Two Planets, One Species: Does A Mission to Mars Alter the Balance in Favour of Human Enhancement?

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Abstract

In this chapter we examine the implications of a crewed mission to Mars, possible colonisation of the planet, and the wider implications this may have on genetic enhancement in both a terrestrial and space context. We consider the usage of both somatic and germ-line genetic engineering, and its potential impact on the evolution of *Homo sapiens*. We acknowledge that a mission to Mars may require the usage of such technologies if it is to be successful. Our investigation suggests that the use of such technologies might ultimately be linked with the transformation of our own species. We also consider projected timescales for the development of these genetic enhancements and the ethical questions raised by the possibility of speciation. Cooperation amongst spacefaring nations in this context and the development of norms for the use of such technologies is desirable.

5.1 Introduction

Although the initial exploration of Mars will involve only a very small number of humans, it seems very possible that the act of making the journey will alter how we view ourselves as humans. This is particularly likely if the journey is successfully undertaken so as to create a small colony to act as a 'reservoir' of humans in the event of a disaster wiping out humanity on Earth.

A precedent for this change in how we see ourselves is *Earthrise* (Fig. 5.1), the photograph taken by Apollo 8 crewmember Bill Anders on December 24, 1968. Sometimes described as the most influential environmental photograph ever taken, the iconic photograph of Earth as a fragile ball spinning in space gave us a sense of interconnectedness and a deeper understanding of humanity itself, and contributed to fostering a conception of responsibility for the stewardship of Earth's delicate ecological systems. It may even be that an awareness of this interconnectedness helped prepare us, at least in part, for the challenges of globalisation which followed. It provoked the realisation that we are one human family, sharing a common homeland we call Earth. A mission to Mars will similarly challenge our understanding of ourselves, not least because some form of genetic enhancement may be necessary to ensure the success of such a mission. In addition, if colonisation becomes a reality, even if it involves only the smallest group of humans, then our concept of interconnectedness is likely to become an extended one as we are represented both by humans on the Earth and by humans on another planet.

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All this is taking place against a backdrop of our increasing awareness of the effects of deep space weather, of the danger of asteroid strikes[1] and of the place we occupy in the wider cosmos. Indeed, space science and the many technologies developed in this context have both increased our understanding of our place in the cosmos and provided access to information that may be vital for better modelling of Earth's weather systems, which may prove pivotal as we look for solutions to the increasingly serious threats presented by anthropogenic climate change.

Research into deep space weather could be equally important if a manned mission to Mars is to be successful (Hapgood, 2019), and it is entirely possible that we may gain valuable information as a result, which could make all the difference to understanding the rapid climate changes we are experiencing on Earth. In addition, the geological history of Mars itself may hold clues: research suggests that Mars was once Earth-like, with an ocean in its northern hemisphere, perhaps covering roughly one fifth of the planet's surface with water. Human exploration of Mars might allow for far more detailed studies than robotic studies offer, and may therefore play an important role in understanding climate change on Earth.

Of course, space exploration has adverse consequences – and not just the opportunity costs (think of the money). Although we have been a spacefaring species for only a few decades, we have already begun to pollute space: debris now orbits our planet and traces of our presence can be found even in remote parts of our solar system, as well as on our own Moon. A human presence on Mars will add to this. And the traces of our presence are not limited to inorganic materials, but include microbial matter that we have left behind.

Coupled with these concerns is an emergent astropolitics, running parallel to the geopolitical tensions that too often dominate relationships between nations on Earth. There are two major factors we can identify in this: (a) hardware in space is part of an essential infrastructure to support our globally integrated economies (e.g., satellite communications); this is naturally a concern; (b) a more general tendency to see space as an extension of territory, with a colonial approach being adopted in respect of resources that space may offer. China has suggested that a base on the Moon could be used as a centre for mineral extraction from asteroids, and that the Moon might be considered a staging post for missions to Mars as well. Does this mean militarisation of space is likely, if not inevitable? In August 2019, President Trump authorised the creation of a US Space Command,[2] whilst announcing the intention to press on with the creation of a Space Force, a sixth branch of the military, describing space as "the next war-fighting domain" (Rogers & Cooper, 2019). President Trump duly signed the 2020 National Defense Authorization Act, which established the Space Force, in Hangar 6 at Joint Base Andrews, on 20 December 2019.[3] There are, of course, vital national interests that any country may indeed feel it needs to protect, especially as so much of the hardware which supports our globalised world is in orbit above us. Even so, at the very least, the rhetoric is regrettable and potentially inflammatory.

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[1] International Asteroid Day was established in 2016 by United Nations resolution [A/RES/71/90], to be held yearly on 30 June, the date of the Tunguska asteroid impact in Siberia, Russia in 1908, to highlight the risk to life on Earth posed by asteroids.

[2] A similar body was created during the Cold War, established in 1985 and disbanded in 2002, and was closely linked to the SDI (Strategic Defence Initiative, colloquially referred to as 'Star Wars'). The latest incarnation is charged with the development of Space Force Operations (see www.atomicheritage.org).

[3] https://www.whitehouse.gov/briefings-statements/remarks-president-trump-signing-ceremony-s-1790-national-defense-authorization-act-fiscal-year-2020/.

The language of colonisation is being increasingly employed. Ye Peijian, the head of China's lunar programme, when asked in 2018 why China is intending to send a *taikonaut* (Chinese astronaut) to the Moon by the 2030s replied:

> The universe is an ocean, the moon is the Diaoyu Islands, Mars is Huangyan Island. If we don't go there now even though we're capable of doing so, then we will be blamed by our descendants. If others go there, then they will take over, and you won't be able to go even if you want to. This is reason enough. (Hong, 2018)

President Xi Jinping has identified 'leading in outer space' as one of China's goals for the 100th Anniversary of the foundation of the People's Republic of China. The driving principle behind this is wealth creation and the harvesting of mineral resources to support China's growth. Namrata Goswami, an analyst specialising in the geopolitics of space, remarks "Unlike NASA, which is aimed at space exploration and space science missions, China's space programme is aimed at long-term wealth creation for the Chinese nation" (Goswami, 2019). It is projected that the space economy will be worth some 2.7 trillion dollars by 2040, currently estimated to be 350 billion dollars, a seven fold increase (Morgan Stanley, 2019). Of course, the history of the European Age of Discovery suggests that governments do not always find it possible to draw a clear line a clear line between economic and military interests, especially when their vessels are some distance from home.

All this suggests that the astropolitics of the 21st Century may indeed come to mirror the geopolitical tensions we have struggled to keep in balance on Earth since the 1950s. The Cold War itself was a catalyst for space exploration – the Apollo missions that brought humanity to the Moon an offshoot of the competition between the world's then two superpowers. And yet, despite this, space has also been a place which has allowed us to reflect on our humanity, on what it means to be human, as well as a place for healing tensions. The 1967 Outer Space Treaty (current signatories include the US, China and Russia, 109 nations in total) established, inter alia, that space must remain free of nuclear weaponry and not be used for testing of such weapons. Though no mention is made of conventional weaponry, the Treaty did represent an awareness of the need for cooperation in space at a time of extreme global tensions. Under article II of the Treaty, neither the Moon nor any other 'celestial body' can be claimed as part of the sovereign territory of any country (United Nations Office for Outer Space Affairs, 1967).

In this chapter our focus is on the question of whether a mission to Mars would alter the balance of arguments in favour of human enhancement, not least because of the possibility that such enhancement will be necessary if the colonisation of Mars is to result in a self-sustaining community. We begin by setting out some of the scientific and cultural significance of a journey to Mars.

5.2 Journeying to Mars

There has been a long fictional history about humans journeying to Mars and inhabitants on Mars journeying here (May, 2017). H. G. Wells' (1898) *The War of the Worlds* provided a dystopian portrayal, in which humanity is only saved from obliteration by the susceptibility of the Martian invaders to Earthly pathogens. While it is possible that Mars does harbour life, it won't be anything like that. More recent literature, with more of a semblance of reality, tends to concentrate on issues to do with us journeying to and surviving on Mars (e.g. Weir, 2011).

The attraction of Mars in fiction and in reality are similar. From an astronomical perspective, Mars is close, though its distance from us varies greatly as a result of its orbital eccentricity and that fact that its orbit around the Sun is not synchronised with ours. Mars is also not too dissimilar to Earth in a number of important respects (size, length of day, typical light levels, force of gravity, length of year, axial tilt, the presence of ice, the presence of 'soil' – albeit with no good evidence, as yet, of any life therein). Of course, there are important differences. In particular, Mars has virtually no atmosphere, is usually much colder (average surface temperature of -46 ^{o}C with a range of -143 ^{o}C to 35 ^{o}C) and has substantially higher levels of damaging radiation.

A mission to Mars is probably still some time off though it remains unclear whether it would result from private or government funding. A lot of work is being undertaken to determine the practical and psychological consequences of such a mission (Messeri, 2016). For example, the Mars Desert Research Station in Utah is a simulated Mars analogue habitat (there are plenty of digital Mars simulations too). Visitors or potential astronauts typically stay there for between one week and three months and engage in activities to help prepare for a journey to Mars or time on the planet (Fig. 5.2). Equally, a huge amount of work is being undertaken, mostly using rovers, to better understand the Martian landscape (Vertesi, 2015).

5.3 Ethical Arguments Concerning a Mission to Mars

There are important arguments about whether a human mission to Mars is even needed. Ongoing advances in robotics are such that it seems virtually certain that there will at some point be no scientific arguments in favour of humans, as opposed to robots, going to Mars that are strong enough to outweigh the arguments against such a mission (Campa et al., 2019). These arguments are primarily about human safety, though there is also the argument that humans would risk introducing Earth life to Mars (widely agreed to be undesirable) to a far greater extent than would robots (which are much easier to sterilise).

By far the strongest argument in favour of a human mission to Mars is to establish a human colony to serve as a space refuge for post-catastrophic Earth (Szocik et al., 2019). It can even be argued that humans have a *duty* to colonise Mars (or another space body) to increase the chances of survival for the human species. Of course, it might be objected that the very substantial financial cost of such a colonisation programme means that the money would be better spent here on Earth reducing the chances of such a catastrophe (by dealing with climate change and environmental degradation, improving incoming asteroid detection and ways of dealing with these, and possibly also by investing in peace education and demilitarisation). To this we can respond that while the two of us are all for dealing with climate change and environmental degradation, investing in peace education and demilitarisation (a) we would not want to bet the survival of humanity on these coming about and proving to be of lasting success and (b) it might be wise both to strive for Earth's survival (for humans) *and* to plan for a refuge. As any conservation biologist knows, it's risky to have only one place for a species to live.

5.4 Should we Enhance Humans?

What is potentially wrong with enhancing humans? Isn't that something we do all the time when we help people to learn and when we improve technologies such as those used in communication, transport and clothing? We can set aside arguments to do with cheating in competitive sports. Those arguments are all about trying to get a level-playing field. There is nothing immoral about using a particular kind of swimwear, designed to reduce friction, just because it isn't allowed in competition. In 2009, FINA, the Fédération internationale de natation, aka the International Swimming Federation, decided to reverse its existing policy and ban all body-length swimsuits. These swimsuits allow for increased blood flow to muscles, hold the body in a more hydrodynamic position (so reducing drag) and increase flexibility. A partnership between Speedo and NASA had led to the LZR Racer, which has been reported as reducing competition times by between 1.9 and 2.2% (Anderson, 2008), a huge amount at elite levels.

Rivals referred to the LZR Racer as 'technological doping'. Doping is, of course, rigorously prohibited in competitive sports but, for those of us who do not so compete, is it safety considerations alone that should caution us against taking such substances? If anabolic steroids help me to get the body shape I want or erythropoietin helps me to run faster, which I find satisfying, why should I not be able to use such drugs? After all, they are prescribed by doctors in certain situations.

In what follows we concentrate on genetic engineering but it is important for ethical analysis to consider whether it is enhancement per se, gaining an unfair advantage in competition, risking one's health or something else that is objected to. Ethical arguments about enhancement often rely, even if implicitly, on a concept of 'naturalness'. We tend to presume, for example, that it's fine to use medicines to restore someone to normality but hesitate or object to the same medicine being used to exceed normality. Consider, for instance, human growth hormone. Human growth hormone deficiency can result in children being of short stature. Treatment with the hormone, whether obtained 'naturally' from pituitary glands or made synthetically, can lead to increased growth. Indeed, Genentech's recombinant (genetically engineered) human growth hormone was approved for clinical trials use back in 1981 (Genentech, 1981). It has since been widely employed for medical uses and is generally reckoned to be safer than the 'natural' version (which is more likely to be contaminated).

5.5 Should we Enhance Humans for a Mission to Mars?

At present the genetic engineering of humans is in its early stages, unlike the genetic engineering of micro-organisms and plants. Many different plant species have been genetically engineered for such features as resistance to certain diseases while micro-organisms have been genetically engineered for a wide range of purposes including the production of such human proteins as insulin, clotting factors and (as mentioned above) human growth hormone.

Instances where genetic engineering of humans is taking place are in the treatment of diseases that have a genetic component. Examples are still infrequent but include the treatment of certain immune disorders, a type of heart disease and a type of blindness. Scientists and regulators have been quite cautious about allowing such work, no doubt fearing a public backlash and mindful of earlier trails of genetic engineering in humans that occasionally had unexpected and even fatal consequences – the most famous of which was probably the death in 1999 of Jesse Gelsinger in a gene therapy trial. Notoriously, the work in China in 2018 by He Jiankui (who was responsible for the birth of the world's first known gene-edited human babies, twins, to try to make them resistant to their father's HIV infection) proceeded without regulatory approval and has been widely condemned in his home country and internationally. He Jiankui has now been sent to jail for three years and given a heavy fine (equivalent to about USD 425,000).

A standard and important distinction that is often made in human genetic engineering is between somatic and germ-line genetic engineering. The somatic cells are the ones that make up most of our body (muscles, skin, nerves, bone, etc.); they are responsible for everything *except* producing our gametes. The germ-line cells are the ones responsible for producing our eggs and sperm. A change to the DNA in even all of a person's somatic cells therefore does not pass to any offspring they have. However, if some of a person's germ cells are genetically engineered, that change may pass to their descendants. Accordingly, most countries with the available technology do not allow germ-line gene editing. It was largely the fact that He Jiankui engaged in germ-line gene editing that caused such a furore.

If it turns out that genetic engineering of humans would have benefits for astronauts, then it is perfectly possible that somatic gene editing would be used. However, this would only be likely to suffice if the astronaut returned to Earth. For colonisers – given the low likelihood, at least initially, of their having advanced laboratory facilities on Mars – it would make much more sense for germ-line genetic engineering to be employed. Techniques for gene editing, both somatic and germ-line, are advancing rapidly (CRISPR, prime editing, etc.) and it seems possible that regulatory authorities may indeed conclude at some point that the confluence of (a) genetic engineering of humans being safe enough; (b) there being a sufficiently pressing need for humans to colonise Mars; and (c) there being limitations in alternatives to genetic engineering mean that the genetic engineering of humans for the purpose of a mission to Mars is indeed permitted.

What sort of genetic engineering are we talking about? George Church, co-founder of Harvard Medical School's Consortium for Space Genetics, has at the time of writing identified some 55 genes that might be advantageous for long-term spaceflight (Pontin, 2018; Church, 2019). The list includes:

- CTNNBI – radiation resistance
- LRP5 – extra-strong bones
- ESPA1 – allows people to live with lower oxygen levels
- MSTN – reduced incidence of atherosclerosis
- ABCC11 –endows its possessors with low BO (body odour) – useful on a space craft
- as well as a host of genes that might enhance our memories or make us smarter, less anxious or less likely to develop cancers (which often result from radiation damage).

At present, our detailed knowledge of how genes function and of the likely consequences of undertaking genetic engineering of humans are not robust. The geneticist Chris Mason at

Weill Cornell has proposed a 500-year plan for space colonisation (iGEM, 2011). Phase 1 is currently underway, indeed is intended for completion in 2020. It entails a base-by-base examination of the human genome to determine which parts are resistant to mutation and which tolerant of it. In Phase 2 (2021-2040), it is presumed that whole-genome sequencing and molecular characterization is common, cheap and accurate. Work is focused on methods for contextualizing variation and its effects. Efforts begin on integrating new elements into mammalian genomes. In Phase 3 (2041-2050), long-term human trials on genome engineering are begun. In Phase 4 (2051-2060), tests are begun in space environments. Thus far, many will consider that both the scope and timing are realistic, conservative even. Subsequent phases seem more optimistic – and the reader is not encouraged that there seems to be no Phase 5 … Phase 6 (2060-2100) entails the beginnings of settlements on other planets and genesis of synthetic genomes. In Phase 7 (2101-2150), new genomes allow toleration of extremely cold/hot and acidic/basic environments. In Phase 8 (2151-2300), the longest phase, these new genomes are sent off to begin seeding of Earth-like planets. In Phase 9 (2301-2400) humans are shipped off to these new worlds. Finally, in Phase 10 (2401-2500), there is human settlement of a new solar system, used as a model for future systems.

Futurology is never a straightforward science but advances in genetic technologies are happening at an increasing rate. Various researchers have inserted a gene called Dsup (found in tardigrades, Fig. 5.3 – notoriously hardy creatures) which seems to protect cells against radiation damage (Bittel, 2016) into humans. More futuristic possibilities include enabling our kidneys to make the nine so-called ‘essential amino acids’ and engineering the personalities of long-range astronauts so that they enjoy the journey more (cf. the dairy animal in Douglas Adams’ (1980) *The restaurant at the end of the universe* that has been bred to want to be eaten).

So far, we have rather taken it for granted that the sorts of genetic engineering that we have been envisaging (radiation resistance, extra-strong bones, etc.) are indeed enhancements. And so they are from the perspective of us on Earth. However, it could be argued that from the perspective of someone on Mars they are more akin to medical treatments in much the same way that we see genetic engineering on Earth to tackle sickle-cell anaemia, cystic fibrosis, heart disease and cancers as restorative treatment rather than enhancement. If this argument is to be accepted, it weakens ethical objections against the use of genetic engineering to facilitate human missions to Mars.

5.6 Consequences of the Genetic Engineering of Humans for a Mission to Mars

Ted Peters’ piece in this volume discusses what he terms ‘interplanetary sin transfer’ and invites us to consider the theological questions that arise in the context of colonisation of Mars, and considers the possibility of developing a utopian community, and even creating a posthuman species that is morally superior to ours.

‘Interplanetary sin transfer’ sounds very grand but all that is meant is that we humans would take to Mars our propensity to sin. Peters is acknowledging the theological origins of the term ‘sin’, the propensity to sin, in certain religious contexts, being considered an integral part of human nature. Even if one is not a theologian or religious believer, if we accept an everyday understanding of sin as both a capacity and a propensity to do things that are, in either a religious or legal context, undesirable, then the negative aspects of human nature will travel with us wherever we go. Indeed, the history of our migration as a species over the last 100 000 years or so has been one of carrying our sin with us into new places. We have continued with this 'intercontinental sin transfer' more recently as we have established stations in such places as Antarctica. Although crime rates are low on Antarctica, there have been instances of attempted murder and sexual harassment, inter alia (Rousseau, 2016).

In this final section, while acknowledging these important issues, we concentrate on the possibility that a separate colony on Mars might indeed, accelerated by the various sorts of genetic engineering to which we have already referred, result in the formation of a different species.

One response is to see the possibility of our species *Homo sapiens* dividing into two (eventually, possibly more if and when isolated outposts become established on other planets) as something that is undesirable and should be averted. On this reading, perhaps the most significant challenge raised by a long-term mission to Mars is the challenge to remain a unified species. This in itself addresses the problems of allegiance to Earth, raised in the context of conservation of our home planet, and presumes that, even if we are able to engineer our genes to make life on Mars and deep space travel possible, we have a responsibility, even a moral obligation, to ensure that we remain one species.

On this reading, there would need, even at this early stage in space travel, to be increased communication between spacefaring nations, with a view to establishing norms for the utilisation of human enhancement in space contexts. Envisaging the possibility of becoming a two-planet species may provide a suitable time for reflection and unification. The human element in this equation could provide a moment to pause and consider the effects of gene-editing biotechnologies in a terrestrial as well as a distant setting. In this sense we should not become over-focused on the concept of space refuges and utopian dreams, nor should we limit ourselves for fear of the negative effects such a project might have on our allegiance to our own planet. Instead, we should consider the challenge as an opportunity to develop a wider understanding of stewardship both of our environment (on Earth) and of ourselves as a species (wherever we are). Mars and its potential colonisation can then be viewed as a chance to create a larger, more adaptable, but unified human family.

However, before humanity speeds too far down this path, we should pause to ask two questions. First, how likely is it that space travel will lead to a new species? Secondly, if it did, would this necessarily be a bad thing? First it is worth examining precisely what is meant by the term 'species'.

5.6.1 What do we Mean by 'A Species'?

At one point, the dominant question in the embryonic field of history and philosophy of biology was what is meant by 'a species'. As so often is the case with controversies that are rooted in ideas rather than in data, with hindsight, the controversy seems overblown. The matter is still not decided – and the lack of agreement does have consequences for conservation biology (in deciding whether one species has gone extinct and how another might be preserved) – but this is simply because there are two main approaches to deciding what a species is.

The definition of which most people are probably aware is to do with successful interbreeding. Two individuals are said to belong to the same species if they can produce viable offspring. Of course, there are all sorts of caveats (individuals of the same sex don't produce offspring, juveniles can't either, some individuals are infertile, what is meant by viable – e.g. suppose the offspring live but are themselves infertile?, what do we do with species that reproduce asexually?, etc.) but overall it's pretty clear what the criterion is and often it works well.

One problem with this definition is that it can be difficult to put into practice. In principle, one has to sit around and wait for individuals to mate and then see whether they produce healthy offspring. And what do we do about species scattered over very large areas? Do we need to set up a breeding programme to check that grey squirrels in Canada and grey squirrels in the UK belong to the same species?

The grey squirrel issue is exacerbated in the case of fossil species – and most species have long gone extinct. How do we decide where one species of ammonite begins and another ends? After all, there are no ammonites today so we can't even extrapolate from today's to yesterday's ammonites.

The approach used by palaeontologists is to use the criterion of morphological similarity. Individuals are classified as belonging to the same species if they resemble each other sufficiently. Of course, this definition itself has problems. How dissimilar do two species have to be? And then consider dogs: the different breeds look very different yet are capable of interbreeding. Are we really saying that the domestic dog now contains dozens or even hundreds of species? Every time a new breed of dog is recognised, should it be recognised as a new species? This seems like *reductio ad absurdum*.

Despite these problems, biologist manage to agree in the great majority of case where one species, whether extinct or extant, ends and another begins – though there are always lumpers (who prefer there to be fewer named taxa such as species, genera and families) and splitters (who prefer tighter definitions, inexorably leading to more named taxa).

That this debate about the meaning of the term 'species' is not an arcane, angels-on-a-pin one is particularly evident when we move to consider our own species in the context of examining whether it is likely that space travel will lead to a new species of human.

5.6.2 Is it Likely that Space Travel will Lead to a New Species of Human?

There is no doubt that all of today's humans belong to the one species, *Homo sapiens*. Indeed, we are familiar with the phrase 'the human race' precisely because historical attempts to categorise humanity into different races was often tightly associated with racism. Careful work by geneticists and historians of science revealed the extent to which previous biologists and anthropologists nearly always held views that would now be condemned as unacceptable – believing that discrete races could be identified and that such races differed in their mental capacities, with Caucasians almost always placed above other 'races' (Gould, 1981; Lewontin et al., 1984). Indeed, in some cases different sub-species were identified and named, in what, consciously or unconsciously, seems to have been a spurious attempt to provide a scientific veneer to unacceptable views. That such false science contributed to the perpetuation of slavery, inequalities in fields such as education, health and housing, and the Aryan views espoused in Nazi Germany only causes us to recoil from them still further.

And yet, to an evolutionary biologist, there is a different way of viewing biological variability. Under this perspective, the forces of evolution sometimes reduce variability among organisms and sometimes increase it. Reduction in variability principally occurs via the mechanism of stabilising selection when there is a single optimum in a population for a trait so that, for example, birds of a particular species that have bills either shorter or longer than this optimum do slightly less well in the struggle for existence, typically because these sorts of bills are slightly less adept at catching the birds' preferred prey. An increase in variability can have a number of causes. To continue with the bird example, it may be that, for whatever reason, some individuals begin to specialise on a slightly different sort of prey compared to the majority. Typically, such behaviour has no long-term evolutionary consequences. It is possible though, especially if these individuals become separated from the others (e.g. by reasons of geography), that such a simple behaviour is the very start of a long process that may eventually result in speciation – as is widely presumed to have happened in the iconic case of Charles Darwin's Galapagos finches.

So, how likely is it that comparable forces might lead to speciation in humans? For the foreseeable future, the simple answer is 'negligibly likely'. Even if genetic engineering of the type discussed above results in colonists with such characteristics as radiation resistance, stronger bones, reduced incidence of atherosclerosis and less BO (!), the genetic engineering being talked about is at the level of existing variants. Such individuals will still be as much members of *Homo sapiens* as we are.

But this might change. If genetic engineering really does result in individuals whose genomes are very different, it is possible that on both the interbreeding and the morphological similarity criteria astronauts and their descendants could eventually belong to a different species. This is particularly likely to be the case if large changes are made to our genomes. For example, it is not impossible that astronauts heading to Mars might be given an additional chromosome, so that their 'normal' (diploid) cells would have 48 chromosomes and their eggs or sperm 24. This additional chromosome would be a convenient way of hosting major initiatives such as the ability, mentioned above, to synthesise all the amino acids.

Even without such step changes, the phenomena of natural selection and genetic drift will undoubtedly mean that if Martian colonies are sustainable (in the sense of producing offspring over successive generations without the arrival of new humans from Earth), the individuals in such colonies will slowly start to differ genetically from their Earth counterparts. Natural selection means that there will be additional strong selection for genetic variants better able to deal with high levels of radiation, low gravitational force and so on. Genetic drift is the phenomenon whereby isolated populations slowly diverge genetically as random forces lead to the disappearance of certain genetic variants in one population whereas in another population the same variants come to predominate.

The differences we see between indigenous people in very separate parts of the globe are precisely those that an evolutionary biologist would expect to see in any sexual species. Given reproductive isolation and the passage of sufficient generations – there are no hard and fast rules as to how many – geographically separated populations begin to diverge genetically. From an evolutionary perspective there aren't absolute boundaries around species. In the early stages of such divergence we see what we see today in humans, that there are recognisable morphological and physiological differences (cf. the Inuit and the Maasai women in Fig 5.4) but these are insufficient to cause reproductive isolation. *Homo sapiens* has only existed for about 200,000 years. As a rule of thumb (and such a rule is rough and ready), it takes about five times as long for speciation to occur in mammals.

But speciation can happen much more quickly. Scott Solomon (2016) has suggested that within a few hundred generations – perhaps just 6000 years – a new type [the context shows that he means 'species'] of human might evolve on Mars, given that it is likely that selection pressures will be extreme.

5.6.3 Would it be Undesirable for there to be Two Species of Humans?

In principle it would be possible to ensure that all the descendants of today's *Homo sapiens* remain members of the same species – a judicious blend of mandated contraception and genetic tweaks should see to that. But why bother? We need to ask if there is anything problematic about there being more than two species of humans.

We note that this possibility is one that has been addressed in science fiction. In *The Time Machine* (Wells, 1895) humanity has evolved (the year is 802 701) into the ineffectual Eloi and the thuggish Morlocks. Ursula Le Guin's writing features a number of humanoid species and explores the relationships between them – e.g. *The Left Hand of Darkness* (1969) has considerable interspecific altruism as Estraven (from Gethen) risks everything, and eventually loses his life, to save Ai (a Terran). In Mary Doria Russell's *The Sparrow* (1996), the story revolves around a Jesuit-funded trip in the year 2019 to Rakhat, which turns out to be inhabited by the peaceful Runa and the aggressive Jana'ata. Spoiler Alert: none of these books are optimistic about the coexistence of different humanoid species.

Precisely because of the history of racism and xenophobia, there may be much to be said for striving to avoid speciation in humans. As soon as such speciation happens (indeed, long before), there will be those who divide humanity into 'them' and 'us' – and such political divisions are likely to be exacerbated if we really do not longer belong to a single species, are separated by huge geographical distances and live in very different circumstances.

And yet, isn't this to buy into a presumption that our one species is superior to all others, that we have a right to existence that trumps the considerations of all other species? Is it possible that having two species of humans (*Homo sapiens* and, say, *Homo astronauticus*) might cause us to re-examine presumptions of our superiority to other species? After all, since 1993, the Great Ape Project has striven to give rights to the non-human great apes: chimpanzees, bonobos, gorillas, and orangutans. We are more sensitive now to the accusations of 'speciesism', that it is wrong to favour our own species over others simply on the grounds that we belong to different species.

5.7 Conclusions

Mars has always held a special place in the human imagination. The technological capabilities we are now on the threshold of developing are likely to enable us to make a successful journey to Mars in the not too distant future, and perhaps even establish a colony there. In considering whether such a mission should be supported – the ethical and political implications it raises, specifically the need to focus on anthropogenic global climate change and concerns over the usage of genetic enhancement and even the possibility of speciation – the authors believe that by asking the right questions at this early stage, we have a genuine chance of ensuring that such a mission will not lead humanity into a dark corner, but rather has the potential to support the genuine flourishing of our species. We advocate for increased cooperation between spacefaring nations, and perhaps establishing guidelines for the utilisation of human enhancements for space travel.

If a mission to Mars does come to be the moment *Homo sapiens* becomes a two-planet species, perhaps it will also mark the moment when we begin to transcend the violent tendencies of our terrestrial past. Indeed, a very high level of cooperation will be necessary if this, the most ambitious project we have ever undertaken, is to be successful. The dawn of the space age offered us an opportunity to see ourselves as one human family, and has made the technological integration of our planet possible. We hope that this next phase of space exploration will build on this, and may offer us an even greater chance to deepen our concept of interconnectedness and stewardship, both on our own home planet, Earth, and in the wider heavens which our descendants may inhabit in future; to become more than we are, to fully realise our human capacities, transcending the negative propensities we recognise in ourselves and perhaps even bringing life elsewhere in the universe.

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Fig. 5.1 Earthrise. Available at https://en.wikipedia.org/wiki/Earthrise#/media/File:NASA-Apollo8-Dec24-Earthrise.jpg.

Fig. 5.2 A rover (foreground) participating in a Mars Society University Rover Challenge Hill Climb with Mars Desert Research Station in the midground. Available at https://commons.wikimedia.org/wiki/File:Mars_Society_University_Rover_Challenge_Hill_Climb.jpg.

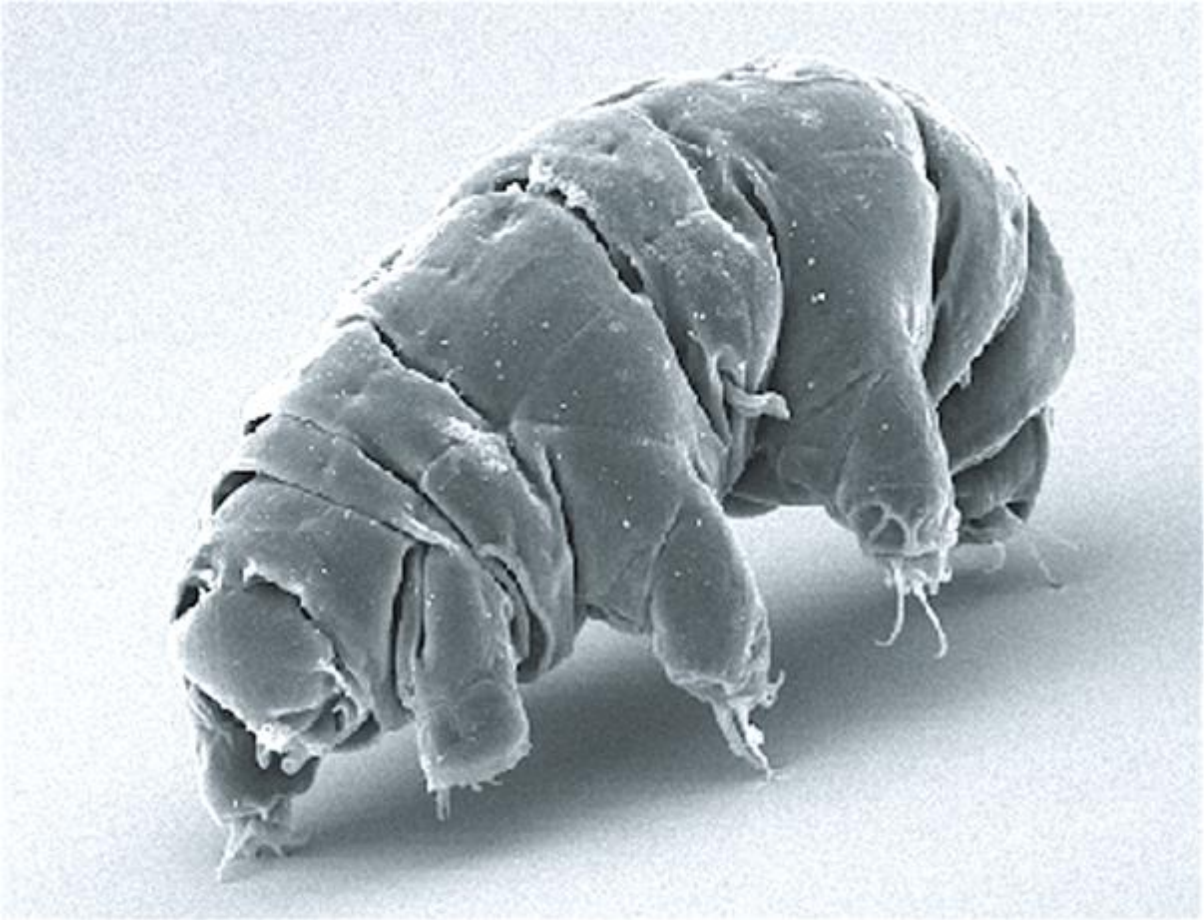

Fig. 5.3 A tardigrade (water bear). Tardigrades are notoriously hardy; inserting one of their genes into human cells makes them more resistant to radiation damage. Available at https://upload.wikimedia.org/wikipedia/commons/thumb/c/cd/SEM_image_of_Milnesium_tardigradum_in_active_state_-_journal.pone.0045682.g001-2.png/1024px-SEM_image_of_Milnesium_tardigradum_in_active_state_-_journal.pone.0045682.g001-2.png.

Fig. 5.4a Inuit woman chewing sealskin to soften it for making boots, with child from Kinngait. Available at https://upload.wikimedia.org/wikipedia/commons/thumb/3/37/Kulusuk%2C_Inuit_woman_%286822271943%29.jpg/2048px-Kulusuk%2C_Inuit_woman_%286822271943%29.jpg.

Fig. 5.4b Maasai woman with child. Available at https://upload.wikimedia.org/wikipedia/commons/thumb/a/a3/Masai_woman-child.jpg/2048px-Masai_woman-child.jpg.