics*, 3rd Edn. Cambridge, UK: Cambridge University Press.
Singer P (1995) *Animal Liberation*, 2nd Edn. London, UK: Pimlico.
Smith KC (2009) The trouble with intrinsic value: an ethical primer for astrobiology. In Bertka CM (ed.), *Exploring the Origin, Extent, and Future of Life: Philosophical, Ethical, and Theological Perspectives*. Cambridge, UK: Cambridge University Press, pp. 261–280.
Sonesson G (2007) From the meaning of embodiment to the embodiment of meaning: a study in phenomenological selDiotics. In *Embodiment*, vol. Vol. **1**, pp. 85–128. Berlin, Germany: De Gruyter. https://doi.org/10.1515/9783110207507.1.85.
Sonesson G (2009) The view from Husserl's lectern: considerations on the role of phenomenology in cognitive semiotics. *Cybernetics & Human Knowing* **16**, 107–148.
Sonesson G (2013) Preparations for discussing constructivism with a Martian (the second coming). In Dunér D (ed.), *The History and Philosophy of Astrobiology: Perspectives on the Human Mind and Extraterrestrial Life*. USA: Cambridge Scholars Publishing, pp. 185–200.
Space Studies Board (2019) *An Astrobiology Strategy for the Search for Life in the Universe*. USA: National Academies Press. https://doi.org/10.17226/25252
Tarter J (2001) The search for extraterrestrial intelligence (SETI). *Annual Review of Astronomy and Astrophysics* **39**, 511–548.
Traphagan J (2015) *Extraterrestrial Intelligence and Human Imagination* (D. Vakoch, Ed.). Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-10551-2
United Nations (n.d.) Space supporting the Sustainable Development Goals. Retrieved February 1, 2023, from Available at https://www.unoosa.org/oosa/en/ourwork/space4sdgs/index.html
Vakoch DA (1998a) Constructing messages to extraterrestrials: an exosemiotic perspective. *Acta Astronautica* **42**, 697–704.
Vakoch DA (1998b) Signs of life beyond earth: a semiotic analysis of interstellar messages. *Leonardo* **31**, 313.
Vakoch DA and Dowd MF (2015) *The Drake Equation: Estimating the Prevalence of Extraterrestrial Life Through the Ages* (D. A. Vakoch & M. F. Dowd, Eds.). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781139683593
Wallace RJ (2021) Humanity as an object of attachment. *Inquiry: A Journal of Medical Care Organization, Provision and Financing* **64**, 686–698.
Weston A (1988) Radio astronomy as epistemology. *The Monist* **71**, 88–100.
World Commission on Environment and Development (1987) Our common future. Available at https://digitallibrary.un.org/record/139811
Zlatev J (2012) Cognitive semiotics: an emerging field for the transdisciplinary study of meaning. *Public Journal of Semiotics* **4**, 2–24.
Zlatev J (2015) Cognitive semiotics. In Trifonas P (ed.), *International Handbook of Semiotics*. Netherlands: Springer, pp. 1043–1067. https://doi.org/10.1007/978-94-017-9404-6_47