The terraforming of Mars as seen through the lens of biocentrism and ecocentrism

Manfred Freuding, Student No.: 2009549

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ABSTRACT

This dissertation undertakes to investigate whether biocentrism and ecocentrism can serve as a viable ethical framework to guide human space exploration in general and the terraforming and colonisation of Mars in particular. The first part involves the provision of the necessary background information: the history and motives behind human space exploration and Mars colonisation, the reasons why anthropocentric approaches have failed the environment so far, the current Martian environment and the technical requirements of the terraforming process. The second part of the study focuses on presenting the principles of ecocentrism and biocentrism, to include a critical discussion of the criteria applied to award moral standing and of the practical aspects of the management of conflicts of interests in either theory. The last part, then, combines the findings of the previous research to establish that ecocentrism and biocentrism permit the terraforming of Mars – whether or not it contains indigenous life – provided that the rationale given is strong enough and the execution is such that respect for the environment and living things is guaranteed.

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Introduction

Humankind's interest in the stars and the planets goes way back, the Babylonians being the first civilization to systematically observe the sky and prepare astronomic records. The Ancient Greeks began to take the interest in the heavens further, and the first celestial maps were drawn up, listing hundreds of stars. Gaining knowledge of the skies, however, was not a mere lofty enterprise. Rather, it served practical ends such as keeping time for ritualistic and agricultural applications (European Space Agency, 2019). Despite all advances in celestial knowledge, space continued to be viewed as an out-of-reach divine area and served as a backdrop on which myths played out (Cheston, 1986, pp. 20-21).

These days of quiet for the cosmos, however, were to come to an end when "the space-flight revolution" of the twentieth century broke out (Cheston, 1986, p. 21). This revolution saw humankind travel to Earth's orbit and set foot on the Moon as the United States and the Soviet Union were locked in a great-power competition during the Cold War (Panagiotarakou, 2016, p. 48- 49). Following a brief respite after the end of the Cold War (Panagiotarakou, 2016, p. 50-51), the 21st century saw plans being crafted to explore Mars by sending unmanned spacecraft (Williamson, 2006, p. 22), a development culminating more recently in serious considerations and efforts to establish a human presence on Mars (McKay, 2019, p. 1).

Behind the shiny facade of a seemingly never-ending success story of humankind as it sets its sight on the space frontier now that nearly every inch of the Earth has been discovered (Hartman, 1986, p. 120), however, lurks the grim truth about the often devasting effect human progress and discovery have had on the environment and other living things (Reiman, 2009, p. 85). While anthropocentrism arguably gives some consideration to the protection of the environment, recent examples such as the US government's decision to permit oil drilling on Alaska's North Slope show how quickly environmental concerns can give way to political and economic considerations (Milman, Lakhani and Singh, 2023). Environmental impacts of human activity are not restricted to space alone as is shown by the tonnes of debris resulting from spacecraft crashed into the lunar surface alone – either deliberately or by mistake (Williamson, 2006, p. 101-102).

As these examples show there is a strong need for a proper ethical framework to guide human space exploration going forward if one wishes to bypass the alternation of trial-and-error that has characterized human-centric approaches to the environment so far. Instead of merely reacting to environmental harm done, more pro-active approaches taking into account the needs of the space environment are therefore required. Owing to the above-described shortcomings, purely anthropocentric ethics now longer seem to offer the moral guidance necessary. This dilemma has led to calls for development of a new ethics that replaces the hitherto geocentric outlook with a cosmocentric one. (Moore Daly and Frodeman, 2008, p. 139-140). The question, however, is if – instead of reinventing the proverbial wheel – one should focus on non-anthropocentric theories already in existence to see whether they can be applied to bridge the ethical gap.

Given the shortcomings outlined above this dissertation will analyse and identify existing ethical theories that are apt to guide non-anthropocentric human space exploration. The two theories selected for this purpose are the holistic ecocentric theory and the egalitarian biocentric theory. Both of these theories have the additional advantage that they have been widely discussed and scrutinized already. The study of these two theories, particularly against the backdrop of space exploration, will outline the degree of their applicability to resolving the ethical challenges of the age of human space colonisation, thereby contributing to the emerging field of space ethics and helping to address the shortage of ethical guidance on issues of space exploration.

Therefore, taking all of the above into account, the objective of this dissertation will therefore be to show whether, instead of developing a new ethical system from scratch, humankind can apply existing non-anthropocentric ethical outlooks, namely ecocentrism and biocentrism to space exploration or – more specifically – to the colonisation and terraforming of Mars in order avoid irreparable damage to the hitherto more or less pristine planetary environments. In order to fulfil the above purpose, the study is structured as follows.

The first chapter serves to provide information about activities about past, present and future human space activities which will serve as the backdrop for the analysis to be carried out. This will include a brief overview of the history of space exploration and of the poor environmental and humanitarian track record of purely anthropocentric approaches to colonisation undertaken so far. With this in mind, the first chapter will go on to portray the environmental conditions on Mars and the search for life on the planet. It will then will conclude with a description of the challenges involved in turning Mars into a habitable planet, to include a depiction of terraforming, a resource- and technology-intensive by which the planet is to be turned into a second Earth.

The second part of the dissertation is dedicated to an analysis and comparison of ecocentrism, as a holistic theory, and biocentrism, as a more egalitarian theory, in order to provide an ethical framework as an alternative to anthropocentrism to guide space exploration. The analysis begins with an overview of biocentrism, a theory that uses being alive as a criterion for affording moral standing and requires respect for the interests of all living beings. The section on biocentrism will then conclude with a brief look at how biocentrism manages conflicts of interests among living things, analysing the distinction into basic and non-basic needs in order. This is followed by a discussion of ecocentrism, a holistic theory placing supreme moral relevance on the stability and well-being of the ecosystem, thereby reducing the value of individual beings to a mere instrumental role. In this context, the main tenets of ecocentrism will be fleshed out, to include discussions of the principles underpinning the affording of moral relevance to beings and things. The section on ecocentrism then will conclude with an overview of its practicability in terms of the management of conflicts of interests.

The third chapter will then apply the findings of the first part with the findings of the second chapter. In order to avoid redundancy, ecocentrism will be applied to an uninhabited Mars, whereas a scenario where life will be found on Mars will be analysed through the lens of biocentrism. Next will be discussed whether ecocentrism, with its geocentric outlook, can in the first place be applied to Mars and whether Mars – in the absence of indigenous life – can be said to have an ecosphere worthy of protection. On the basis of these findings then the inherent value of a lifeless Mars will be compared with the vital needs of humankind. Then, the biocentric outlook will be applied to a scenario where life is found on Mars. The discussion will focus on a comparison of the needs of the Martian life and the interests of humankind, giving special consideration to the question of whether the latter's interests are of such a nature, for instance survival in the event of a global disaster, so as to override the interests of the Martian microbes.

Relying on an extensive review of theoretical sources form the fields of academia and science, this work aims to provide some guidance on a more ecologic approach to human space exploration. However, space ethics is an ever-evolving field as knowledge about Mars and space continuous to grow. Therefore, as humankind approaches ever closer to the day where Mars colonisation could become a reality, new findings – for instance related to the existence of indigenous Martian life – will continue to shape the outcomes of the discussion undertaken herein.

1 Terraforming and space colonisation

This chapter will outline the contours of the terraforming complex. First, the genesis of plans to explore space, in general, and Mars, in particular, will be presented, including the origins of human interest in space, the development of space-faring technology and the idea to turn Mars into a second Earth. This will be followed by a discussion of why space exploration requires an ethical framework that transcends anthropocentrism in order to avoid a repetition of past tragedies and failures. This chapter will then close with a portrait of Mars itself, including a discussion of its current state, its geological history and the technological processes required to turn it into a habitable planet.

1.1 Creating context: the road to space exploration

The opening of the space frontier took place in 1957 when the Soviet Union launched the Sputnik satellite (Hargrove, 1986, p. IX). The build-up to the space race that ensued had been fuelled by military competition, first between Nazi Germany and the Allied Nations, then between the Soviet Union and the United States (Cheston, 1986, p. 27). However, since exploration had been driven by Cold War competition between the two power blocs, there was a sharp decline in the funding of space activities once this competition came to an end in the late 1980s. This was accompanied by a shift in public opinion, including calls for a stronger focus on terrestrial issues instead of investments in spacefaring activities (Panagiotarakou, 2016, pp. 50-51). Setbacks such as the 1986 Challenger disaster and the difficulty that NASA faced in keeping the public interested in space exploration[1] while working within a tight budget likely exacerbated this trend[2] (Brin, 1986, pp. 6-7).

The period of relative dormancy, however, more recently gave way to renewed efforts to explore space, a development partly fuelled by private companies such as SpaceX and Virgin which are among others in the market to develop tourism or the rights to mine resources on asteroids. In the past decade, the United States passed legislation in support of the

[1] However, public disinterest in the less mundane side of astronomy goes back to the days of the ancient world. This is perfectly illustrated by yet another likely apocryphal tale about Thales of Miletus. In said story, Thales reaps laughter after falling into a ditch while gazing at the sky (Panagiotarakou, 2016, pp. 55-56).

[2] Prior to this decline, however, human space activities also produced some tangible effects. While the age of space exploration gave new impetus to ecological movements as pictures of Earth taken from outer space highlighted its vulnerability (Hartman, 1986, p. 119) as a planet floating in a vast sea of nothingness (Cheston, 1986, p. 26), it also brought within reach of realization long-held dreams of space travel and settlement. This had for a long time been a theme in science fiction literature (Fogg, 2000, p. 205). Ideas for space exploration were put into more concrete terms by Gerard K. O'Neill, who proposed the construction of cylinders floating in space to serve as space habitats and as stepping stones for exploration deeper into space (Baxter, 2016, p. 15). O'Neill's ideas, which also included using space as a source of natural resources to protect the environment on Earth (Munevar, 2016, p. 31), did not come to fruition though, one reason arguably being that his plans relied on the space shuttle which turned out to be a rather unreliable and expensive means of transportation (Munevar, 2016, p. 40).

privatization of space, for instance by issuing private companies legal guarantees for ownership of space resources. These efforts could eventually lead to conflict between these above-mentioned private interests and the interest of the Chinese government[3] (Panagiotarakou, 2016, pp. 52-54). This coincides with a reinvigorated sense of importance that the US government attaches to space activities, as is exemplified by then US President Donald Trump's 2018 announcement to create a space force. These developments, therefore, may be understood as heralding a new competition in space among superpowers, this time between the United States, Russia and China (Szocik, 2019, p. 52). As all this played out, NASA, however, did not sit by idly but launched space missions of its own, with a strong focus on Mars (The Planetary Society, 2023). The reason why efforts are mainly concentrated on Mars may be that it is the most promising planet to potentially serve as a habitat for human colonisation of the solar system (Levchenko *et al.*, 2019, p. 1).

1.2 How Mars became the focus of space colonisation schemes

Hopes for Mars as being a habitable planet were first raised in the second half of the 19th century by the discovery of canals on the planet's surface which were interpreted as evidence of ancient civilizations[4] (Rothschild, 2009, p. 132). Such ideas became a theme of contemporary literature, the most famous example possibly being H. G. Well's novel War of the Worlds. These high hopes, however, were dashed in the 20th century when the Mariner[5] and Viking missions revealed the barrenness of the Martian environment and closer inspection showed the artificial canals to be natural craters (Cheston, 1986, p. 27). However, since Mars' geological features suggest that at some point in its history water was flowing on the planet's surface, there is a possibility that the planet once contained life. This discovery helped spark an interest in looking for a second origin of life in our solar system (McKay 2010, p. 1).

The idea to colonise Mars was for the main part being debated and organised in the context of *The Case for Mars* conferences, which started in 1981. This was accompanied by the belief that through a process called terraforming a breathable atmosphere suitable for human beings could be created on Mars (Fogg, 2000, pp. 205-206). Another factor at play is that the scientific exploration of the universe so far has yielded little in the way of planets that are like Earth (Pilcher and Lissauer, 2009, p. 144), and none of them is believed to be habitable

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[3] Space projects undertaken by the Chinese government include the completion of a space station in 2022 (Tepper and Shackelford, 2022), landing a rover on the far side of the moon in 2019 (Jones, 2022) and sending a rover to Mars in 2020 (Tingley, 2023)

[5] This shocking discovery even prompted then US president Lyndon B. Johnson to muse that "it may just be that life as we know it, with its humanity, is more unique than many may have thought." (Cohen and Cox, 2019, p. 69)

for humans (Pilcher and Lissauer, 2009, p. 153). Mars, however, being relatively Earth-like, became the target of colonisation efforts (Lee, 1994, p. 90).

This has led to a greater push to go to Mars, and such efforts are now no longer undertaken by government space agencies alone (McKay, 2019, p. 317). For instance, SpaceX, which is owned by Elon Musk, has already developed detailed plans for terraforming Mars and "making humanity multiplanetary" (SpaceX, 2022a). This includes plans for spacecraft to provide shuttle services between Earth and Mars (SpaceX, 2022b); considering that now it seems to become technologically possible to send humans to Mars, at least on a one-way trip, such projects seem less fantastic than they used to (Levchenko *et al.*, 2019, p. 1). Missions to Mars could take several forms such as shorter missions by smaller crews, the establishment of longer-term research outposts, settlements for larger populations numbering thousands of people and terraforming projects (McKay, 2019, p. 1). With these possibilities on the horizon, it is worth looking at the themes and ideas that motivate them.

1.3 The theories underpinning the colonisation of Mars

While early on in the space age there were fears that the exploration of other planets could create an attitude towards the Earth as that of a disposable planet (Hartman, 1986, p. 121), the exploration of space can help humans understand more about the processes on Earth and foster a more respectful attitude towards the planet. An example of this is the exploration of Venus[6], which helped scientists gain an understanding of the effects of an uncontrolled greenhouse effect (Schwartz, 2013, p. 5). There are also fears that an overreliance on technological progress – which is the driving force behind Mars colonisation efforts – is what has caused current environmental problems in the first place (Hartman, 1986, p. 123). However, this ignores the possibility that exploration may be a feature of our culture as it enables humankind to discover something new place in order to build new and better worlds (Golley, 1986, p. 221-222). Exploration may also fit humankind's natural curiosity and provide access to a vast amount of resources which are urgently needed (Hartman, 1986, pp. 124- 125), thereby helping humankind save resources on Earth (Hartman, 1986, p. 129).

This last point dovetails with the argument that space exploration contributes to improving life on Earth. An instance of this is the use of satellite technology to better understand weather and climate patterns (Schwartz, 2013, p. 5), a point of even greater importance in the face of the current debate on climate change. Space technology not only can help humans to understand nature, but also can be useful in managing and preserving nature, for instance by

[6] While in some respects similar to Earth, Venus has a carbon-dioxide-rich atmosphere which causes an uncontrolled greenhouse effect and a surface temperature of 477°C. For more information, see Rothschild, L. J. (2009) 'A biologist's guide to the solar system', in Bertka, C. M. (ed.) *Exploring the Origin, Extent, and Future of Life. Philosophical, Ethical, and Theological Perspectives*. Cambridge: Cambridge University Press.

the use of geostationary satellites (Ulhir and Bishop, 1986, p. 192). While this is a useful application, one should not overlook the risk posed by the pollution of the space environment by debris[7] [8] (Ulhir and Bishop, 1986, p. 196). Another example of the positive effects of spacefaring activities is the close link between space technology and medical applications such as imaging and scanning technology which helped to improve the quality of human life (Levchenko *et al.*, 2019, p. 3).

Furthermore, the colonisation of Mars can be regarded as a contribution to the development of humans as a species (Levchenko *et al.*, 2019, p. 2) A past example of such development is the growing consciousness of the Earth's vulnerability and the rise of ecology in the wake of humankind's first advances into space (Callicott, 1986b, p. 244). Going to space might help humankind furthermore help experiment with different societal forms, thereby reducing potential for political conflicts and opening up avenues for putting into practice alternative visions for society[9] (Hartman, 1986, pp. 135-136). The idea of development and better is also reflected in the notion of space being the ultimate challenge for humankind, a notion based on the idea of *Frontierism*, according to which overcoming obstacles produces virtue. (Yorke, 2016, pp. 68-69). However, space exploration can also be viewed less favourably, namely "as a jingoistic boondoggle – the ultimate expression of a crazed technological society that insists on carrying through whatever mad schemes have become technologically feasible" (Briggs, 1986, p. 121).

The main reason presented is arguably the survival of the human species. Even in the early stages of spacefaring, O'Neill noted that a civilisation that manages to colonise space is practically insured against being extinguished by cosmic disasters (Munevar, 2016, p. 44). This idea could even be taken one step further by noting that not pursuing space colonisation dooms humankind to certain extinction in the face of looming disasters such as the explosion of the sun or asteroid impacts (Hartman, 1986, p. 132). However, while the laws of physics may not limit interstellar space travel, the prospects to do so are rather faint at the moment owing to the vast amount of energy needed to propel even a tiny spacecraft through interstellar space

[7] In this context, Williamson highlights the large degree to which planetary surfaces have been polluted by spacecraft since 1959. For more information, see Cockell, C. (2007) Review of *Space: The Fragile Frontier* by M. Williamson. *Science Direct*, 23, pp. 186-187.

[8] The problem was deemed severe enough to even catch the attention of the United Nations and to warrant discussion of the topic by the United Nations Committee on the Peaceful Uses of Outer Space (UNOOSA). For more information, see UNOOSA (no date) *Space Debris*. Available at: https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/index.html.

[9] Space colonies could – in theory – provide the stage on which utopian ideas of a diversity of libertarian communities of any political flavour flourishing in the absence of strong central states could play out (Wolff, 1991, p. 134)

at a meaningful speed[10] (Sutter, 2019), and, therefore, colonisation of Mars, for instance, would not ensure continued existence of humankind in the event of a solar explosion. Furthermore, recent history has shown that humankind may now be able to divert the course of asteroids, therefore making it unnecessary to leave Earth to be sheltered from asteroid impacts (Tavernier, 2022). This is supported by Callicott's observation that space exploration will always be reliant on support from Earth (1986b, p. 229). While technology has arguably made great progress in the meantime, humankind's most stellar outpost in space – the International Space Station – also could not operate without technical support services based on Earth (NASA, 2020). Whatever the state of technology may be, the idea to spread human civilization across the solar system has found support among wealthy and influential figures such as Elon Musk (head of the aforementioned company SpaceX), who cites the preservation of the light of consciousness, a possible hint at the ratio-centric ideas behind such efforts – as a reason to go multi-planetary. It should be noted, however, that preserving consciousness alone may not be a sufficient reason to colonise space; rather, preserving the moral integrity of human space exploration should be aspired to (Levchenko *et al,.* 2019, p. 9). This holds especially true for the space environment where the instrumental value which is afforded to nature on Earth (Fogg, 2000, p. 207) may no longer play a role because of a lack of interdependency between the environment and humankind (Lee, 1994, p. 90).

1.4 Why anthropocentrism is insufficient to guide human space exploration

Without proper ethical guidance, space exploration may lead to disastrous consequences. While this is certainly a bold statement, it is arguably bolstered by the rather poor environmental track record of industrialized society (Marshall, 1993, p. 227). As mentioned earlier, harmful effects on other planets could be even worse within an anthropocentric approach than they are on Earth, given that the space environment has no instrumental value for humankind, at least not an easily perceptible one (Lee, 1994, p. 90). Furthermore, since terraforming involves the complete re-arrangement of the environmental make-up of a planet (Golley, 1986, p. 219), there is the question of the right way to progress if life were discovered or suspected to exist there (Levchenko, 2019, p. 8). This causes a likely conundrum since the contemporary anthropocentric and necessarily earthbound ethics comes to its limits once humans leave planet Earth (Moore Daly and Frodeman, 2008, p. 139) as the place that shapes and supports human life (Fogg, 2000, p. 207). While microbes on Earth may play an instrumental role for the survival of humankind, on Mars, for instance, they might play a rather different role (Cockell, 2016, p. 168). On the other hand, rescinding any attempt to explore or colonise Mars due to the presence of microbes might seem implausible to many

[10] Studies also seem to suggest that sustainability and energy requirements may actually place a limit on how far from the sun one can venture into space. Any extraterrestrial life forms, provided they exist, would likely face similar problems of overcoming energy shortages in inter-solar space (Williams, 2023).

since this would involve affording to Martian microbes a better moral standing than to terrestrial microbial life (Smith, 2016, pp. 202-203).

Even if Mars is a dead planet, a purely geo-centric and anthropocentric point of view could make humans fail to realize the value and uniqueness even in seemingly lifeless objects and sites (Rolston, 1986, p. 154). Such sites may even have aesthetic value as argued by McMahon (2016, p. 214), which would be lost after the wholesale re-arrangement of the planet's ecosphere mentioned above. Furthermore, pollution of space could be a problem if an Earth-first strategy were adopted and dirty industries be outsourced to space (Reiman, 2009, p. 83). This could even lead to the judgement that Mars or other planets seemingly supporting no life have no value at all for humankind (Lee, 2004, p. 100). Such an approach would place large parts of the solar system at risk of losing value in the eyes of humans, eventually leading to ethical double standards for Earth and for space (Fogg, 2000 p. 209). For this reason, there are even calls for a new approach to ethics – a new Copernican revolution – in order to satisfactorily handle the problems likely to be encountered in space exploration (Moore Daly and Frodeman, 2008, p. 140).

1.5 A portrait of Mars

Mars – despite once being the object of romantic ideas about advanced civilisations (Levchenko *et al.*, 2019, p. 1) – has a rather harsh climate that appears not suitable for sustaining life (McKay, 2010, p. 1) and a much thinner atmosphere than Earth, with average temperatures hovering at approximately minus 60 degrees Celsius (NASA, n. d.). Owing to the thin atmosphere, there is also a high degree of solar radiation on the planet's surface (Rothschild, 2009, p. 134). As the conditions found on the planet can likely be compared to early Earth or Earth at the time when life originated (McKay, 2010, p. 3), no organism living on Earth could survive the current climate on Mars (McKay and Marinova, 2001, p. 89). The landscape on Earth that is closest to the conditions on Mars would be the interior of Antarctica, in whose interior plant life in the form of algae and lichen is confined to an existence beneath the surfaces of sandstone rocks. As will be discussed later, this kind of life could be the first to be settled on Mars once the planet's atmosphere will be more supportive of life (McKay and Marinova, 2001, p. 104).

Throughout its geological history, however, Mars has not always been a planet so barren and lifeless. It is assumed that the planet once had a rather thick CO^2 atmosphere (Fogg, 1998, p. 417), which would have made the planet much warmer – as can be seen on Venus, which is much hotter than Earth because all CO^2 is trapped in the atmosphere (Rothschild, 2009, p. 131). Whatever happened to Mars' early atmosphere is not entirely clear though; it might have been degraded through erosion caused by the impact of celestial bodies or stored in minerals on the planet (Fogg, 1995, p. 6-6). Another factor could be that too much

CO^2 was stored in carbonates, i. e. mineral salts, and there was no mechanism to return sedimented CO^2 back to the atmosphere (McKay and Marinova, 2001, pp. 95-96).

Geological features of Mars are arguably a sign of the previous existence of water. While the canals once supposed to be signs of an ancient civilization turned out to be features of the planet's natural geology (Cheston, 1986, p. 27), the Martian landscape in part seems to have been shaped by flows of liquids (Rothschild, 2009. p. 133). This evidence points to the presence of considerable amounts of surface water on early Mars (Beech and Comte, 2022, p. 142). The question then is if this water is still present on Mars or beneath its surface. Likely locations of water resources are the polar ice caps on Mars – which present a climate similar to some places on Earth (Rothschild, 2009, p. 134) – the permafrost soil or underground reservoirs (McKay and Marinova, 2001, p. 98).

1.6 Traces of life on Mars

While the discourse and literature of the 19th century teemed with a belief in the existence of life on Mars, as exemplified by H. G. Wells' novel *War of the Worlds*, the scientific exploration of the 20th century brought rather sobering news. For instance, the Viking mission failed to detect life on the surface of Mars (McKay, 2010, p. 4). Furthermore, analysis of the surface soils revealed that they are not fit to support any vegetative life due to their chemical composition (Beech and Comte, 2022, pp. 140-141). Despite such rather sobering discoveries, there is still a faint possibility of life existing beneath the planetary surface (McKay, 2019, p. 318). For instance, many of the building blocks of life, such as sulphur, are thought to be present on Mars (McKay and Marinova, 2001, p. 94). However, as it appears, any life found would be microbial in nature (Smith, 2016, p. 195), the probability of which is further bolstered by the fact that back on Earth microbes can be found in places with an extremely harsh climate, such as under the surface of the ice-sheet in Greenland[11] (Moore Daly and Frodeman, 2008, p. 145).

In the event that traces of life or organic matter were found on Mars, such traces would still have to be tested to find out whether they are of biological or chemical origin. While this is in general not a difficult process (McKay, 2010, p. 5), it could be complicated since human knowledge of biology is related to Earth (Moore Daly and Frodeman, 2008, p. 145) and life on other planets could be based on an altogether different biochemistry – for instance on silicon instead of on carbon polymers (Callicott, 1986b, pp. 237-238). Here, the Lego principle offers a way out: this procedure is based on the assumption that in biological matter, the building

[11] The first evidence of life in glacial environments was found in the late 1990s. Ever since research in this area has intensified and it was discovered that microbes in such environments are "as biologically active as those found in warmer soils as far south as the Mediterranean." (Poppick, 2016).

blocks that make up life are arranged unevenly, whereas in chemical matter, they are arranged evenly (McKay, 2010, p. 6). Remotely controlled robots could therefore be deployed on Mars to check for biological amino acids with an unequal distribution of building blocks (amino acids and fats). Such an approach would enable humankind to find out if there is any trace of life on Mars (McKay, 2019, p. 3). However, any attempt to find traces of sub-surface life or even fossils so far has turned out unsuccessful. Life-finding missions are further complicated by the fact that any life existing on Mars is probably found far below the surface. For instance, on Earth life has been found at a depth of several kilometres below the surface (Beech and Comte, 2022, pp. 140- 141). It may therefore be rather difficult to know any time soon whether life exists or ever existed on Mars[12].

The bleak picture however might change if a definition of life that differs from the current terrestrial outlook is employed. For instance, Callicott suggests that a more general definition of life as a property of planetary surfaces experiencing cycles of self-organization, reproduction and self-disintegration be used. Such a cycle could be carried on infinitely and constitute something akin to an evolutionary process[13] (1986b, p. 237). Such a definition, however, would remain rather controversial, having implications that go beyond the question of space colonisation and presenting humankind with a practically unsolvable ethical conundrum even here on Earth[14].

1.7 The challenges involved in colonising and making Mars habitable

In general, space colonies can either be built on planetary surfaces or in planetary orbits (Golley, 1986, p. 214) in the form of biospheres floating in space (Fogg, 1998, p. 415). Possible examples are the O'Neill[15] cylinders, which were envisioned to serve as a stepping stone for space exploration (Baxter, 2016, p. 15). On the surface of planets like that of Mars with its harsh climate, systems for life support, gravity and protection from radiation will play

[12] As concerns the existence of previous life on Mars, there is an ongoing discussion whether meteorites of Martian origin found on Earth indeed contain evidence of life. While the existence of biological traces in these meteorites has not been proven conclusively, traces of certain elements point to the habitability of Mars earlier in its history (Beech and Comte, 2022, p. 150).

[13] This argumentation could succeed in at least somewhat meeting the criteria of NASA's definition of life which runs as follows: "Life is a self-sustaining chemical system capable of Darwinian evolution" (NASA, 2023).

[14] This is beautifully reflected in the debate on whether inanimate objects deserve moral consideration. In this context, Goodpaster noted that the extension of moral consideration to inanimate objects was incoherent because they did not possess interests and therefore could not be harmed or benefitted (Goodpaster, 1980, p. 282).

[15] Gerard K. O'Neill was a physics professor at Princeton University. There, he developed an interest in space colonisation and became an advocate for the settlement of space by humankind. His first book *The High Frontier* highlights the benefits of human space exploration (Space Studies Institute, 1993).

an essential role. Therefore, human needs will have to be taken care of more extensively than during the more minimalist approaches characteristic of previous space exploration (McKay, 2019, p. 1). This also concerns the level of mental stress on the journey to Mars and during the stay on outposts on Mars, which could be enormous given how little space would be available for privacy (Levchenko *et al.*, 2019, p. 7). As regards travelling to Mars, technological standards appear to make it unlikely that an age of mass migration into space will be ushered in; it is rather likely that scientific outposts will be set up – similarly to Antarctica[16] – for scientific or possibly national prestige (Pyne, 2007, p. 149). However, recent technological developments, for instance the successful launch of the Falcon Heavy rocket capable of delivering large payloads to Mars[17], arguably add more light to the otherwise gloomy picture (Levchenko *et al.*, 2019, p. 2).

Even if colonisation were conducted on a smaller scale by deploying small scientific teams, their outposts would be heavily dependent on Earth because the technology needed to survive on Mars cannot be produced on site at the moment, which also applies to the equipment needed for scientific exploration. Therefore, Mars would not be an alternative site for humans to live independently of Earth (Levchenko *et al.*, 2019, p. 2-3). This seems to echo observations made almost four decades ago by Golley, who noted that the mechanical systems on which space exploration is built upon will result in a dependence on Earth (1986, p. 215), which defeats the purpose of going to Mars to save humankind in the first place. Conducted on such a reduced scale, Mars exploration and colonisation may then fail to keep the general public interested, as happened in the 1980s and after the Cold War (Panagiotarakou, 2016, pp. 50-51). This does not mean, however, that colonisation of Mars is doomed to fail since there is a different avenue to explore, namely that of biological solutions (Golley, 1986, p. 216). Relevant approaches have come to be subsumed under the umbrella of terraforming, a term first coined by the science fiction genre[18] (Fogg, 1998, p. 415). Fogg (1995, cited in Fogg, 1998, p. 415) defines terraforming as follows:

> "… a process of planetary engineering, specifically directed at enhancing the capacity of an extraterrestrial planetary environment to support life. The ultimate in terraforming would be to create an uncontained planetary biosphere emulating all the functions of the biosphere of the Earth—one that would be fully habitable for human beings."

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[17] The Falcon Heavy rocket forms part of the Falcon launch vehicle family completed by the Falcon 9 rocket. As of 2020, over 200 Falcon rockets have been launched, making it the most-used U.S. launch vehicle (SpaceX, 2021).

[18] Arguably, the term terraforming was first used by science fiction writer Jack Williamson in the short story *Collision Orbit* of 1942 (Genta, 2022, p. 10)

Given the above information, how would terraforming look on Mars? In short, the procedure would be conducted as follows: First the temperature of the planet has to be raised by means of introducing greenhouse gases in order to trap solar heat on the planet; then, the ice at the polar caps will melt to release water; as a next step, nitrogen and carbon dioxide would be released and the precipitation would help vegetation to grow and then oxygen generators could help to raise oxygen levels to acceptable levels. All in all, the process could take two centuries to be completed (Lee, 1994, p. 91).

While the overall process does not sound too complex, there are some details that need to be considered. As noted by McKay and Marinova, the first step would be to decide whether the goal is to create an atmosphere with or without high levels of oxygen; in the first case, terraformed Mars would resemble early Earth (2001, p. 91). With high CO^2 levels and low oxygen levels, micro-organisms could survive. The current oxygen levels would be sufficient for such purpose, provided that the overall atmospheric pressure were increased (i.e. a thicker atmosphere is produced). Levels of CO^2 would have to increase more significantly to achieve sufficient warming (McKay and Marinova, 2001, pp. 91-92). The difficulty in creating an oxygen-rich atmosphere is a result of the need to convert CO^2 into oxygen, a process that requires a biosphere[19], and the requirement to prevent the release of additional CO^2 into the atmosphere as a result of decaying organic matter (McKay and Marinova, 2001, p. 100). However, even an atmosphere rich in CO^2 would offer advantages to human beings: the thicker atmosphere would provide protection from cosmic radiation and pressure suits could be replaced with breathing gear (Fogg, 1998, p. 416).

Whichever course is settled on though, the question remains as to whether there is enough CO^2, oxygen or any other gas needed available on Mars. Since the high costs involve forbid the importation of these elements to Mars, hopes are based on stores available on Mars (McKay and Marinova, 2001, p. 94). The polar ice caps consist of a layer of frozen water covered by a layer of frozen CO^2 (Beech, 2022, p 437). Another way would be to free CO^2 from the planet's regolith[20], which would only require modest temperature increases (Fogg, 1998, p. 417). However, CO^2 may also be stored in minerals such as carbonates, from which it is difficult to release as such a process requires extremely high temperatures (McKay and Marinova, 2001, p. 96). According to more recent estimates, then, easily accessible CO^2 is not available in sufficient quantity to achieve sufficient warming. However, more deeply located reserves seem to be ample enough to enable the creation of a sufficiently thick atmosphere (Beech, 2022, p. 451) Tapping such reservoirs could require harsh methods such as

[19] Given the efficiency of the biosphere on Earth, this process could take more than 100,000 years (McKay and Marinova, 2001, p. 100).

[20] The regolith is the layer of soil up to a depth of one kilometre (NASA, 1977).

underground nuclear explosions, heat beams (Fogg, 1998, p. 418) or causing comets to impact the Martian surface (Beech, 2022, p. 451).

But how to achieve modest warming to release at least some CO^2 stored in the poles then? The best way apparently is the use of super greenhouse gases, which are more potent than CO^2 and are required in small amounts only. It is, however, not possible to transport them, therefore they have to be found on Mars or be produced there, which could be possible with present technology (McKay and Marinova, 2001, p. 101). According to estimates, approximately 100,000 tonnes of such greenhouse gases would be required per year, which is only a small quantity compared to the global production of greenhouse gases in the 1970s (Genta, 2022, p. 12). This would solve the problem posed by the fact that these super greenhouse gases would dissolve quickly and have to be replaced at a high rate (Fogg, 1998, pp. 417-418).

Once warming occurs, liquid water would need to form, and meteor finds suggest that there is a high amount of water present on Mars (McKay and Marinova, 2001, p. 98). However, releasing it requires warming the surface and since the sunlight on Mars is not used efficiently the process could take around 500 years to melt all the ice layers on Mars (McKay and Marinova, 2001, p. 99, 100). However, such processes could also be shortened by using more disruptive means such as the use of explosions to destabilize underground aquifers or drilling to form lakes (Fogg, 1998, p. 419). The ground could also be heated mechanically through the use of giant mirrors floating in space and aiming a concentrated beam of sunlight onto the Martian surface (Beech, 2022, p. 458) Also, water could be provided from different sources such as comets made to crash on the planet's surface (Genta, 2022, p. 14).

As it has been shown even the most straightforward approach – a CO^2-rich atmosphere on Mars – is a rather complex process taking thousands of years and requires maintaining the CO^2 level in a delicate balance in order to avoid letting the planet revert to its original condition if levels are too low or avoid causing a runaway greenhouse effect if levels are too high (McKay and Marinova, 2001, p. 101). However, creating a breathable atmosphere seems even more difficult, with required timespans estimated at over 100,000 years[21]. According to Fogg, it seems therefore rather a daunting task to terraform Mars, but it is no longer a fantasy since it takes account of current technology (1998, p. 419). This is contrasted, however, with the rather bleak observation made by Beech that "Mars cannot be turned into an Earth Mark II on any timescale that bears commonality to past human endeavour and/or experience" (2022, p.460).

[21] However, as noted by Genta, projects conducted over such long timespans run the risk of funding running out or being only half-completed (Genta, 2022, p. 10).

2 An ethical framework for space exploration – biocentrism and ecocentrism revisited

Picking up where the previous chapter left off, this chapter will be dedicated to the discussion of a possible ethical framework to guide human space exploration. As was found above, purely anthropocentric approaches to ethics are not ideally suited to satisfactorily guide human action in space, partly due to the rather poor track record of an ethic solely centred around human needs. This is exemplified by the ever-accelerating disappearance of natural species and ecosystems as a result of the expansion of human civilization (Taylor, 2011, p. 4). Therefore, the ethical investigation herein will concentrate on two non-anthropocentric value theories that take different approaches to ethics: ecocentrism and biocentrism The first is based on the idea of holism, giving weight to the integrity of ecosystems at the expense of individual living beings; whereas the latter is based on the notion of ecological egalitarianism (Attfield, 2014, p. 38).

The expansion of rights under biocentrism can be seen as the logical continuation of a tradition under which rights were extended to previously disenfranchised groups, starting with human rights, moving on to animal rights and concluding with the inclusion of all living organisms (Marshall,1993, pp. 227-228). One of the most sophisticated accounts of the egalitarian biocentric view is arguably presented by P. W. Taylor in his book *Respect for Nature*, in which he "emphasizes the moral importance of individual organisms, as opposed to species or natural processes" (Taylor, 2021, p. 120). Ecocentrism, in turn, states the stability of the ecosystem as its key objective (Leopold, 1993, p. 108), thus focusing all its efforts on the achievement of the collective good at the expense of individual beings (Attfield, 2014, p. 38). Important contributions to ecocentric theories were arguably made by Aldo Leopold in his *land ethic*, a holistic theory giving particular consideration to "the integrity, stability, and beauty of the biotic community" (Callicott, 1980, p. 311).

The discussion of biocentrism and ecocentrism will be preceded by a brief detour into more general ideas underpinning notions of values and moral standing. This will include a look at the term intrinsic value used to express the idea that something has a value that is inherent in its existence (Cockell, 2016, p. 168). At the other end of the spectrum lies instrumental value which means that something contributes to the satisfaction of subjective interests (Rolston, 1988, pp. 110-111). Part of the examination will focus on whether there can be such a thing as intrinsic value or valuation in general without a human observer or valuer.

2.1 Intrinsic value and the possibility of objective valuation

The discussion of notions of intrinsic value goes back to Ancient Greek philosophy. There, the idea of the inherent goodness of pleasure, for instance, was discussed in a number of Platonic dialogues (Zimmermann and Bradley, 2019). This idea plays an instrumental role in theories of utilitarianism, which use pleasure and pain to measure the rightness of an action (Sargent, 2005, p. 1034). Accordingly, the ability to feel pleasure and pain became a standard to judge the moral value of beings (Rolston, 1988, p. 106), as for instance in sentientism, which affords moral standing to some animals (Brennan and Norva, 2022). This point of view is arguably based on an anthropocentric perspective, which affords some degree of considerability to the suffering of animals – even though they may be somewhat removed from the suffering of human beings (Hurka, 2006, p. 375). As concerns the valuation of all living beings or even entire species – as under bio- and ecocentrism, it remains to be seen whether one can move away from an anthropocentric perspective of valuation. This would require the recognition that a general good for all beings is to "develop their natures" (Hurka, 2006, p. 375). This is compatible with the view that each species has its own distinguishing sets of key traits and that therefore it is illegitimate to cherry pick human traits as supposed evidence of human moral superiority (Taylor, 1993, p. 75).

The notion of a general good for all raises doubts as to whether it is not futile to speak of non-anthropocentric values in the absence of human observers or human evaluation (Attfield, 2014, p. 53), a picture further complicated by the seeming reluctance of nature to abide by human moral standards (Callicott, 1980, pp. 335-336). Is it therefore really the case that without a valuer any object is not subject to ethical considerations and therefore without value (Cockell, 2016, p. 169)?

If not seen through the lens of human values, any object or being may be bereft of any value – be it instrumental or intrinsic – since any such value would be in the eye of the observer and projected on any object that otherwise would merely be carrying out chemical reactions with no value attached to them (Cockell, 2016, p. 169). This attitude to values springs from the modern scientific view dividing reality into an objective physical world and the internal subjective realm; therefore, an object or being may be "valuable for its own sake, for itself, but it is not valuable in itself, i. e., completely independently of any consciousness" (Callicott, 1986a, pp. 142-143). This notion of value being conferred by human beings onto objects may be countered by arguing that rather than projecting value, humans translate signals received by objects into subjective values (Rolston, 1988, p. 113-114).[22]

[22] Rolston compares "seeing" values to the process of "seeing" colours, in which electromagnetic waves are received by the eyes and transformed into colour in the brain, a process that may result in different pictures for beings with a different sight apparatus, e. g. in dogs who have black-and-white vision (Rolston, 1988, p. 141). This notion appears to rekindle memories of the question of whether a falling tree makes a sound when nobody

This notion of the existence of a human-independent universal value is not unheard of in Western philosophy and goes back as far as Plato (Callicott, 1986a, p. 141). The forms – as these universals are called by Plato – help anchor knowledge in an otherwise chaotic and ever moving world, thereby acting as a guarantor of stability (Gottlieb, 2001, p. 181). While the idea of universals as presented by Plato may be regarded somewhat critically when seen through the lens of modern science, there are features in the universe which have a general quality. One of these features is the projective nature of the universe, i. e. its propensity for creation (Rolston, 1986, pp. 154-156). This propensity for creation, here on Earth, appears as nature's tendency to create as many species as possible (Taylor, 2011, p. 157).

Even if one accepted that there are no universal qualities, one could still make the argument that the human-centric ascription of values is not entirely confined to the realm of subjectivity. This is because human consciousness itself cannot be separated from nature – it is rather a result of human biological capabilities (Nagel, 2012). From a non-dualistic perspective, ethical deliberations carried out in the human brain are just chemical and electrical processes (Cockburn, 2001, pp. 56-59), and it appears difficult to accept why these processes should be so much more different than chemical processes underway elsewhere in nature.

The above discussion has hopefully shown that the restriction of valuation to the realm of subjectivity is – if not misguided – at least in dire need of further and better explanation. Particularly in light of the great debt owed by subjective life to objective life (Rolston, 1988, pp. 110-11), it appears all the more becoming for conscious beings to finally acknowledge that they are standing on the shoulders of giants and pay a healthy dose of respect to objective life. This is a gesture already performed by the proponents of the non-anthropocentric theories to be discussed below.

2.2 The biocentric outlook

While the idea that the quality of being alive confers moral standing to living beings has a rather long history and is reflected, for instance in the teachings of Hinduism and Buddhism, the biocentric view is a relative latecomer on the stage of Western ethics, first gaining some popularity through Albert Schweitzer (Carter, 2005, p. 62). In his reverence-for-life ethics, every object that is alive deserves moral consideration due to its will to live (Callicott, 1986b, pp. 248-249)[23].

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is around. Here, too, the tree sends out signals in the form of vibration and pressure waves as it hits the ground; these signals may be interpreted differently by different subject depending on their hearing apparatus. Even with nobody around, the signals would be emitted anyway.

[23] This view is shared by Goodpaster, who in 1978 argued for the extension of moral consideration to non-sentient beings (Goodpaster, 1978) because they have a good of their own and therefore can be benefitted or harmed (Attfield, 2014, p. 39).

As opposed to the holism of other non-anthropocentric ethical theories, biocentrism has a strong egalitarian streak in that it focuses on individual organisms (Attfield, 2014, p. 38-39). While all biocentric ethics share the view that being alive is a sufficient criterion for affording moral standing, the individual streaks of biocentrism differ in how they impart comparative value to members of individual species. Paul Taylor, for instance promotes an egalitarian view arguing that "in principle, all living things are equally morally significant" (Palmer, 2017, p. 102), while for instance biocentric consequentialism as presented by Robin Attfield "argues that expressions of more complex or psychologically sophisticated capacities have higher moral significance" (Palmer, 2017, p. 102). This section will follow the biocentric ethical theory as laid out by Paul Taylor, while giving due consideration to biocentric pluralism as presented by Sterba and biocentric consequentialism proposed by Attfield.

2.2.1 Moral standing in biocentrism

In biocentrism, being alive is generally considered to be a necessary and sufficient condition to having interests that are morally considerable (Goodpaster, 1978, p. 310). This means that the circle of those deserving of moral consideration is widened beyond human beings and sentient animals to include all living things (Carter, 2005, p. 64). Based on the notion that living organisms have a good of their own (Taylor, 2021, p. 120), their well-being is regarded as an end in itself (Taylor, 1993, pp. 67), thereby replacing such anthropocentric and zoocentric criteria as rationality and sentience as cut-off points (Callicott, 1980, pp. 315-316). The ideas underlying such a life-centric view are species impartiality, which denies human superiority and affords inherent worth to all living beings (Taylor, 1993, p. 81), and the notion of all living things being teleological centres of life, pursuing their own good, whether conscious or not, and striving to "preserve [their] existence by protecting and promoting [their] well-being" (Taylor, 2011, p. 45). This means that non-sentient living things such as plants have interests and therefore can be harmed and benefitted in the pursuit of the underlying values of life (Rolston, 1988, p. 109).

While that may be the case, the question remains as to how human beings should be able to ascertain what is in the best interest of non-sentient living beings absent such obvious criteria as reaction to pain that can be observed in sentient animals[24]. Here, Taylor suggests that human knowledge of scientific and biological facts can help understand the interests of living organisms (Taylor, 2021, pp. 120-122). This argument may be countered by pointing out

[24] The reliance on pain as an indicator, however, can be tricky as well since – absent the capacity to use language – it is difficult to say whether a reaction to an impulse is instinctive or if a being really feels pain. This is known as the difference between nociception and pain, wherein "[n]ociception is the sensory process by which we detect damage" and "[p]ain is the suffering that ensues" (Yong, 2022, p. 120). This is reflected in the ongoing debate whether fish feel conscious pain or just act reflexively to impulses (Yong, 2022, pp. 125- 126).

that such attempts amount to nothing more than anthropomorphizing non-sentient living things (Goodpaster, 1978, pp. 322-323). It should be noted, however, increased knowledge of the circumstances and lives of living things may lead to an ever deeper understanding of what actually harms and benefits these beings (Taylor, 2011, pp. 66-67)[25]. An illustration of this is human knowledge about how organisms such as trees respond to environmental influences to improve their well-being, for instance by growing their roots deeper to access water (Rolston, 1988, p. 108). The fact the organisms like plants have no consciousness also makes it easier to assess their interests from an external point of view, thereby evading the problems possibly involved in placing oneself in the shoes of another conscious being, as shown by Nagel, who argued that it was impossible to know what it feels like to be a bat (Van Gulick, 2022).

While arguing whether human beings can know the interests of living things is one side of the coin, arguing whether they are things that can have interests is quite another. There is the notion that living things such as plants do not have interests since all their needs are solely related to carrying out their biological functions which are assigned by human interests alone. Therefore, these living things have no interest in their own well-being since they lack consciousness. For instance, while a tree needs water to grow and survive, the well-being of the tree has value in the eyes of human beings only (Feinberg, 1974, pp. 51-55). However, as Goodpaster notes, such a standard for the award of moral considerability is unnecessarily strict because living things such as plants may be argued to possess and pursue their own interests. This is possibly exemplified by trees having a tendency to care for and heal themselves when injured (Goodpaster, 1978, p. 319). This notion appears to be supported by recent research that shows how trees behave and communicate in more advanced ways than was previously believed, for instance by sharing nutrients with one another[26] (Grant, 2018). Another aspect to considered is that the act of affording interests to living organisms through the lens of human interests may lead to controversial outcomes. It could be interpreted as meaning that only things that serve human interests really matter, an argument which could also be used to justify the disenfranchisement of other human beings or sentient beings (Goodpaster, 1978, p. 319). Furthermore, the idea that wants and desires are a necessary prerequisite for the possession of interests is in itself an example of human-centric chauvinism; the reason is that the selection of the above traits as threshold criteria expose an inherent confirmation bias favouring human

[25] Cf., for instance, the case of Mary, the super-scientist. This thought experiment concerns itself with the notion of whether – despite her perfect knowledge of the physical world – Mary will learn something new once she leaves her black-and-white world and for the first time ever experiences colour. The argument made is that not all information is physical; however, there are also those who argue that knowledge of physical facts is sufficient to understand or to imagine the world (Nida-Rümelin and O'Connaill, 2021).

[26] While the idea of trees and plants as social organisms has also been criticised for being yet another instance of anthropomorphism, even those critics do not deny that plants and trees carry out actions to further their own survival and thus their own interests (Flinn, 2021).

beings over others (Sterba, 1995, p. 193). Before downplaying the importance of biological functions of other living things, one should not forget that first of all human beings only recently entered the evolutionary stage and share the same evolutionary history with all living things (Taylor, 1993, pp. 70-71). It should also be noted that the brain processes that likely constitute consciousness may themselves be nothing more than physical processes (Stoljar, 2022) and that the subjective functions in human beings such as consciousness rely on more basic biological functions (Rolston, 1988, pp. 110-111).

2.2.2. Managing conflicts of interest

Once it has been accepted that all living things deserve moral standing, another issue appears on the horizon: the management of conflicts of interest between human beings and other living organisms. While there are arguably some controversial issues related to managing conflicts of interest between human beings, balancing the interests of non-sentient life and humans is considerably more complicated. This may even be an impossible task since, as noted by Schopenhauer, practicing a lifestyle based on the reverence of life might even be suicidal (Callicott, 1986b, p. 250).

In response to this argument, most biocentric theories in general have adopted a distinction between basic and non-basic needs. This means that where the basic needs of humans and non-humans clash, human needs are prioritized. For instance, Sterba proposes the principle of human preservation to allow aggression against the interests of other species in order to secure one's own basic needs. While such an approach may be feasible in inter-human ethics in extremely limited circumstances only, it reflects the natural preference of one's own species that is found in nature (Sterba, 1995, pp. 196-197). As one progresses beyond basic needs, a holistic approach taking account of the good of the entire ecosystem is pursued (Sterba, 1005, p. 201). However, Taylor – unlike Sterba – seems to abandon a restrictive view of needs and opts for giving priority to some non-basic human needs over basic needs of other living organisms (Taylor, 2021, p. 126). An example of this is the destruction of land to build a library. While arguing that as little harm as possible should be committed in such cases, Taylor introduces a principle of restitution for wrongs committed in the process (Norton, 1987, pp. 266-267). This priority of basic over non-basic needs is also upheld in such theories as biocentric consequentialism where human interests are given preference over non-human interests owing to the former's more developed capacities (Attfield, 2005, pp. 85-86).

The distinction into basic and non-basic needs thus seems to be a unifying principle of biocentric theories, which raises the question as to whether there is a proper definition of basic needs. According to Taylor, basic interests are such that their lack causes "serious harm or deprivation" (2011, p. 271) to a living thing; for human beings, "basic interests are what rational and factually enlightened people would value as an essential part of their very existence as persons” (Taylor, 2011, p. 272). However, while increasing understanding of biology will enable humans to understand the needs of non-human living things (Taylor, 1993, pp. 73-74), finding agreement on what constitutes a basic need among humans is more difficult. While Taylor wonders whether “the right to use paper products always overrides the well-being of the trees that would have to be cut down for the paper” (Taylor, 2011, p. 152), one may point out in disagreement that at least until more recently printed books have played an immensely important role in educating people and building their rational capacity.

Such conflicts could be overcome if humans adopted “the attitude of respect for nature” (Taylor, 2011, p. 313) which will imply ethical obligations towards non-human living things that go beyond purely anthropocentric stances (Norton, 1987, p. 261). While at first this may seem challenging, such an attitude is not entirely new to human beings: respect for the environment and all living beings was an important part of the ethical systems of Native American tribes – although they – seeing nature as enspirited – ascribed value to non-human organisms for entirely different reasons than those proposed by Taylor (Callicott, 1982, p. 310).

Once such conflicts of interest are overcome, it would still be difficult to see biocentrism as being a continuation of a movement of liberation of the hitherto disenfranchised (Callicott, 1989, p. 313). This is largely due to the fact that beyond general recognition of the moral standing of all living things, a ranking system to define whose basic interests are prioritized is introduced (Goodpaster, 1978, p. 323). The introduction of ranked interests does away with any symmetry between human ethics and environmental ethics (Norton, 1987, pp. 265-266), which holds particularly true if one sees moral standing as being related to an inviolable sphere of negative rights (Mack, 2022).

2.3 The ecocentric outlook

Unlike biocentrism, which can be seen as the logical continuation of the struggle for individual rights, ecocentric theories – which were heavily influenced by Aldo Leopold’s *land ethic* – do not lie on the further side of the same spectrum, but rather form a counterpoint to egalitarian theories in that they are “inclined to establish value distinctions not on the basis of higher and lower orders of being, but on the basis of the importance of organisms, minerals, and so on to the biotic community” (Callicott, 1980, p. 319). The theory is based on the premise that humans occupy an ecological niche in the Earth’s ecosystem, whose integrity they should further through appropriate action. This leaves little space for duties to other individuals (Taylor, 2011, pp. 285- 286). Ecocentrism’s focus on the collective good may, however, render it unsuitable as a basis for normative ethics because acts of keeping or breaking promises would lose their moral significance (Attfield, 2014, p. 38). Critics also pointed out that ecocentrism constitutes a form of “environmental fascism” (Carter, 1995, p. 81) for its relegation of individuals to a mere instrumental role serving the good of the ecosphere. This ties in with criticism that in ecocentrism individual rights do not turn on the inherent worth of individuals, but on the welfare of the species. For instance, the value of individual members of a species is upgraded or downgraded depending on whether the species they belong to happens to be endangered (Sagoff, 1993, p. 92). Seemingly taking this criticism to heart, Callicott later adapted his theory to avoid the most extreme conclusions and adopted a concentric circle theory in which individual organisms finding themselves at the centre are awarded a greater share of rights and obligations than living organisms closer to the periphery of the circle (Callicott, 1988, pp. 167-168).

2.3.1 Moral standing in ecocentrism

As previously noted, ecocentrism stands in stark contrast to more egalitarian theories in environmental ethics in that it attaches value not so much to the individual members of the biotic community, but to the stability of the entire system. For instance, in a grave departure from animal liberation theories, it allows for the hunting of animals (Callicott, 1980, p. 311). This means that systems and species become the bearers of moral value. While biocentrists had to grapple with the question whether plants and trees can have moral standing, ecocentrists have to show whether species or systems can be said to have moral standing.

Ecocentrists argue that scientific findings show that the ecosystem possesses a high level of interdependence, as opposed to being inhabited solely by isolated individual organisms (Callicott, 1980, p. 321). This is based on the notion of the existence of a biotic pyramid through which energy is distributed by means of food chains (Leopold, 1993, pp. 102-105). Therefore, the next logical step to take would be to consider individual organisms as being parts of the biotic community, a move mirroring the integration of human beings into human communities in which individuals are considered to have moral obligations to the overarching system (Callicott, 1980, pp. 321-322). Then, human beings will no longer be intruders, who bring disorder to biotic communities (Leopold, 1993, p. 104), but proper citizens of such communities (Leopold, 1993, p. 97) cognizant of the interests they share with the biosphere (Taylor, 2021, p. 112). This is supported by past cooperation between human beings and the biotic community; Leopold cites the settlement of the Americas by European settlers as an example of human success being facilitated by the ecosystem (1993, p. 98).

Like biocentrism, ecocentrism, too, seems to base moral principles on scientific knowledge (Taylor, 2021, p. 110). The question, however, is how ecocentrists aim to move from scientific fact to moral obligation. While Taylor bases his biocentric outlook on the factual recognition of duties owed to the members of the biosphere (Taylor, 1993, p. 81), Leopold and Darwin, for instance, see ethics as based on moral sentiments extended to members of the community. The circle of bearers of moral standing can be widened over time as the boundaries of societies are enlarged (Callicott, 1993, p. 115). Moral sentiments are based on a recognition of mutual interests and over time "[t]he sociological community thus becomes the ethical community" (Taylor, 2021, p. 112). A historical example of such ethical communities are Native American tribes who at times fostered closer ethical relationships with animals or plants than with human beings belonging to a different tribe, adopting an ecological outlook that faded as lifestyles were Europeanized (Callicott, 1993, p. 128). While – just as Wittgenstein's attitude towards a soul[27] – the idea of an ethics based on moral sentiments may seem arbitrary from the rationalist viewpoint (Taylor, 2021, p. 116) and run counter to the idea of ethics being based on reason (Callicott, 1993, p. 113), it should be pointed out that human beings – though being rational creatures – seem to favour people close to them to others belonging to an anonymous mass (Naess, 1989, p. 177)[28]. However, at the same time, they can develop an affection to greater organizational systems (Naess, 1989, p. 173), a development that may one day be extended from the recognition of a global community of humans enjoying human rights (Callicott, 1993, pp. 126-127) to the entire biosphere. This would be a process in which moral sentiment "may be both amplified and informed by reason" (Callicott, 1993, p. 114).

There is furthermore the question whether collectives such as species can be meaningfully said to be the bearers of moral rights. Critics note that while nation states may enjoy rights in the sphere of international politics, nature features none of the traits that make states legitimate bearers of rights. This pertains to the absence of fixed organizational structures, to include rules for the discharge of duties (Feinberg, 1974, p. 56). This ignores, however, the highly complex level of organization in nature (Leopold, 1993, pp. 102-103), the knowledge of which – in particular the importance of indirect effects[29] on the overall system – is limited (Golley, 1986, pp. 213) and still being studied (Moon and Moon, 2011). Furthermore, it cannot be said that nature does not have any rules for carrying out tasks as natural processes are strictly governed by biological, chemical and physical processes[30] (National Geographic Society, 2022a). There is another parallel between states and nature in that natural collectives such as species are more than just a sum of their parts in that they have interests different

[27] In settling the question of other minds, instead of relying on a logical deduction from visible features and behaviours in other persons, Wittgenstein relies on an affective disposition towards others, recognizing them to have souls (Gaita, 2004, pp. 173-176).

[28] This becomes also obvious when regarding how a moral agent's feelings change when the object of an action is not a stranger but a person close to them (Gaita, 2004, p. 150). Here, attention should be paid to Williams who criticized the notion of impartiality in consequentialism for neglecting existing sentiments and loyalties to others (Brink, 2006, p. 387).

[29] "Direct effects, as the name implies, deal with the direct impact of one individual on another when not mediated or transmitted through a third individual. Indirect effects can be defined as the impact of one organism or species on another, mediated or transmitted by a third." (Moon and Moon, 2011)

[30] Ironically, though, the notion of the environment governed by physical processes, for instance, led to nature being perceived as lifeless and mechanical for instance by Descartes (Callicott, 1982, pp. 297,298).

from those of individual members (Sterba, 1995, p. 192). For instance, the removal or reduction of predator animals from a biosphere may benefit other species on which they prey but may effect a negative outcome for the entire biosphere in which predators play a more important role than for instance domesticated animals (Callicott, 1980, p. 320). Likewise, a negative effect (for instance an attack) on a country may be felt differently by different parts of the population: some may be affected negatively, some positively, while the country as a whole suffers.

2.3.2 Managing conflicts of interest

While ecocentrism attaches some moral standing to individual organisms, their value is only relative to the well-being of the ecosystem (Callicott, 1980, p. 320), which makes the balancing of the interests of individual members of the ecosystem less complex than in egalitarian theories. There is, however, a problem in deciding what is best for the ecosystem given the complexity of processes in nature and the outsized influence human presence alone has on ecosystems[31]. In addition to possessing the required authority, decision-makers would also need the requisite knowledge and enlightened interest in the good of the biotic community. Callicott hence cites Plato's republic as a possible model for an ecocentrist regime (Callicott, 1980, p. 328). It remains, however, dubious whether such a regime would be practically implementable nowadays since the world of Greek small states where social experiments could be entertained no longer exists (Russell, 1972, pp. 118-119). In the absence of an effective enforcement mechanism, a radical ecocentrist regime therefore seems implausible, especially given the fact that having to let people die of starvation to preserve a natural balance seems íncompatible with human ethics (Rolston, 1988, p. 182). A more benign form of ecocentrism, later adopted by Callicott, places the interests of a closer community, for instance close-knit human communities, above the interests of more fare-flung communities such as the biotic community (Carter, 2005, pp. 82-83). This bears an uncanny resemblance to Taylor's distinction into basic and non-basic needs and Sterba's biocentric pluralism, which is based on a mixture of holistic and egalitarian elements (Sterba, 1995, pp. 201-202). While being closer to human ethics, this version of ecocentrism bears little resemblance to a holistic theory. The ecocentric theory rather seems to fall back on a variation of enlightened self-interest in human society to be achieved through education and is revealed to be "less about the intrinsic value of nature than the true nature of human interests" (Taylor, 2021, p 117). Such enlightened self-interest, however, will be more difficult to achieve in light of the ambitious goals formulated by Callicott, who claimed that ecocentrism would "require discipline, sacrifice, retrenchment,

[31] Cf., note Taylor's observation that human action may turn nature into a vast artifact (2011, p. 5)

and massive economic reform, tantamount to a virtual revolution in prevailing attitudes and lifestyles"[32] (1980, p. 338).

2.4 A new ethics for space exploration?

The two theories discussed above as ethical frameworks to guide space exploration instead of anthropocentric approaches have shown shortcomings and promising features. While giving due consideration to nature and non-human organisms, they were met with certain problems: biocentrism at times can either be so egalitarian as to prove an undue burden on human development and life, while ecocentrism with its disregard for individual worth may seem too misanthropic to be considered a serious alternative to anthropocentrism. However, as was shown in chapter 1, space and Mars in particular are fundamentally different from Earth in that in those places humankind is not inextricably linked to the surrounding biosphere and can more easily remove itself from the picture if needed. Hence, the application of the above theories in outer space should be easier than on Earth, which will be discussed in the next chapter.

[32] This would probably also require the global population to shrink; Callicott pointed out that conflicts between the ecosphere and humankind are in part also attributable to an oversized population (1980, p. 326). However, biocentrists may face a similar problem, as for instance Attfield notes that a global population size of approx. 8 billion would be sustainable (1995, p. 88). Whether population growth will decline or level out automatically in the face of growing industrialization, however, remains to be seen. However, a declining of population started to materialize itself for the first time in decades in China in 2022, following al lager trend across East Asia (Minzner, 2023).

3 Discussing mars colonisation through the lens of ecocentrism and biocentrism

Combining the findings of the two previous chapters, this chapter will analyse attempts to terraform Mars through the lens of ecocentrism and biocentrism in order to gain insights to guide human action on Mars and avoid the dangers of purely anthropocentric approaches. Since the differences between holistic and individualistic theories have little bearing on the question of whether terraforming Mars is permissible[33] (Schwartz, 2016, p. 8), this chapter will – for brevity's sake – apply the ecocentric view to a lifeless Mars scenario; this may help determine whether ecocentrism has any relevance as concerns the inherent value of uninhabited landscapes. This will be followed by a comparison of the inherent value of Martian life and the value of humankind's interest in settling Mars as seen through a biocentric lens.

3.1 The value of a lifeless planet judged from an ecocentric perspective

The investigation, however, should ideally be preceded by a brief discussion of whether ecocentrism is applicable to outer space. This is because one could argue that Leopold's land ethic, one of the keystones of ecocentrism, does not concern itself with the extraterrestrial realm since it is based on the kinship and shared origin of all members of the planet's ecosphere (Callicott, 1986b, pp. 245-247). However, during Leopold's time the space age had not yet begun, and therefore outer space does not play a role in his land ethic. The fact that Leopold's land ethic and ecocentrism do not explicitly mention space exploration does not mean that they have nothing to say about the topic. With this in mind, the following paragraph will try to apply the underlying principles of ecocentrism to the challenges of the spacefaring age[34].

3.1.1 Applying ecocentrism to outer space

Callicott's observation that ecocentrism is so Earth-centric that any extension of consideration to extraterrestrial ecosystems could be effected by way of "diplomatic relations" only (1986b, pp. 246-247) seems to be supported by the picture of "the blue globe of Earth hanging in black space" (Hartman, 1986, p. 120). This sense of isolation is heightened by an awareness of the strong link between the well-being of the planet and the prospering of life on the planet (Reiman, 2009, p. 84). One could argue, though, that the evolution of life on Earth

[33] Unlike on Earth where human beings are an integral part of the biotic community (Callicott, 1986b, p. 247), human beings would approach the biotic community on Mars – if existent – as outsiders. The presence of life on Mars, therefore, would pose similar challenges to terraforming guided by ecocentrism and to terraforming guided by biocentrism. The differences between the theories would be cast into sharper relief at a later stage only – once terraforming is already underway or completed.

[34] Such an approach is not unparalleled; in his essay 'Why Greek Philosophers Might Have Been Concerned about the Environment', Rist attempts to identify general principles of Ancient Greek philosophy that could be applied to current environmental problems, problems not discussed by the Ancient Greeks for lack of awareness (1997, pp.20-21).

is inextricably linked to the development of the universe (Rolston, 1986, p. 151), which makes it impossible to see Earth as separate from the rest of the solar system. This notion is supported by the fact that all things that exist in the solar system, including human beings, are made from the same materials (Rolston, 1986, p. 143); furthermore, one can argue that the solar system helps sustain life on Earth: for instance, the sun provides the initial energy that flows through the entire biotic system (Leopold, 1993, pp. 102-104). This is reminiscent of Rolston's notion of the extent to which sentient life owes its existence to the workings of non-sentient beings (1988, p. 109); if one couples this idea with Leopold's observation of the inanimate parts of the Earth's ecosphere belonging to a greater whole (Callicott, 2021, p. 32), one could argue that the space environment also forms part of this underlying life-facilitating stratum of lifeless things. This is exemplified by the important role Mars plays in keeping Earth on its trajectory, thereby assuring the existence of life on the planet (Lee, 1994, p. 98). While this may sound reminiscent of ideas of instrumental value, the acknowledgement of Mars' contribution to the existence of Earth's biosphere can rather be seen as the application of Leopold's idea of the cooperation between land and people to outer space (Leopold, 1993, p. 97). All this suggests that ignoring the link between Earth and outer space could be seen as a display of disregard for the important role non-biotic entities play for biotic life (Rolston, 1986, p. 156).

3.1.2 Is there an inherently valuable biosphere on Mars?

While the above discussion has shown that the Earth's biosphere – while largely an enclosed system – can be understood to include outer space among its integral inanimate parts, one can easily see that this does not provide any clues yet as to the permissibility of terraforming. This is because a terraformed Mars would continue to be a part of the solar ecosphere with its underlying inanimate structure still intact, the only difference being that instead of supporting Earth's biosphere over a relatively large distance, it would be supporting its own domestic biosphere[35]. Hence, it makes sense to investigate whether the current environment on Mars constitutes an entity that can be said to share the traits of a biosphere.

Leopold considers rocks and mountains as valuable parts of the ecosphere, i.e. as indivisible parts of a living organism (Callicott, 2021, p. 34). It should be noted, however, that his definition of land includes soil, water, plants and animals (Leopold, 1993, p. 96). Therefore, it is not said that a landscape consisting of rocks alone would be considered a biotic community. Furthermore, the idea of the land as a biotic pyramid through which energy derived from the sun is dissipated by means of food chains does not seem similar to the processes encountered on Mars. While planetary surfaces certainly are home to chemical and geological processes

[35] Leopold, for instance, cites the Kentucky dust bowl as an example of the deterioration of soil through improper land use (1993, p. 98). One could therefore argue that the revitalization of such a desert place would be beneficial to the biosphere, an argument that could also be applied to Mars.

of self-organisation and self-disintegration (Callicott, 1986, p. 237), which is exemplified by the planet's history of volcanic activity that has continued until the recent past and may continue in future (Cohen and Cox, 2019, pp. 102-103) or the strong winds eroding and shaping the Martian landscape (Cohen and Cox, 2019, p. 87), the link between such processes and the biological processes on Earth is rather weak though. This is cast into even sharper relief if one considers an ecosphere as a field of vitality geared towards species diversification (Rolston, 1993, p. 153).

Another way of bestowing value upon geological processes, however, would be to value them for their "projective tendencies", thereby recognising that it is an invariable feature of the universe to create and destroy planets. This would place value on creative power instead of on the ability to undergo subjective experience (Rolston, 1986, pp. 156-157). While the solar system outside of planet Earth may not have a rich biodiversity with a tendency to diversify species, it has a large diversity of planets, each of them with different geological features (Rolston, 1986, p. 165). This includes the rocky planets closest to the sun, for instance Mercury, Venus, Earth and Mars, and planets such as Jupiter, Saturn, Uranus and Neptun, which are made up almost entirely out of gas (Cohen and Cox, 2019). Just as life and human beings can be seen as an expression of nature's creativity, such planets should be awarded respect for the same reason, instead of being regarded as failed mutations, i.e. as planets that failed to be like Earth (Rolston, 1986, pp. 170-172).

3.1.3 Does ecocentrism permit the terraforming of Mars?

While the above discussion has shown that – from an ecocentric perspective – outer space can be regarded as part of the Earth's biosphere and as a place of inherent value, it does not follow that terraforming Mars is out of the question. This is because while leaving the Martian landscape alone would preserve its integrity and stability (Schwartz, 2013, p. 9), there may lie even greater benefit in a terraformed Mars and in replacing an arid desert with a biosphere teeming with life. While the land ethic values stability, it values stability of a biotic community, which is characterized by energy flowing through "soils, plants and animals" (Leopold, 1993, p. 103). Therefore, a stable biotic community is preferable to a stable lifeless landscape. One may disagree with this, pointing to the intrinsic value of the Martian landscape, but such argument fails to consider the consequentialist streak of ecocentrism, an example of which is the fact that an animal belonging to an endangered species has more value than an animal belonging to a species existing in abundancy (Sagoff, 1993, p. 92). If one then considers that Earth is the only planet in the solar system containing a rich biosphere (Callicott, 1986, p. 238), one must conclude that this places the terrestrial biosphere on a higher ethical plane as compared to the relative abundancy of lifeless planets in the solar system. Human intervention through terraforming could improve Mars' value (Fogg, 2000, p. 209) by creating an even greater evolutionary diversity on Mars if terraforming successfully manages to create an atmosphere and biosphere close to that on Earth. This would bring into existence another planet teeming with a new diversity of life (Schwartz, 2016, p. 9) since – given its unique features – terraformed Mars will not necessarily be an exact copy of Earth. Rather, evolution on Mars would likely follow its own path and develop an ecosystem adapted to the needs of the planet (McKay and Marinova, 2001, p. 105).

Furthermore, it appears somewhat anachronistic to claim that the universe and Mars should be left alone (Smith, 2016, p. 196). This attitude not only bears a resemblance to the Aristotelian notion of the universe as being an unchanging sphere of the divine (Russell, 1972, pp. 206-207), but seems odd given that human activities extend into space already now, including such activities as the use of satellites to help manage the environment (Ulhir and Bishop, 1986, p. 192). Furthermore, Leopold acknowledges humankind's influence on the environment in that he speaks of a partnership between people and the land (1993, p. 97), and the turning of Mars into a fertile planet could be seen as a further instance of such cooperation. In this regard, it is also worth pointing out that in its earlier history Mars used to be a much greener planet (Cohen and Cox, 2019, p. 75) and that Mars in its current condition may be similar to early Earth (McKay, 2010, p. 3). In ignorance of the human-caused transformation of the planet, future visitors to a terraformed Mars would likely assume that the planet had simply entered another phase in its evolutionary history (Schwartz, 2016, p. 15). One could, however, argue that terraformed Mars would constitute a human-made artefact, thereby continuing the trend observed on Earth where the environment is increasingly adapted to human needs (Taylor, 2011, pp. 4-5). Proponents of terraforming cannot point to the argument that owing to its capability of continued existence without humankind's intervention a terraformed Mars would constitute a mere "quasi-human artefact" (Lee, 1993, p. 96) since the Martian atmosphere would be in need of continued management to either keep it from cooling out or overheating (McKay and Marinova, 2001, p. 101).

Ecocentrism, therefore, seems to be more permissive of terraforming than one might suppose; however, the entire process would need to be carried out so as to promote the well-being of the biosphere. At first glance this seems to be the case as a terraformed Mars will be second home to humankind, which might help alleviate population pressure affecting the environment. However, this depends on whether the currently observable stagnation of worldwide population growth will continue. If one assumes that birth rates are influenced by the level of economic development (Nargund, 2009, p. 191), then this trend will likely continue – likely on Mars, too, since space programmes are indicative of a high level of technological and economic development (Szocik, 2019, p. 55). The trend of decreasing birth rates may be intensified by the harsh conditions, resource restrictions and psychological challenges early settlers are likely to encounter on Mars (Levchenko et al., 2019, p. 7)[36]. What also matters here is whether Mars will be a place permissive of social experiments (Hartman, 1986, pp. 135-136) where laws curtailing human activity are passed for the benefit of the biotic community or whether the laws of the countries investing in Mars will prevail (Levchenko *et al.*, 2019, p. 4).

Furthermore, it is unclear whether the benefits of terraforming are outweighed by the harm that the arguably energy- and resource-intensive terraforming process would cause to the terrestrial biosphere and the space environment. This is because intrusive methods like the deployment of nuclear weapons (Fogg, 1998, p. 418) and resource-intensive devices such as giant mirrors floating in space (Beech, 2022, p. 458) may be required to warm the planet quickly enough and to free up the required amounts of CO^2 and water. The number of nuclear weapons required for terraforming is multiple times the size of the current global arsenal (Beech, 2022, p. 446); the dimensions of the space mirrors would be such that the required materials would have to be mined in outer space (Fogg, 1998, p. 418), which potentially jeopardizes the integrity of the space environment. Furthermore, a lack of local resources needed in the terraforming process may also require engineers to have asteroids crash into the planetary surface and release whatever material they are made of into the Martian atmosphere (Genta, 2022, pp. 14-15), thereby causing large-scale damage to the planet. The potential need to carry out on-site mining to sustain the early Mars colonies (Hajduk, 2022, pp. 344-345) could create to a situation where people are not citizens of a biotic community, but rather "conqueror[s] of the land-community" (Leopold, 1993, p. 97).

If one furthermore considers that Elon Musk, one of the most vocal advocates of Mars colonisation in the private sector, cites the need to preserve the continued existence of conscious beings, i.e. humans, (Levchenko *et al.*, 2019, p. 8) as a reason to colonise Mars, one begins to realize that deep-seated anthropocentric motives may be behind the terraforming project. Lofty ideals of changing humankind's approach to nature, which is a cornerstone of ecocentric theories, hence begin to fade into the background. This is reflected in Beech's observation that Mars colonisation will not help solve existing problems on Earth (2022, p. 419), which is particularly true if one considers the huge economic cost involved in the project and that a large shift in attitude toward nature is required to withstand the temptation to mine Mars for its resources in order to recover the funds invested. As has been shown, ecocentrism may permit the terraforming of Mars and may even offer useful ethical guidance to colonisers, but it may be difficult to resist anthropocentric temptations given the stakes

[36]On the other hand, there is also reasonable doubt as to whether a sustainable minimum population, which Levchenko *et al*. put at 5000, can ever be reached (Levchenko et al., 2019, p.6). This highlights the fact that enormous population sizes are required to make a modern economy function (Smith, 2021). At present, it is still difficult to assess how this will change if the recent advances in artificial intelligence and automation continue.

involved. The next section will try to explore whether biocentrism can help open up a different perspective on the terraforming complex.

3.2 Biocentrism applied to the terraforming of a Mars inhabited by life?

As opposed to ecocentrism, biocentrism clearly can only be applied to places where life exists. While so far no traces of life on Mars have been found, life could exist many hundred metres or even further below the surface. For instance, microorganisms were found to live at such depths in regions in Western Siberia (Beech and Comte, 2022, p.141). However, this supports the notion that any indigenous life on Mars would exist in the form of microbes (Smith, 2016, p. 195) and raises the question as to how value would be ascribed to Martian microbes vis-à-vis terrestrial life.

3.2.1 Can value be meaningfully ascribed to Martian microbes?

The question here is whether such microscopic life has inherent value even without displaying any form of consciousness or evolutionary capacities (Cockell, 2016, p. 170). A contributing factor here is that the idea that terrestrial microbes have as much moral standing as human beings or other living things appears rather implausible (Smith, 2016, p. 202). This is because on Earth microorganisms such as bacteria are frequently associated with disease and antibiotics are used to significantly lower the risk of death from bacterial infection (Hutchings, Truman and Wilkinson, 2019, p. 72). While bacteria may also carry out functions useful to human beings, it appears that microorganisms seem to play a minor role only in environmental ethics, which is exemplified by the idea that microorganisms should be protected only when they do not interfere with the daily life of human beings (Cockell, 2016, p. 172). This is exacerbated by the fact that on Earth one cannot even try to preserve microorganisms where non-vital needs of human beings are concerned because any harm done to bacteria is not even noticeable to the average person[37], which is due to the fact that human life is closely intertwined with the terrestrial biosphere (Lee, 1994, p. 90). A striking example is the daily routine of washing one's hand with soap in order to clean them of dirt and bacteria, which became even more important during the COVID-19 pandemic.

However, it seems that – in the case of microorganisms – value could be afforded on the basis of location, that is – if located in an area where human beings cannot (yet) settle – bacteria and their basic needs should take priority over the non-vital needs of human beings. In this context, Cockell speaks of a duty to preserve microbes where they do not interfere with affairs of daily life (2016, pp. 172-173). This is even more true if one considers the effect that human intrusion may have on pristine environments, as is exemplified by the influence of

[37] This could only be achieved by avoiding certain remote locations in order not to interfere with the local biosphere. However, even remote and previously inaccessible places like Antarctica have begun to become tourist destinations. For instance, over 20,000 people visited Antarctica in 2019/2020 (López, 2023).

increasing tourism on the wildlife in Antarctica (Williamson, 2006, pp. 243-244). As concerns space, the influence of human presence on the space environment was recognized as far back as in the 1950s, when the idea emerged to avoid the forward contamination[38] of extraterrestrial planetary bodies in order to preserve their pristine nature (Williamson, 2006, pp. 113-114). The concern about contamination, however, was likely motivated by legal and scientific considerations rather than ethical ones (Marshall, 1993, p. 231). In order to decide whether this kind of intrusion is permissible, one would have to establish whether human basic needs are at stake since it is unlikely that the non-vital needs of human needs would be considered to take priority over the basic needs of bacteria, given biocentrism's preference of basic needs (Attfield, 2005, p. 86). These considerations are neatly illustrated by the encounters between polar bears and tourists on the Norwegian island of Svalbard, which often result in both tourists and polar bears being tragically killed (The Guardian, 2022). The question here is whether harm to humans and animals could be averted if humans stayed away from the area, tourism to the archipelago arguably not being the fulfilment of a basic human need. While therefore at first it may seem that the apparently different treatment of terrestrial and Martian microbes is indicative of an ethical double standard, it is rather a question of where basic needs of humans collide with the basic needs of microbial life, which is the case in most places on Earth, but not so much on Mars unless going to Mars is a basic human need.

3.2.2 Does biocentrism permit the terraforming of an inhabited Mars?

The reasons usually stated for going to Mars include ensuring the survival of humankind, establishing whether human life could survive on Mars, achieving general technical progress to improve the quality of life, developing as a species and gaining an advantage in national and economic competition (Levchenko *et al.,* 2019, p. 2). The first two, closely intertwined reasons seem more obvious candidates for basic needs and will therefore be analysed at the end of the section. Technological progress, including advances in medical technology, seems to occupy a grey area somewhere nestled between basic and non-basic needs and as such will be the first area to be analysed, followed by development as a species and national competition which will be both regarded through the lens of self- and character development.

One might argue that technical progress, to include medial technology, not only helps to increase the quality of life but also lengthens life expectancies. Such progress, therefore, could count as a basic need, particularly considering that its lack could cause or fail to alleviate "serious harm or deprivation" (Taylor, 2011, p. 271). There are certainly medical developments

[38] Forward contamination means that a spacecraft or a similar space device brings contamination to another planet or celestial body; back contamination in turn means that upon return from space, a spacecraft bring contamination to Earth (Williamson, 2006, pp. 113-114).

such as improvements in medical imaging that are closely linked to space exploration (Levchenko *et al.,* 2019, p. 3). However, there are also recent developments such as telemedicine which provide benefits to patients and doctors and are based on internet technology (Tee-Melegrito and Balingit, 2022), the development of which was not related to space exploration (Science and Media Museum, 2020). Furthermore, medical advances such as the discovery of antibiotics discussed above were made before the beginning of the space age. While medical and technological progress therefore can be cited as being in humankind's basic interest, they are not inextricably linked to space exploration.

Then there is the question whether development as a species, or gaining an edge over other nations, can be counted as a basic interest of human beings. As concerns the latter, one may argue that international competition may bring forth beneficial technological developments such as the internet, which was developed during the Cold War (Science and Media Museum, 2020). However, there are other factors that can act as a catalyst of innovations, such as environmental concerns and resource shortages that contributed to the widespread development of electric cars (Matulka, R., 2014). Furthermore, fierce international competition may also result in warfare, thereby jeopardizing the continued existence of the human species[39], which the proponents of Mars colonisation strive to preserve. The second question is whether the exploration of space can be regarded as a basic feature of humankind's possibilities because it is part of the human psychological make-up (Williamson, 2006, p. 2). The reason cited for this is that human consciousness, which makes technological progress and space exploration possible in the first place, is a natural occurrence of the universe and should not take a backseat to the rights of microbes; denying human beings the fulfilment of their evolutionary potential would place them on a lower moral rung then microbes (Fogg, 2000, p. 210). While it can certainly be argued that human progress is part of nature, this does not prove that exploration is a basic need of individual human beings since it certainly is not needed "to pursue those goals and purposes that make life meaningful and worthwhile" (Taylor, 2011, p. 272). Since biocentrism is an egalitarian theory, one needs to see how these needs are satisfied at the individual level, and for most human beings, exploring space is certainly not necessary to find meaning in life[40]; indeed – at least in the beginning – very few people will be able or willing to go to Mars since owing to suitability requirements or for lack of

[39] Considering the amount of nuclear weapons likely required in the terraforming process is many times more than the currently available global arsenal (Fogg, 1995, p. 6-18), one might wonder whether a race for the colonisation of Mars coupled with increased nuclear production might not increase the likelihood of nuclear confrontation.

[40] Since after the end of the Cold War, public interest in spacefaring activities waned (Panagiotarakou, 2016, pp. 50-51), to say that human development is linked to exploration would mean that during that period humankind could not find meaning, which arguably is quite an absurd claim.

transportation space (Levchenko *et al.*, 2019, pp. 6-7). Also, while most places on Earth have been explored by humankind (Williamson, 2006, p. 2), on the individual level there are plenty of opportunities to discover something new on Earth and satisfy this curiosity. Furthermore, the need of humankind to explore could also be a result of a culture of exploration which saw human beings not as partners of the biological community, but as its conquerors. Such attitude would in the end prevent human beings from adopting the perspective of the biocentric outlook and realize the common bonds with nature and its inhabitants (Taylor, 2011, p. 44).

This leaves the option of going to Mars to guarantee humankind's continued survival. Survival is undoubtedly a basic need of every living thing, and therefore the question to be settled herein is whether colonising Mars will help further the existence of humankind. Establishing a second home to human beings on Mars would certainly ensure humankind's survival should environmental disasters or war make Earth uninhabitable. However, such disasters can be prevented through global cooperation without relying on space exploration[41], and – as was discussed in chapter 1 – technologies begin to emerge that will help change course of asteroids potentially headed for Earth thereby removing a major threat to humankind and life on the planet. How would Mars colonisation, however, affect humankind's long-term survival beyond the end of the sun's life cycle which will destroy life on Earth (Cohen and Cox, 2019, p. 20)? Since travel beyond the limits of the solar system seems all but impossible at the moment (Sutter, 2019), Mars colonies will have little impact on humankind's continued existence in the long run. However, since the moment when life on Earth will be obliterated by the exploding Sun is several billion years away (Cohen and Cox, 2019, p. 20), there would be enough time to use Mars as a springboard and develop the technologies required to venture beyond the limits of the solar system. This would be a continuation of humankind's advance into space, starting with Earth's orbit, then continuing to the Moon and next venturing to Mars (Williamson, 2006, pp. 8-9).

3.3 Summary of findings

The above analysis has shown that ecocentric and biocentric approaches to space colonisation appear to be far more permissive towards the terraforming of an either uninhabited or uninhabited Mars than one might expect. While naturally more restrictive than a purely anthropocentric approach, both ecocentrism and biocentrism appear to give ample space to considerations of human well-being vis-à-vis either the Martian landscape or microbes flourishing beneath the planet's surface; this, however, is not as surprising as it may seem given the incredible stakes at hand, i.e. the survival of humankind, as is shown in the brief

[41] An example is international cooperation in the fight against climate change which – although producing only modest results so far – offers a reasonable and realistic way to avoid disaster (Mariana, 2023), particularly considering the difficulty involved in getting to and terraforming Mars.

overview of the specific ecocentric and biocentric arguments for Mars colonisation presented below.

As concerns ecocentrism, it was shown that the prospect of creating a second independent biosphere on Mars outweighs concerns about the integrity of the pristine Martian environment, also in consideration of the benefits for the terrestrial biosphere owing to the possible alleviation of population pressures and the implementation of more ecocentric policies on both Earth and a terraformed Mars. The entire process will likely create a greater diversity of life in the solar system, while still preserving the variety of different planetary landscapes. Given the vast input of resources needed, however, it remains to be seen how much damage would be done to the terrestrial and outer space environment in the process. Human history so far largely appears to demonstrate a tendency to destroy natural places (Reiman, 2009, p. 85) and turn them into human-made artefacts (Taylor, 2011, p. 4-5). This phenomenon, however, is not limited to Earth, but also shows itself in the large amount of human-made space debris circling in the Earth's orbit alone (Williamson, 2006, p. 57).

As concerns biocentrism, humankind's need to survive can be seen as a sufficient reason to override the well-being of the Martian microbes and turn Mars into a second Earth. The question is whether that requires full-scale terraforming of Mars or whether approaches can be found that safeguard the interests of microbic life on Mars and the interests of human beings in survival, for instance, by creating outposts on Mars rather than terraforming the planet or terraforming the planet through a slower process in the course of which areas home to Martian microbes below the surface remain untouched. Since the prospects for travelling beyond the confines of the solar system appear rather dim at the moment, one may wonder if colonies established on Mars will in the end suffice to save humankind from extinction once the time comes for the Sun to take its final breath. However, given the rate at which technology has evolved in the past few centuries alone, there is a chance that once that fatal moment comes humankind will long have found a way to visit other stars and solar systems.

The adoption of either biocentrism or ecocentrism can therefore be helpful in guiding Mars exploration and offer a more balanced approach, taking into account both human and ecological needs. Furthermore, once complete, a terraformed Mars could be home to social experiments that contribute to the development of the human species by permitting human life to be organized along the lines of ecocentrism or biocentrism. However, considering the negative impact colonisation has historically had on discovered lands and areas, a little scepticism as to whether financial and political interests will take a back seat to ecological and humanitarian considerations seems warranted. The colonisation of the Americas which was fuelled in parts by profit-seeking motives and a hunger for resources offers a cautionary tale as regards the attainment of more ambitious moral objectives (National Geographic Society, 2022b).

Conclusion

As humankind stands on the cusp of a possible age of space colonisation, the poor environmental track record of previous history of human colonisation provides a necessity for a new ethical approach to human space activities. Given the failures of anthropocentric approaches, this study undertook to show that instead of building a new space ethics from scratch existing non-anthropocentric theories can be used. The aim of the study undertaken herein, therefore, has been to analyse and demonstrate how the two existing earth-bound ethical theories ecocentrism and biocentrism can be applied to the terraforming of Mars as a viable alternative to anthropocentrism.

The investigation consisted of three parts. The first part was dedicated to providing historical and scientific background information, to include information on the history of space exploration and the environmental conditions on Mars. The second part sought to create an alternative ethical framework based on biocentrism and ecocentrism to be used to guide space exploration instead of anthropocentric theories. To this end, the two theories were analysed in terms of their principal tenets and their practicability as concerns the management of conflicts of interests. The final part consisted of the application of ecocentrism and biocentrism to the terraforming of Mars, with the first theory applied to a lifeless Mars and the second to a Mars inhabited by indigenous life.

The study proved that ecocentrism and biocentrism can be applied to and permit the terraforming and colonisation of Mars – if carried out under strict observance of ecological principles and if properly justified – in order to create a greater diversity of life in the solar system or ensure continued survival of the phenomenon of consciousness, i.e. the continued existence of humankind in the event of an ecological disaster. They were shown to be superior to purely anthropocentric approaches in this regard, as they apply stricter criteria than anthropocentric approaches would when it comes to deciding whether human activities in space are permissible.

To provide more detail, the study revealed that ecocentrism is not restricted to the terrestrial biosphere but, by way of interdependence, also extends to the cosmos. While ecocentrism therefore attaches value to the Martian landscape, it does not prohibit the terraforming of Mars since doing so would increase the diversity of biospheres and landscapes in the solar system and would possibly decrease population pressures on existing and future ecosystems by achieving a more equitable distribution of populations. However, some doubts remain as to whether the process can be conducted without causing excessive damage to the space and terrestrial environment. Another lingering question if whether the temptation to mine Mars for resources to make up for investment made can be resisted and Mars can be managed in accordance with ecocentric principles. As concerns biocentrism, however, it was found that microbial life could be meaningfully ascribed value on Mars since there – as opposed to Earth – it is not inextricably intertwined with human life, i.e. value would be bestowed on the grounds of location so to speak. In order then to override the rights of Martian microbes, humankind needs strong justification which must go beyond mere goals of development as a species and technological progress that can and have been achieved through other avenues. It was found, though, that the continued survival of humankind is an acceptable reason to terraform and settle Mars even though at present humankind lacks the capacity to travel beyond the confines of the solar system and escape the destructive force of the explosion of the sun.

Reflecting on the aim of this dissertation, which has been to provide a viable non-anthropocentric ethical framework to guide human space exploration, it was shown that both ecocentrism and biocentrism are applicable to the realm of outer space. The reason is that while they were conceived with the terrestrial biosphere in mind, the interdependent nature of the universe in general and the solar system in particular, firmly embed the terrestrial ecosphere in a wider cosmical context. A combination of the two theories furthermore has the advantage of preparing humankind for two possible scenarios as concerns Mars: that of a planet being a lifeless, barren desert or that of a planet teeming with indigenous life, albeit it microbic in nature. To conclude, it should be noted that the approach taken herein is not so much aimed at placing ideological shackles on or arguing against human space exploration in the first place. It rather serves as a call of warning, not so much of a looming ecological disaster, but of a missed opportunity, an opportunity for humankind to develop as a species and take up a new ethical approach towards the environment and itself.

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