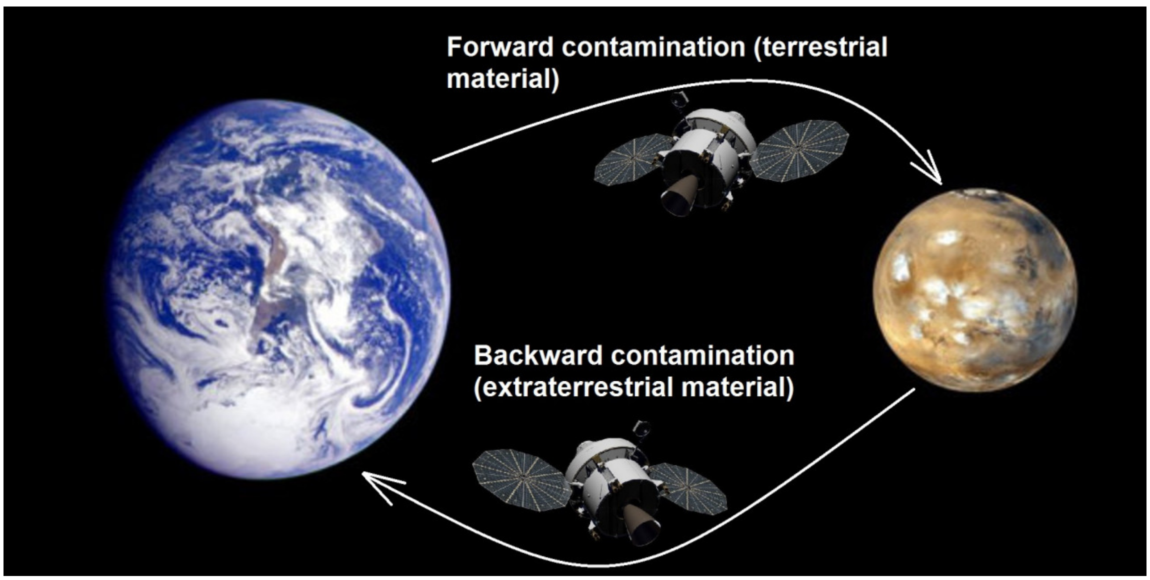
Roskilde University

International Bachelor for Natural Sciences

Basic Project III

An ethical Discourse about directed Panspermia



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1 Abstract

Directed panspermia is a relatively unknown concept which may have severe and irreversible consequences. This paper attempts to bring forward the discussion about panspermia, highlighting the importance of considering the implications of our actions before permanent damage is done.

The following research question was posed in order to deal with this subject:

What are the ethical implications of directed panspermia?

The paper applies deontological and consequentialist argumentation to the ecocentric, anthropocentric, biotic ethical and deep ecological worldviews. Parallels to subglacial lake exploration were made as the ethical issues involved are very similar. In addition, the legal aspects of directed panspermia were researched, as well as how laws pertaining to it are enforced. It was found that anthropocentric views are very much in favour of directed panspermia, and the remaining three can result in a more conservative approach, finding that waiting for technological advancements and better understanding of our universe before acting is a much preferred scenario. It was also found that there is a clear difference between the de jure and de facto legal systems. These results show that, unless one adheres to an entirely anthropocentric view, humanity is not yet advanced or learned enough to be moving life around the galaxy. It also highlights a need for a more aligned or enforced legal system.

2 Acknowledgements

We would hereby like to thank everyone that was involved with improving this project. This includes our opponent groups, their supervisors and others who reviewed the report.

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3 Introduction

Ever since mankind sent their first rocket into space; space-colonisation and the possibility of finding new life has been fervently discussed. As technology advances, the ability to reach further and further into the universe becomes more realistic, more strived for, and more financially viable. While mankind's natural curiosity may make it tempting for us to forego our better judgements and set out in search for the great beyond, it is perhaps more prudent to calmly take a step back and consider the implications.

One of the most important considerations that has to be made lies within the discovery and/or disturbance of extraterrestrial life. A mere space-shuttle during a mission, landing on Mars or another planet, has the potential to contaminate it with terrestrial microbial life, either through careless planning or deliberate actions. The term for such movement of microbial organisms from one planet to another is called panspermia; more specifically, if it is accidental, it is known as planetary contamination, and if it is deliberate then it is known as directed panspermia.

A good example of what directed panspermia could look like is presented by a recent paper. The Genesis project discusses the possibility of spreading terrestrial life across the universe to seed transiently habitable planets. This would be done through the help of sending autonomous space-shuttles into space. These shuttles will then analyze the atmospheres of the body they were sent to and use on-board gene laboratories to create microbial organisms able to live in these worlds [1].

Although there are no cases yet to show what effects directed panspermia may have, it is perhaps possible to make parallels with events here on Earth: for example, the spreading of diseases such as smallpox from Europe to the Americas during the Age of Discovery or the introduction of seemingly innocuous creatures such as the rabbit to the Australian continent, which caused unpredicted and unprecedented damage to the local ecosystems.

Perhaps a more relevant parallel can be drawn between directed panspermia and the recent case of subglacial lake exploration of Lake Vostok. Lake Vostok is a lake located beneath the Antarctic ice sheet. Due to its isolation, it has created an environment completely untouched by its surroundings. Conducting scientific drill missions to uncover how these subglacial lake ecosystems formed may help us gain otherwise unattainable knowledge by allowing a glimpse into a new world. Assuming that life is found within these environments we may discover new, alternative biological pathways for life's development. Yet, such drill missions use unsterilized fluids and thus pose a risk of contamination for these pure environments with foreign organisms - Just like the case with directed panspermia, a pristine environment is endangered through the acts of mankind.

These events can be viewed as an analogy to the imminent age of space exploration as panspermia could just as easily have similarly damaging effects on the concerned systems as well: for this reason, a discussion about mankind's attitude toward the issue of panspermia seems to be unavoidable, and perhaps a discussion that needs to happen earlier, rather than later.

A philosophical-ethical discourse about different worldviews and arguments that speak for and against directed panspermia fits perfectly into the constraint of the current semester. This will include comparisons of major bioethical standpoints by applying consequentialist and deontological argumentation. There will also be a small discourse comparing the results of the discussion against the current legalities applied to directed panspermia. For this reason, the upcoming research question has been chosen to be of major relevance for further discussion.

3.1 Research Question

What are the ethical implications of directed panspermia?

3.1.1 Sub-Questions

What is panspermia?

How do different worldviews value life?

How is directed Panspermia currently handled legally in regards to planets where life could be found, such as for example Europa or Enceladus?

How is the ethical discussion of subglacial lake exploration relevant for the discussion of directed Panspermia and what are its arguments?

How can directed panspermia be argued for and against from a deontological standpoint?

How can directed panspermia be argued for and against from a consequentialist standpoint?

3.2 Life's emergence on Earth

The question of how life began on Earth is a very disputed topic. Many different hypotheses have been proposed, yet no conclusive answer has been found. In the following section, the most sound theories will be described and analyzed.

The first possible hypothesis is the abiogenesis theory - the Earth was formed approximately 4.54 billion years ago [2] and its first oceans appeared soon after, at roughly 4.41 billion years ago. This formation happened during the Hadean Eon. Earth's conditions were extremely hostile for the development of life; the atmosphere had not yet formed, meaning there was no ozone layer to block ultraviolet radiation. Scientists therefore suggested that life was first able to thrive deep in the oceans ca. 4.28 billion years ago [3]. Hydrothermal vents likely provided a good starting point. One reason for why life emerged in the oceans is that water makes for a good shield to protect from radiation.

Abiogenesis suggests that life formed under different conditions than the ones we now see on Earth. A good example would be the previously mentioned, seemingly inhospitable hydrothermal vents. Yet, despite their harsh conditions, these vents are teeming with life, and some fossilized microorganisms show that primitive forms have been living there since ancient times [4].

The second theory, the so-called Primordial Soup Theory, originated in 1924 when Alexander Oparin and J.B.S. Haldane hypothesized that organic molecules can be created from non-living matter [5]. Oparin proposed in his book "Origin of life" that some organic compounds necessary for life cannot be formed in the present Earth's atmosphere. He suggests that the atmospheric oxygen of our young Earth could have provided the necessary environment for organic synthesis. Chemistry has so far determined four key compounds from which life could arise: carbon, hydrogen, oxygen and nitrogen. They are present in form of carbohydrates (saccharides), lipids (used to form cell walls), amino acids (amine and carboxyl functional groups) and nucleic acids (DNA/RNA self-replication). If this theory proved to be correct, one would need to explain how these compounds originated and describe how they cooperate with one another [6].

The next possible theory is the panspermia theory.

3.3 What is panspermia?

Planetary contamination is the biological contamination of extra-terrestrial bodies by humans, whether deliberately or not. This paper will discuss the ethical implications of contaminating foreign bodies with terrestrial life as well as the methods available to promote or reduce contamination accordingly.

Before covering the issues of human-caused contamination, the ways in which life may naturally propagate throughout the universe will be discussed to inform topics later in the paper. The general term to describe the hypothetical propagation of life throughout the galaxy is "panspermia", and within this umbrella term are a number of sub-terms. If the method of panspermia is not as a result of human interaction it is known as "natural panspermia".

There have been proposed theories that intelligent, extraterrestrial beings seeded our solar system, either deliberately, in which case there could be codes hidden, for example, in our DNA, or accidentally, in the form of extraterrestrial waste products dumped on our planet and forgotten. As neither of these theories have any solid grounding, no more time will be allocated to them [7][8][9].

Radiopanspermia is a hypothesis proposed by Svante Arrhenius in his book "Die Verbreitung des Lebens im Weltenraum" (The Distribution of Life in Space) [10]. In this book, he:

"postulates that microscopic forms of life, for example, spores, can be propagated in space, driven by the radiation pressure from the Sun, thereby seeding life from one planet to another or even between planets of different solar systems. [He] based his considerations on the fact that the space between the planets of our solar system is teeming with micrometer-sized cosmic dust particles, which at a critical size below 1.5 μm would be blown away from the Sun with high speed propagated by radiation pressure of the Sun. However, because its effectiveness decreases with increasing size of the particle, this mechanism holds for very tiny particles only, such as single bacterial spores" [11].

This theory; however, was met with a good deal of scepticism, especially as our knowledge of cosmic radiation grew: in 1966 Carl Sagan and J.S. Shklovskii released "Intelligent Life in the Universe" which questioned the longevity of spores under the intense UV radiation of outer space. Further testing on a number of orbital experiments drew significant evidence that the intensity of the UV radiation in space coupled with the distances required to travel were enough to rule out any individual spore travelling the distance to other celestial bodies, but concluded that spores encased in a minimum of one metre thick rock could have sufficient protection from the radiation [11][12][8]. This leads directly to the notion of lithopanspermia.

Lithopanspermia is the hypothesis that life may be transported throughout the solar system encased in large rocks expelled from one celestial body during, for example, a large meteor impact. These rocks may then reach a different celestial body, landing there, and giving any life brought with them a new environment to potentially proliferate.

Within our solar system a likely period during which lithopanspermia could have occurred was that of the Late Heavy Bombardment [13]. During this period the terrestrial planets and moons were hit by an uncommonly large numbers of asteroids, causing high volumes of ejecta to be thrown from their planets into space [14]. It is important to note, that although the existence of the Late Heavy Bombardment is an established theory, it is not the only one, and there are other competing theories; however, that is not the nature of this discussion, and there is sufficient evidence that large meteoric impacts have occurred throughout the history of our solar system [15]. This allows the hypothesis of lithopanspermia some credence, especially when coupled with the fact that, to date, 240 Martian meteorites have been found on Earth. This number could be higher if shergottite meteorites are more conclusively proved to be of martian origin - Bogard and Johnson (1983) found gases trapped within a meteorite that match more accurately Martian atmospheric gases rather than Terrestrial ones [16][17].

As aforementioned, the first evidence of life on Earth are fossilised microbial mats from microbes that existed some 3.5 billion years ago as well as chemical signatures consistent with life that date back 3.8 billion years [18][19]. This shows the earliest life forms starting to proliferate on Earth just after the Late Heavy Bombardment 4.25-3.9 billion years ago [14]. This demonstrates that life started to emerge shortly after the celestial bodies had exchanged a good deal of matter between them, a strong indicator that lithopanspermia may have been involved, especially if Mars already had life at the time, which will be discussed later.

The next large issue with lithopanspermia is the durability and longevity of any microbes that are to be transported on these ejecta. Worth, Sigurdsson and House (2013) [13] found that:

"Material from the surface of a planet can be ejected into space by a large impact and could carry primitive life-forms with it. [They] performed n-body simulations of such ejecta to determine where in the Solar System rock from Earth and Mars may end up. [They] found that, in addition to frequent transfer of material among the terrestrial planets, transfer of material from Earth and Mars to the moons of Jupiter and Saturn is also possible, but rare. (...) [they] also note significant rates of re-impact in the first million years after ejection. This could re-seed life on a planet after partial or complete sterilization by a large impact, which would aid the survival of early life during the Late Heavy Bombardment."

This is an elegant proof that, at least theoretically, life can be thrown into space, thus allowing it to land on a different celestial body. Of course, this could take an incredibly long time; however, Cano and Borucki (1995) [20]:

"revived, cultured, and identified [a bacterial spore] from the abdominal contents of extinct bees preserved for 25 to 40 million years in buried Dominican amber. (...) Several lines of evidence indicated that the isolated bacterium was of ancient origin and not an extant contaminant" [20][1].

There is also some evidence for a 250 million year old bacterium, but there is contention about its validity due to its genetic similarity to modern bacteria [24][25]. A point of note in terms of durability of bacterium can be highlighted through *Deinococcus radiodurans*. This extremophile bacterium can survive cold, dehydration, vacuum, acid, and, very importantly, extremely high levels of radiation. Its resilience went as far as earning *D. radiodurans* a Guinness world record as the "World's Toughest Bacterium" [26]. All of this information brings to light that there is a plausibility for life to survive the arduous journey around the solar system, and potentially further.

3.4 Epistemological questions regarding the discovery of extraterrestrial life

"The search for extraterrestrial life: epistemology, ethics, and worldviews" written by Mark Lupisella [27] has brought up many crucial questions to the way we (mankind) are approaching the theme of extraterrestrial life of different origin. Followingly, Lupisella put forth several key considerations regarding its epistemology [27]:

1. How can we deal with the limitations of knowing only one kind of biology? [27]

2. What will be the criteria for discerning an independent origin of life? [27]

3. What will be the criteria for assessing the biological status (for example whether life exists, its distribution, nature, etc.) of a region or perhaps entire planet? [27]

The following paragraphs will aim to elaborate more thoroughly on Lupisella's notes.

3.4.1 "The 'one data point' problem"

The one data point problem describes the limitation of our knowledge of biology and the application thereof, essentially saying that we have so far only found one form of life. All life on Earth shares the same basic biochemistry and thus strongly suggests a common ancestor. Apart from this, our knowledge is also derived from ecology and evolution. Lupisella sums up all of these aspects as one data point. Extrapolating knowledge from a single data point is limiting and the question arises: how can this limited knowledge of only one data point be used to search for and determine extraterrestrial life [27]?

Lupisella argues that, as we would like to be as thorough as possible in order not to miss out on any chances to discover life, it is of great importance not to harm or destroy other indigenous life that would be from different origin than our own. Lupisella suggests there are an infinite number of lines that could be drawn through one data point. Followingly, confidence coming from

[1] Weyrich, LS et. al contended that Cano and Borucki's results are flawed; however, Weyrich references Fischmann, saying that Fischmann is critical of Cano and Borucki, which is dubious at best; furthermore, Weyrich claims that Yousten and Rippere disproved Cano and Borucki's results, a claim which is invalidated by Yousten and Rippere's conclusion which states "Our results do not disprove the ancient origin of the isolate" [21]. It is perhaps best, however, to show some scepticism of Cano and Borucki's results due to some uncertainty in their accuracy and methods [22][21][23].

extrapolation should be viewed with a critical eye; nevertheless, the usage of today's knowledge about terrestrial biological constraints such as the need for water or organic compounds might bring humanity closer to the discovery of extraterrestrial life. This argument can however also be criticised by the fact that life has continuously found new ways to challenge humanity's preconceptions of what it is. A good example of such a case would be the bacterium *D. radiodurans* [27].

Further options to gain new insights in these fundamental thoughts could be found via the studies of synthetic or simulated life. In addition to the previous paragraphs, this one-data-point challenge can also lead to other, broader questions: How can extraterrestrial life be best protected against negative effects that may come with its study, especially by human presence? Is it even possible for lifeforms of different origin to coexist? How confidently can we come to a conclusion about these issues [27]?

3.4.2 Discerning independently developed life

In his second theme about epistemology, Lupisella addresses concerns regarding the discovery of independently developed life. This discovery would play a key role in the understanding of whether life is common or not. For example, finding life closer to our solar system could imply that it is, in fact, common. This would be due to the assumption that if life were to be found within a smaller range, it would be more likely to be found again farther out. On the other hand, not finding life even in larger areas could indicate a smaller chance of discovery [27].

Finding an independent origin of life would also heavily impact our knowledge on biology, being able to understand how an alternative biological path works could alter how we view our own biological system [27].

In contrast to this, it may not always be obvious, and possibly even very difficult, to distinguish between an independent origin of life and ours. Lupisella continues by describing an email from Bruce Jakosky: in his writing, Jakosky shares Lupisella's view and poses that this distinction of independence may be an even greater issue than assumed. Jakosky mentions that all terrestrial life is bound together by basic characteristics, the usage of RNA, DNA and ATP etc., which can be found in a common ancestor that shares these properties. If we were to go back further in time, we would encounter worlds where RNA and pre-RNA prevailed, with simpler and simpler entities that could be found [27].

The following excerpt from Jakosky's email encapsulates the previously mentioned concerns:

"I suspect that if you pulled something from the pre-RNA world, it might not share enough of the biochemistry with modern organisms to be recognized as necessarily related to it. (...) How would we be able to recognize it as not having come from Earth at a very early time?" [27]

This statement is very critical and touches the firm foundation of our knowledge about life. The example found in the email describes that it would be hard to distinguish whether life forms were of an independent origin from one another, had they spread to other planets, for example Mars, during the RNA or pre-RNA world [27].

Picking up on this concern, Lupisella stresses the importance to mitigate contamination as much as possible in order to allow for better chances of discovery and differentiation of a distinct origin of life. NASA's planetary protection regulations, which are stated more thoroughly later in the report, are trying to appeal to this issue [27].

3.4.3 Biological assessment criteria

In order to align this with the issue of contamination, it should be discussed to what extent the biological status of any planet has to be assessed to allow us to determine whether or not it hosts life. Is the area of assessment just a certain location, region or even the whole planet? And if this process will take place, another major question becomes apparent: What level of confidence is needed in order to make a say about the place's status? How many missions and experiments need to be conducted in order to reach that level of certainty? When thinking about these topics, many other questions buried underneath will be unveiled. Lupisella puts forth a numerous amount, for example "Is life an all-or-nothing phenomenon?". In this case, life, would it exist, could either live widely spread over the whole planet, or not at all. Thinking about the former case, Lupisella questions what density life would need to have; would it need to cover the whole planet, or specific niche areas [27]?

Even though theoretical expectations and likelihood-probabilities could be possible answers to these questions, Lupisella suggests a conservative approach in order to determine broad guidelines. The conservative approach in this case would assume that it is possible for life to exist on a planet, but that it could be sparsely distributed. Assuming sparse distribution, the questions from before come up again: How many times do missions need to be made? And what factors would determine the thoroughness of these missions, for example in terms of depth below the surface? On another note, Lupisella argues that many people would agree with a cautious, safer approach; however, when taking into consideration difficult circumstances or also broader interests, such strict guidelines may arrive at the essential question: how much do we value extraterrestrial life and why do we assign value to it [27]?

Such a question may not be easily answered. For this reason, the comparison between different worldviews and ethical approaches is unavoidable.

4 Different worldviews

Lupisella's essential question marks the importance of elaborating different worldviews - the following paragraphs will establish four stances that each vary in their values. Anthropocentrism, Biotic Ethics, Ecocentrism and Deep ecology will be presented. The latter three may easily be mistaken as having somewhat the same premises. Indeed, parts of their ideology overlap, however, there are fine differences in between. These seemingly insignificant variations may lead to different arguments when approaching the issue of directed panspermia and it is thus relevant to view each one as a separate position.

4.1 Anthropocentrism

Anthropocentrism is a worldview which argues that mankind is superior over everything. It argues that only human life has an intrinsic value, whereas natural resources or other living beings do not and thus only exist to serve the benefit of humans. Furthermore, the value of these resources or beings is based on their usefulness for humanity. This leads to the general assumption that there is no ethical consideration to be made when exploiting natural resources or other living beings [28].

Anthropocentrism can commonly be found in Western societies or religions and many ethicists believe its roots to be found in the creation story of the Judeo-Christian Bible. In the creation story, humans are created in God's image and are told that the world has been made for them. This can be interpreted as mankind being of a higher position than anything else and that every entity, be it life or resource, was made for human benefit. This instrumental view of nature is however not only limited to Jewish or Christian theology and can also be found in other stances, such as Immanuel Kant's moral philosophy [28].

Multiple facets of anthropocentrism exist. The cornucopian point of view, for example, denies the notions of limited resources on Earth or that a potential carrying capacity for human population may eventually be reached. These notions are either exaggerated, or, when faced with a critical situation, mankind would always find a solution in one way or another. This could, for instance, be achieved through technological advancements. Subsequently, people that have adopted the cornucopian stance would argue that implementing laws for the protection of natural resources or the like are unnecessary [28].

Some supporters of anthropocentrism have been criticising certain aspects of its exploitative nature. Still, they do not see the exploitation of nature in itself as a problem; however, as resources are used, it may have adverse effects on mankind's well being. Current environmental issues present a good example of this case: atmospheric pollution has become worse, and consequences such as the rising of sea levels may lead to much misery for populations living near to the water. For this reason, it would be a duty of every anthropocentrist not to further damage the environment. The philosopher and theologist Holmes Ronston III has proposed a better treatment of all living beings asserting that if humanity did not follow that notion, they would be disrespecting the creations of God [28].

Other criticism has been suggested by conservationists such as John Muir and Aldo Leopold that pose two essential challenges to the anthropocentric worldview [28]:

- Why should humans be considered of higher value than other living beings?
- Nature has perhaps an intrinsic value and should not only be judged based on its usefulness for humanity.

4.2 Biotic ethics

By definition, biocentrism is an ethical point of view, that, in contrast to anthropocentrism, extends inherent value to all living organisms and ecosystems [29][30]. Mankind is currently exploiting a multitude of ecosystems and organisms. Applying the biocentric view to this matter would result in the duty that humans should not endanger the integrity of other species or ecosystems they coexist with [31]. The principles of biocentric ethics further define life as a process of safeguarding the propagation of life and securing the survival of all species. Biotic ethics then extends its values to the smallest organisms - microorganisms.

Biotic ethics supports the evolution of new species, assigns life a unique position in the natural world and interconnects all cellular organisms. Based on molecular biology, these principles connect all life through self-propagation of both genes and proteins. Humans share the gene and protein cycle with other organisms and are thus bound to the fundamental moral actions of spreading and sustaining life instead of destroying it. Biotic ethics value the significance of the above-mentioned protein and gene cycles by preserving existing species.

When applying the fundamentals of a biocentric view on a large scale, protecting life throughout the galaxy, the term panbiotic ethics is used. The goal of panbiotic ethics is to disseminate the gene and protein cycle through space in any possible ways. As a subcategory of biotic ethics, which favors evolution, panbiotic ethics appreciates the progressive diversity among new organisms that could potentially evolve in an untried space environment [30].

4.2.1 Interconnectivity of all life through self-replication

One could say that humans are connected to various life forms either through reproduction or through the overall evolution of the species. These two assertions are currently widely discussed in context of the most essential arguments [30][32]. Only organic biological life is able to reproduce by cell division and can thus evolve after adapting to a certain environment in which it lives. Self-reproduction may be recognised as a complex process of transcribing molecular patterns into new DNA sequences which requires a constant flow of information, biological matter and energy [30][32][33]. However, DNA cannot reproduce without the help of enzymes, nucleotides and ATP (energy bearing molecules) [34]. Biological matter thus consists of genetic information stored in DNA sequences and all biological life shares this protein and gene method of self-replication [30][35].

The intricate processes that stand behind well-assigned functions of a protein family and t-RNA molecules may give life a unique value. As mentioned by M.N. Mautner [30], even the simplest cell has countless functions that operate in harmony with the cell environment.

Humans share certain characteristics with microbial life which unifies us with otherwise seemingly diverse organisms. The complex patterns we share are common to all biological life on Earth, moreover humans share over 99 percent of a genome with other humans, over 95 percent with chimpanzees and 90 percent of a genome with mice [36]. In fact, the connection of all terrestrial life can be traced back to a common ancestor as summarized in phylogenetic trees [35].

4.3 Ecocentrism

Ecocentrism treasures the intrinsic value of all species and their natural habitat regardless of any usefulness for the human race. Ecocentrism is a nature-centered view, finding its foundations in ontological principles, that is no distinctions are being made between human or non-human characters. The central aspects of ecocentrism concern ecological groups, i.e ecosystems, species, habitats and populations. In fact, a more holistic approach of ecocentrism proposes an equality of intrinsic value between species and expresses a demand for conserving and protecting the entirety of ecosystems and a protection of populations and species, even from human interaction [37][29]. This focus on ecosystems, while still valuing life, differentiates ecocentrism from biotic ethics. Lives of single components in ecosystems or lives of individual species in certain populations are not as important as maintaining the overall ecological integrity. In particular cases, the reduction of an overpopulated species and similarly the culling of invasive organisms can be considered in favour of ecocentrism [37]. Organisms posses a certain value which is measured depending on the role they play within a larger system [29].

When relating space to ecocentrism, the term astroecology is used. Astroecology searches for the relationships in the plant and animal communities that share common characteristics that could be applied to a cosmic environment [38]. Astroecology revolves around aspects such as radiation, pressure, (micro)gravity, available resources and temperature as well as natural and directed panspermia.

4.4 Deep Ecology

Deep ecology is a movement which seeks to promote diversity in every possible way. Arne Næss and George Sessions, who initially coined the term, have put forth several versions of Deep Ecology [39][40]. Næss proclaims the eight basic principles that form the foundation of the movement [40]:

1. The well-being and flourishing of human and nonhuman Life on Earth have value in themselves (= intrinsic value). These values are independent of the usefulness of the non-human world for human purposes [40].

2. Richness and diversity of life forms contribute to the realization of these values in themselves [40].

3. Humans have no right to reduce this richness and diversity except to satisfy vital needs [40].

4. The flourishing of human life and cultures is compatible with a substantial decrease of the human population. The flourishing of nonhuman life requires such a decrease [40].

5. Present human interference with the nonhuman world is excessive, and the situation is rapidly worsening [40].

6. Policies must therefore be changed. These policies affect basic economic, technological and ideological structures. The resulting state of affairs will be deeply different from the present [40].

7. The ideological change is mainly that of appreciating life quality (dwelling in situations of inherent value) rather than adhering to an increasingly higher standard of living. There will be a profound awareness of the difference between big and great [40].

8. Those who subscribe to the foregoing points have an obligation directly or indirectly to try to implement the necessary changes [40].

The first statement indicates the most vital premise for deep ecology - this premise is also shared by ecocentrism and biotic ethics; however, it does not clearly extend for cases beyond Earth. For the purposes of discussion, this report will assume the premise to hold true for extraterrestrial life as well.

The principles above imply shifts in lifestyle on a personal level as well as nationwide and international political decisions. Particular examples of such changes are however not described. In addition to this, some statements may seem vague or ambiguous: for instance, the third principle states that humans do not have the right to reduce the richness and diversity of life, except if they are necessary to satisfy vital needs - a major difference to ecocentrism whereby humans should not interfere with ecosystems. Vital needs in this case can be interpreted in many different ways. Simply put, a human's needs in a developed country may be satisfied by a safe source of nourishment, water and shelter whereas a human living in a developed country may experience other vital needs such as owning a phone or computer.

Furthermore, changes can also be differently difficult to achieve. Such possibility may often be based on the financial situation of the individual, nation or region. As such, it is important to recognize how the actions to implement deep ecology are subject to change, depending on the individual's state and position they are in.

Compared to ecocentrism and biotic ethics, deep ecology shares the thought of an intrinsic value towards nature; however, deep ecology has a greater focus on promoting species diversity and also suggests ways in which the changes can be implemented - and, importantly, includes the necessity for human needs to be the determining factor whether one should undertake these changes.

5 Contemporary panspermia

This section includes an introduction to the current legal status of directed panspermia - generally referred to by law as interplanetary contamination - and who defines the laws and how. It will also cover the ways in which these laws are obeyed and enforced by both governmental institutions and private companies. This will then be followed by a summary of habitable bodies within our solar system, defining how and why they are relevant to the search for life.

5.1 Legal Aspects of Directed Panspermia

"The Outer Space Treaty entered into force as a binding legal instrument between signatory states on October 10, 1967." - Christopher D. Johnson [41]

The current laws regarding interplanetary contamination are very strict, albeit not very enforced (see below), but surprisingly fluid in their changeability. The laws stem from the Outer Space Treaty, a treaty signed and ratified by 109 countries and signed by a further 23 - all the countries that currently have the ability to potentially contaminate planets abroad such as the US, China, Russia, Mexico, EU states etc. are all ratified members [42]. Article IX of the treaty states that:

"States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose" [43].

The way in which this is put into practise is through the formation of The Committee on Space Research (COSPAR). COSPAR is a platform designed:

"to promote at an international level scientific research in space, with emphasis on the exchange of results, information and opinions, and to provide a forum, open to all scientists, for the discussion of problems that may affect scientific space research. The objectives of COSPAR are to be achieved through the organization of scientific assemblies, publications, or any other means" [44].

During biennial meetings 2000-3000 scientists from around the globe come to discuss matters pertaining to outer-space, including interplanetary contamination, and their recommendations are followed by treaty states [45]. This format also means that the scientific community drives the changes in law based on scientific research rather than any politically charged changes.

The COSPAR Planetary Protection Policy (2011) is a comprehensive guide for space agencies to follow regarding interplanetary contamination; it has guidelines based on mission type (fly-by, orbit, landing) as well as potential habitability of the body in question. Enceladus and Europa, for example, have much stricter controls than Venus [46].

As space travel becomes more commonplace, and military advantages or profits start to become attainable in space, these laws will inevitably become more strained. Ideally the status quo would remain in place and be enforced with due diligence and severity; however, it is not unheard of that countries start breaching international laws once it starts becoming inconvenient or expensive to respect them. A recent example of this case is presented by the Intermediate-Range Nuclear Forces Treaty in which the US suspended the treaty for alleged non-compliance by Russia, followed immediately by Russia also suspending the treaty and the US leaving the treaty permanently a few months later [47]. It is, however, becoming more evident how inefficient the international law is in regards to achieving the goal of stopping contamination. Gustavo Boccardo notes that:

"there are only a very small number of states that have adopted space legislations and only few of them include planetary protection provisions, albeit in a very general manner. ... More specifically, from a review of the participants in Google's Lunar X Prize, there are teams in many states that do not have national space legislations and no supervision is made increasing the risk of forward contamination" [48].

This shows that many countries are not enforcing any international rules, and although some space agencies create their own rules based on COSPAR's recommendations, many do not. Furthermore, private companies are not being held responsible for their actions in space [48]. This is a direct breach of the Outer Space Treaty which states under Article VI that:

"States Parties to the Treaty shall bear international responsibility for national activities in outer space…whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervisions by the appropriate State Party to the Treaty" [43].

SpaceX, for example has no official planetary protection policy shown on their website which indicates they may not have any policy at all, and when written to by the authors gave no response [49]. Israel's recent Beresheet project crash-landed on the Moon, with its cargo of tardigrades, a microscopic animal known for its hardiness in space, creating some fears of contamination even on the relatively inhospitable Moon: if this crash had been on a more viable body the fears would have been greater still [50]. There is also criticism of NASA for not updating their policies quickly enough; especially moving forward, as space travel becomes easier, it is very important that NASA show due diligence with regards to planetary protection [51].

5.2 Bodies in our solar system

In terms of our solar system, there are only a small number of bodies that could realistically be capable of sustaining life, or at least life as we know it (refer to the 'one data point' section of this paper). Bodies are classified by COSPAR dependant on their likelihood of supporting life, with bodies such as the moon regarded as "dead bodies" insofar as that their chances of supporting life are effectively zero [52]. With these bodies there are no restrictions in terms of biological matter being moved around as it is assumed that there are no native life-forms to disturb, nor to return back to Earth. The COSPAR planetary protection requirements give detail on sterilisation requirements, biological payload limits, mission type and organic contamination levels based on the body being investigated (fig 1).

There are, however, a number of more hospitable bodies within our solar system that are of far

	Mission category					
	I or II	III	IVa	IVb	IVc	V
Mission type	Flyby, orbiter or lander	No direct contact: flyby, orbiter	Lander: no life detection instruments	Lander: life detection instruments	Lander: special region[a]	Earth return
Target bodies	e.g., Moon (I), comets/asteroids (II)	Mars	Mars	Mars	Mars	Mars (restricted) Moon (unrestricted)
Example past or *proposed missions*	NEAR (II), Lunar Prospector (I); *Rosetta* (*II*)	Mariner, MGS, Mars Odyssey, Mars Express	Pathfinder, MER, Beagle2 (IVa +)	Viking, *Mars Sample Return* (*MSR*)	*MSL, Phoenix, ExoMars, Next Decade Astrobiology Mission*	*MSR, Lunar South Pole Aitken-Basin Mission*
PP sterilization requirements	None or simple documentation	Cleanroom assembly, some bioload reduction	Microbial reduction	Sterilization of sample path hardware or contact parts	Partial or full sterilization required	Cat IVb for Mars bound craft, collection tools sterilized, no Mars cross-contamination; no restrictions for lunar spacecraft
Initial spacecraft bioload	Unsterilized $\sim 10^6$ spores m^{-2} 50–300 ng cm^{-2}	$<10^6$ spores m^{-2}	Pre-sterilization levels maximum: 300,000 spores/SC and 300 spores m^{-2}	Post-sterilization levels: 4-log bioload reduction[b]	Post-sterilization levels: 4-log bioload reduction[b]	Restricted Earth return same as Cat IVb; not controlled for lunar missions
Organic contamination levels	Not controlled, category II requires organic inventory	Not controlled, requires organic inventory	Not controlled, requires organic inventory	Not controlled, requires organic inventory; for Viking soils: <1–10 ppb[c]	Not controlled, requires organic inventory	Not controlled, for *Apollo* soils, up to 100 ppb

Figure 1: COSPAR's Planetary Protection Requirements [43].

more pertinence to the discussion. These will be covered by the paper to help demonstrate just how possible it is for our solar-system to house life and, by extension, the importance of defining the ethics of directed panspermia. The majority of the candidates for life are of a similar composition to one another, these bodies are all moons, excepting Pluto, a dwarf planet, and all contain sub-surface oceans. These are: Pluto and its moon, Charon; Saturn's moons Dione, Enceladus and Titan; Jupiter's moons Ganymede and Europa; and Neptune's moon, Triton [53][54][55]. All of these bodies are incredibly cold and liquid water on the surface is generally not possible, excepting Titan which has an unusually thick atmosphere. There is some evidence and a number of solid theories that liquid water exists as a mantle layer below the surface, much like the Earth's molten magma mantle. These will not be covered in detail, but methods for detection include cryovolcanism, tidal heating, tidal flexing, spectroscopy, magnetic field interference and ground penetrating radio.

If life is found on any of these bodies, it would be strong evidence that life can exist in the outer solar-system and would completely nullify or redefine the concept of a "habitable zone" [53][56].

The final major contender for life is one of our closest neighbours, Mars. It is thought that in the past the conditions on Mars may have been much more suitable for supporting life than they are today: during the Noachian Era, 3.7-4.5 billion years ago, the atmosphere was much thicker, there was liquid water and the temperature may have even been warm enough to produce rainfall [57][58]. To date, however, there has been no conclusive evidence that there is life on Mars; nevertheless, there is evidence that there *could* be. Mars, like most bodies in our solar system, has a surface that is incredibly inhospitable to life: this is mainly due to its near lack of atmosphere, allowing radiation from space to easily reach the surface, and resulting in radiation levels roughly 50 times higher than Earth's [59]. The subsurface, however, could be a very different story: large amounts of water have been found beneath the martian surface, creating more potential for life [60][61][55]. Methane has been discovered in abundance, and there are even seasonal shifts in methane levels on the martian surface. Whether this methane release is of biotic or abiotic origin is still unknown, but it at least points to the possibility of life [62]. The ESA (European Space Agency) clearly have at least some hope of finding extant or extinct life on Mars. Their new ExoMars project, due for launch in 2020, will be actively searching for signs of life [63]. NASA too, remain hopeful that signs of life may yet be found on Mars, and continue to search for it [64].

6 Subglacial lake exploration - a parallel to directed panspermia

When thinking about directed panspermia, one could suggest that its ethical discussion may not be as important and that more imminent events regarding our planet should be the focus; however, when looking at the exploration of subglacial lakes, a currently discussed topic, clear parallels can be found between the act of directed panspermia and the contamination of said lakes.

Since their first discovery in 1973, over 145 subglacial lakes have been found through use of satellite imaging. The fascinating quality of these lakes is that they are completely isolated from the outside world and have likely been cut off for millions of years. Some of them may even be connected, forming a large web of interconnected aquatic bodies. With this isolation also comes the possibility of independently developed life. This has stirred up an enormous interest in scientific research [65].

Lake Vostok, located approximately 4750 meters beneath Vostok station in an extremely remote region of Antarctica, was the first place to experience exploratory drilling in order to reveal possible answers to life's development. The Russians already started drilling into the ice in 1957. The fact that drilling had begun even before subglacial lakes were discovered marks but a part of the overarching ethical problem. Several decades of technical development allowed the Russians to dig further and by 2011 their hole was within 30 meters' reach of the lake [65].

Several accidents have tainted the history of drilling for Lake Vostok so far: they were most likely caused by drills [65].

The further down the drilling goes, the more pressure is exerted on the hole by the ice above. In order for the hole not to close at depths below 500 meters, drilling fluids must be used to fill it in. These drilling fluids do not freeze and thus provide the possibility to continue drilling after a pause or to retrieve the drills. An example of a drilling fluid the Russians used was a mix of Kerosene and Freon. This fluid contains a vast number of organic compounds, including bacteria, and thus poses probably the greatest risk of contamination once the lake is reached. Figure 2 shows the history of the drilling for Lake Vostok up to 2007 [65]. The Russians are however not the only ones trying to retrieve samples from subglacial lakes: a British team proposed drilling into another lake, Lake Ellsworth, instead. Lake Ellsworth is closer to the surface and thought not to be connected with anything else. In contrast to Lake Vostok, sampling of Ellsworth would not only include samples of the water but also taking some sediment from the bottom of the lake. A third project called The Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) project has three sub-projects, each with their own aims, and plans to work in the area of the Whillans Ice Stream. It is believed that due to the system being at the end of hydrological catchment area (essentially "downstream") the problems of contamination would pose less of a risk [65].

The scientific interest in subglacial lake studies was highly encouraging a race between different parties to see who would be the first one to retrieve samples from subglacial lakes. Assuming that decisions were made under the pressure of such a race, ethical implications have likely not been discussed at a level they were supposed to [65].

In summary, subglacial lake exploration has clear parallels with directed panspermia, and is thus

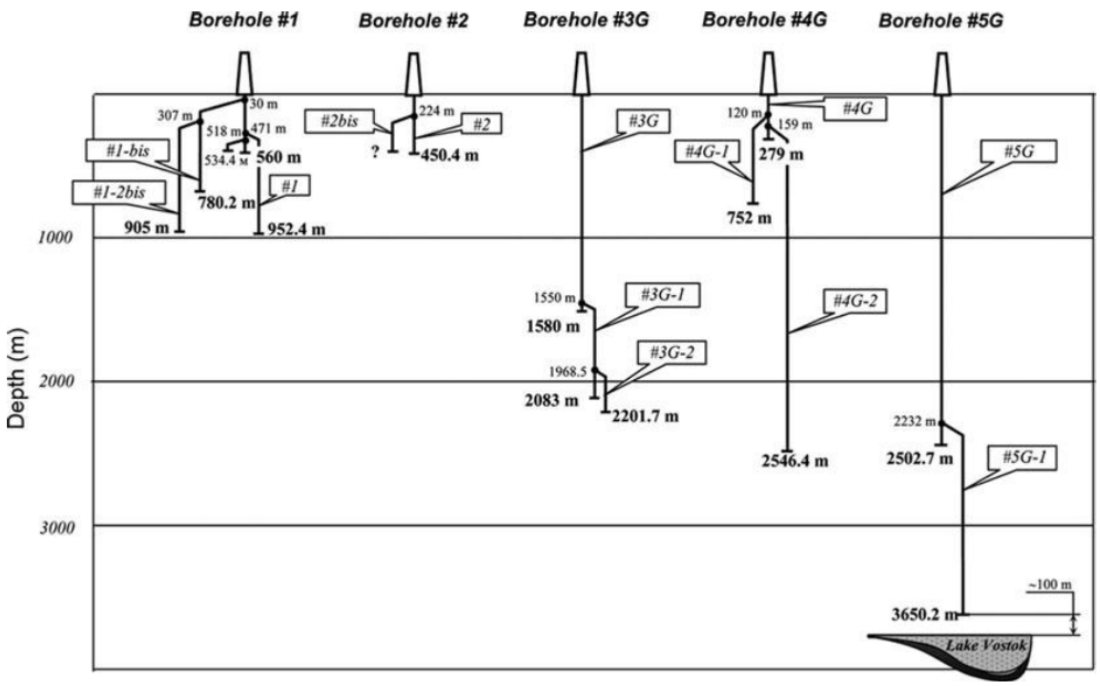

Figure 2: History of drilling done at Vostok station and to reach Lake Vostok up to 2007. Starting with borehole 1, the more recent boreholes have reached greater depths thanks to technological advancements. Each borehole has several branches, which mark a change in drill, either through the loss of the old drill or replacement of a deteriorated one [65].

of major relevance to the discussion of panspermia: in the focus of both cases lie bodies that may or may not contain life and they could unnecessarily be contaminated through human negligence. This stresses the importance of looking into the moral discussions below.

Such an ethical discussion has been attempted by Maxwell et al. and will be summed up in the following paragraphs [65].

6.1 Scientific interest / Knowledge for the sake of knowledge

The possible benefits of gaining new knowledge can be put forth in effort to justify the sampling of subglacial lakes. For instance, it is hypothesized that Lake Vostok may contain an active tectonic rift, the discovery of which could strengthen the knowledge about the geology of Antarctica. Likewise, samples of sediment may contribute to the understanding of Antarctica's glacial formation. These two arguments alone may certainly be very appealing for scientists.

The current structure of the legal system in Antarctica states that science takes precedence over possible environmental or ethical issues [65]. This may lead to the problematic state of projects working in the Antarctica losing sight of ethical or environmental considerations.

6.2 Humanity's quest in search of life

Ever since the emergence of human civilisation, mankind has sought for new types of life. Based on an anthropocentric view, this usually resulted in the exploitation of these lifeforms. Seemingly most humans and also scientists take this right to discovery for granted, this notion, however, has recently been challenged [65]. The position of Deep Ecology decentralizes humanity in the ecosystem and values the diversity of species and the environment more highly. With this in mind, efforts to extend mankind's knowledge may undergo more careful reflection before they are carried out [38].

6.3 Intrinsic value of the wilderness

Followers of the deep ecology movement [40] as well as many ordinary people would argue that wilderness environments have an intrinsic value, which is why they deserve protection from human activity. Darwin's evolutionary model on the other hand states that no life form is more special than another. Thus, no special consideration should be given to environments such as subglacial lakes as they are simply a part of the bigger picture in which (out-)competition justifies the morality of actions between lifeforms [65].

6.4 Agent-Centered restrictions

An argument that was put forth in favor of the restriction of subglacial lake exploration contained the concept of agent-centred ethics. For as long as the results caused by exploration towards the explored object are either damaging, dangerous or unknown, mankind should put constraints on such exploration [66]. An example where these ethics are applied can be found in the case of opening the ancient tomb of China's former emperor Qin. China has rejected repeated requests to explore the tomb, stating that neither technology nor knowledge are fit to do the job properly. Contrary to the argument above, it could be argued that humanity has the responsibility to explore unknown environments and would be restricting itself should it decide to impose limits on exploration [66].

As can be seen in previous paragraphs, the ethical discussion about exploration of subglacial lakes may very well be more expanded upon. Maxwell et al. compared this fact to space exploration and stated the critical situation as followed:

"it seems that the value placed by researchers and explorers of the potential new life does not extend to allowing it to remain isolated – no matter where it is. (...) Both outer space and subglacial lakes are virgin wildernesses, and thus potential candidates for protection based on their intrinsic value. This has not stopped the sending of space probes to many celestial bodies, and humans to the moon. Any argument for the intrinsic wilderness value of the moon or Mars was completely lost in the public clamour for the 'space race' and the public interest of the Martian rovers" [65].

Discussions of this kind appear to have largely been left unnoticed or ignored by contemporary philosophers [66].

7 Approaches for discussion

This report will test each presented view using a deontological and a consequentialist approach and will assess the arguments that are put forth. For this purpose, both approaches will shortly be described in the following paragraphs.

7.1 Deontology

Duty ethics, or deontology, is an ethical theory used to determine what is right and wrong. It assumes the stance that all actions are morally good or morally bad; for example, stealing can be seen as an inherently bad action, whereas helping an old lady across the road can be seen as a good action [67]. Deontology, although not a new concept, was mainly propelled into popular view by Immanuel Kant (1724-1804) and his branch of deontology, Kantian Ethics [68]. He puts forward three moral imperatives;

1. "Act only according to that maxim by which you can at the same time will that it should become a universal law" [68].

2. "Act as though the maxim of your action were by your will to become a universal law of nature" [68].

3. "Act so that you treat humanity, whether in your own person or in that of another, always as an end and never as a means only" [68].

Essentially under duty ethics one's perception of their act defines it's morality, regardless of outcome: if the person acting feels their action is morally good, then they should perform that action, conversely if they feel the action is morally wrong, they should not.

7.2 Consequentialism

Consequentialism is a view that determines the morality of an action depending on its consequences. Contrary to deontology, the action would then not be judged in itself but may change in its morality depending on whether the outcome is positive or negative [69].

A more advanced version of consequentialism is encapsulated by utilitarianism. Utilitarianism attempts to measure the amount of overall positiveness of an action. The action that leads to the most positive value will be deemed the morally right action. Suppose the example of a sinking ship due to too many people being on board. Assuming all options for an action in such a situation are considered, and the best option is throwing one person overboard in order to stabilize the ship and save the others, then that action would be moral. This is an action a person with a duty ethical view would not approve of since the act of sacrificing a person would always be wrong [69].

There is criticism towards the consequentialist approach. The most important one notes that the considerations are often made while assuming the consequences of an action. However, the challenge of that act is to actually determine the value of each outcome. Whether such a value can be determined, if even possible, is usually not a simple task [69].

The key difference between duty ethics and consequentialism is whether one looks at the action itself, or its result. Using the previous example of stealing, from a deontological point of view the morality of this action is relatively clear under both theories; however, when expanded upon these examples and say that the person stealing was stealing from someone very rich, to help support a local family who are struggling financially, it becomes more complex. Under deontology one would find this action immoral, as the act of stealing is inherently wrong; yet under consequentialism one could argue that as the rich man will suffer very little as a result of this action, and the family will benefit greatly, the action is morally right.

8 Discussion and analysis

In the following discussion, the authors aim to outline different arguments that can be made based on each worldview. The structure of the discussion will focus on a worldview, and its analysis first from a deontological and then from a consequentialist perspective. The end will be followed by a summary that includes the legal aspects of contemporary aspects.

8.1 Anthropocentrism

Taking a deontological approach to an anthropocentric viewpoint there is a relatively clear answer to the question of whether directed panspermia should be advocated for. By sending out organisms that help create a more hospitable atmosphere (e.g. photosynthesising bacteria) to all corners of the universe, we could create a whole host of planets and moons that will, in the future, be suitable for human habitation. This is an incredibly favourable situation for an anthropocentrist, as it allows immensurable human expansion throughout the universe. Any damage to existing ecosystems caused by the introduction of terrestrial species is not really of any importance. This view is only correct for as long as terraforming through biological means remains more efficient than terraforming by other methods at which point directed panspermia becomes moot, as there are neither advantages nor disadvantages to the anthropocentrist.

While not necessarily of obvious relation to directed panspermia an anthropocentric argument presents itself when discussing sending manned missions to new planets. These manned missions will transport terrestrial microbial life to any new planets if no strict protocols are enforced to prevent as such. An anthropocentrist would have no reason to enforce such rules, only caring about the risk of back-contamination damaging the terrestrial ecosystem, therefore manned missions under an anthropocentric view are also a form of directed panspermia. With this in mind one can argue the morality of sending manned missions to new planets with no chance of return to the home planet. Under the deontology the action could be classed as wrong, if one was of the opinion that sending any human away from their civilisation, even with their consent, is an inherently wrong action. When a consequentialist view is taken, more specifically the notion of utilitarianism, it becomes a distinctly good action, as any suffering experienced by the cosmonaut personally is greatly outweighed by their contribution to the human race.

Taking the consequentialist standpoint, spreading terraforming life to other planets would have beneficial results for humans. Supposing that the Earth becomes less hospitable in the future, with few to no non-renewable resources, hostile climate conditions, cataclysmic events or other factors that could challenge human life on planet Earth, directed panspermia could present an opportunity for mankind to propagate and save itself from extinction. Anthropocentrism assigns no value to extra-terrestrial microbes, rendering discussion about the destruction of alien life irrelevant. This notion would only be challenged should extraterrestrial life turn out to be useful to the human cause.

It can be assumed that any form of terraforming new worlds will allow humanity to gain new technological, scientific and biological insights. Scientific development could be furthered by new research strategies when examining a planet's surface. This could lead to a number of discoveries that aid mankind, for instance medical advances or access to new resources; however, there is also the risk of, for example, finding dangerous alien microbial life, that could have detrimental effects on human health.

8.2 Biotic Ethics

As biotic ethics assumes the inherent value for life and connects all life through the shared properties of gene and protein cycles it suggests that life should be propagated as far afield as possible. The fact that we have already successfully conducted space missions confirms that humans are capable of spreading life to space. We could thus argue that mankind has the duty to spread life as much as possible, speaking for the case of directed panspermia. Similarly to the proliferation of life, humans also have the ability to look out for and thus the duty of guarding life and protecting it from extinction. The argument of humanity being the sole possibility for (at least terrestrial) life to consistently spread and be protected against extinction would make humans a central part in biotic ethics, possibly putting a higher value on mankind in comparison to other life. The argument for directed panspermia could however be countered by a consequentialist thought - for instance, the contamination through terrestrial life may endanger indigenous life of celestial bodies, which could result in the extinction of organisms.

Another point for consideration is that if we were to find extraterrestrial life, we would then have the duty to make sure that this life would be spread equally as much as our own. Taking an approach biased towards favoring terrestrial life would certainly not fulfill a duty based morality.

8.3 Ecocentrism

Under ecocentrism there are two contradictory results one can achieve when applying a deontological approach to directed panspermia: firstly, if the ecocentric premise were taken that ecosystems should be allowed to flourish unaffected by human interaction, then any transfer of life to another planet is intrinsically immoral; however, if the premise were taken that ecosystems should be protected one can argue that by moving life further into the cosmos we are protecting said ecosystems by giving them as many chances as possible to survive. When applying a consequentialist approach however, one can perhaps reach a more satisfying conclusion: this approach would lead us to say that directed panspermia is moral *only* if it does not interfere with local life.

This would allow the very confident statement that directed panspermia should absolutely not be something we pursue given our current knowledge of biology, our solar system and the universe in general, especially considering that directed panspermia has permanent repercussions. It would seem therefore logical to wait a few hundred more years before starting any serious attempt at populating the universe with life. This period of time is the blink of an eye in galactic terms, but a period during which our knowledge and technology will increase exponentially; and, as there are no immediate threats to life's survival it seems that allowing humanity to learn more about our surroundings before acting is the safest and most responsible thing to do.

8.4 Deep Ecology

The case of panspermia is seemingly clear when looking at it from the view of a deep ecologist; however, building upon the intrinsic value of all living beings, the second rule of deep ecology states that life's value reaches its zenith at its greatest diversity. This, under the assumption that spreading life to different bodies will, over time, lead to greater diversity, advocates for directed panspermia. The previous arguments however do not account for the possibility of life already existing on the body in question. In that case, the authors contend that the mixing of terrestrial and alien life would most likely lead to greater diversity - if, however, one form of life were able to eliminate species of the other form of life, it would be a highly unethical act to contaminate planets with non-native life. This means that it would only be ethical to spread life through directed panspermia under these circumstances:

- Life is not to be found on the body in question and thus there is no risk of reduction in diversity.
- The introduced life does not endanger the diversity and richness of the indigenous life.
- The life of a planet or system is endangered by some irreversible threat, and the only possibility of survival requires directed panspermia.

Deep ecology furthermore promotes the flourishing of both human and non-human life and their cultures and states how a reduction in human population can help with this aim. Allowing some humans to leave the planet could pose an opportunity to reduce human population, or at least create a divergence point for population growth. As a result, the descendants of the emigrating population would no longer require terrestrial resources, allowing the distribution of these resources and overall improving the quality of life on Earth.

8.5 Summary

When looking at the deontological arguments, it becomes apparent that there is great contention between the worldviews, and even within each view itself. This suggests that finding an answer based on deontology would become a tedious process which would be unlikely to end in a decisive outcome.

We can however see that anthropocentrism seemingly has a tendency to speak more for directed panspermia. This is most likely due to the fact that counter arguments against directed panspermia are only apparent when considering panspermia involving manned missions. A biocentric view would most likely also favour directed panspermia as the duty to propagate and protect life is best accomplished through the act of directed panspermia.

Based on the consequentialist approach, we think that a definitive conclusion for or against panspermia is extremely hard to make. This is due to the fact that consequentialism bases morality on how the outcome is valuated. Even though space exploration has existed for over half a century, we still know very little about space or other life forms. This makes it difficult to judge whether an outcome is likely or not, making the arguments more of a thought experiment, that results in no decisive answer. The authors postulate that biotic ethics, ecocentrism and deep ecology can result in a more conservative approach as there is less certainty of a positive outcome.

This limitation in both knowledge and technology could actually be an argument against directed panspermia. As mentioned in the discussion of Lake Vostok, China has continuously prevented attempts to explore the tomb and we suggest that the question of whether directed panspermia is moral can be definitely related to that case - more knowledge and technological advancements should be gained before we unknowingly endanger both the world we seek to explore and ourselves.

Failing to do so could make the act of directed panspermia immoral.

Perhaps we could amass more knowledge of the consequences of panspermia through computer simulation. Surely, crucial knowledge can be gained by looking at what has already been done during subglacial lake exploration and it is probably prudent to carefully evaluate these results before continuing such exploration.

In terms of how the world's legal systems reflect these outcomes, they are clearly written more in accordance with the values of biotic ethics, ecocentrism and deep ecology. They espouse the absolute prevention of interplanetary contamination until such point as it can be confirmed that no indigenous life will be affected. The enforcement of these legal systems however, is lacking, and there are seemingly few to no ramifications for any agencies or companies who fail to comply. Thus a de facto legal system is in place which aligns much more closely with an anthropocentric viewpoint - one that only advocates for space exploration, and which has little interest in reprimanding those who contaminate or damage any extant ecosystems.

As those in favor of stricter enforcement of planetary protection policies have the de jure authority, perhaps they should be pushing organisations and governments to move policy out of the international arena and into national law where penalization of unlawful parties is much more attainable through legislative means.

9 Conclusion

The purpose of this report was to examine the different arguments that can be made for or against directed panspermia: for this reason, different worldviews were discussed, and a comparison was drawn with subglacial lake exploration - an example that requires a very similar ethical discussion due to it facing the same moral problems. Furthermore, the current legal system and candidates most likely to inhabit life were described. The following research question was posed to be answered through this report:

What are the ethical implications of directed panspermia?

The analysis of different arguments of each worldview based on a deontological approach suggests that there is contention amongst the arguments between the worldviews as well as within each view itself. The strongest proponent of directed panspermia is anthropocentrism, followed by biotic ethics and deep ecology; only ecocentrism showed to be more balanced in its argumentation. Both deep ecology as well as ecocentrism showed to be more balanced in argumentation for and against.

A decision based on the consequentialist approach can hardly be made decisively. Biotic ethics, ecocentrism and deep ecology can result in a more conservative approach as there is less certainty of a positive outcome. The lack of both scientific knowledge as well as technological advancements however speak against a near future act of directed panspermia. A safer option would be to amass more knowledge and better technology, as well as looking at the outcome of subglacial lake exploration before risking any long-term negative consequences that cannot be undone.

The current, de jure planetary protection policies express a more conservative approach regarding directed panspermia, which is in favor of biotic ethics, ecocentrism and deep ecology; however, de facto law enforcement heavily supports the anthropocentric approach. The paper thus suggests a revision of the law enforcement in order for it to align with the legal system.

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