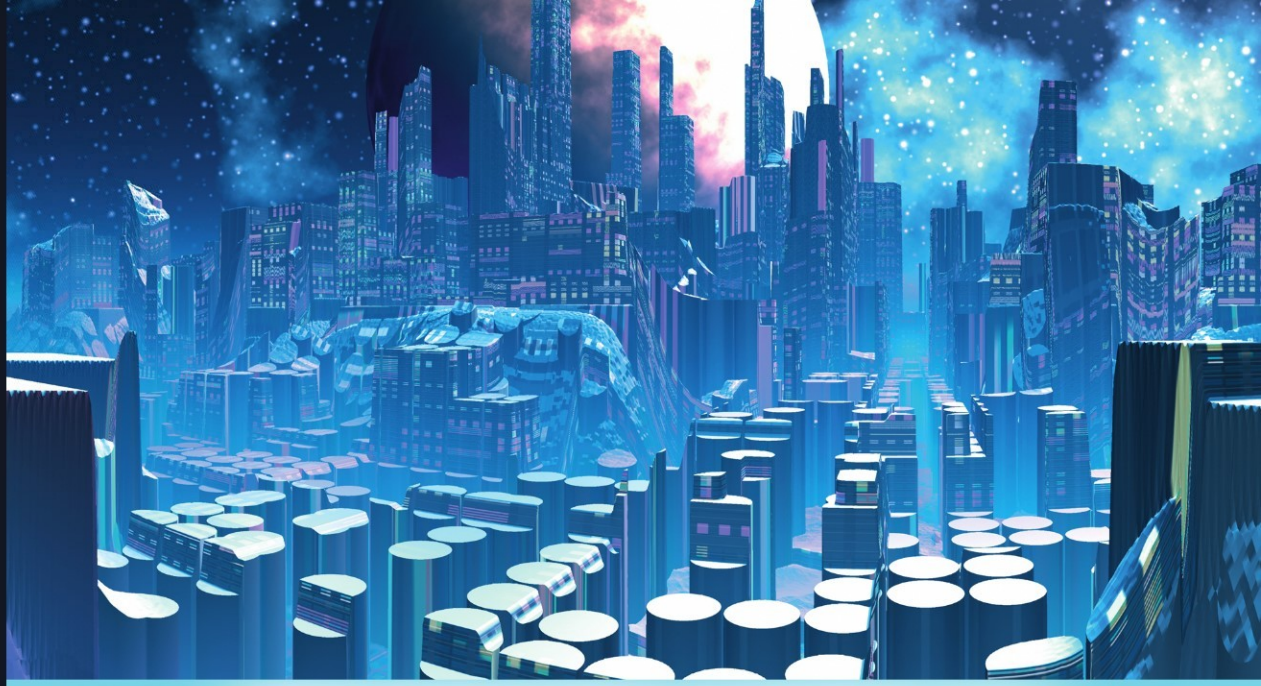
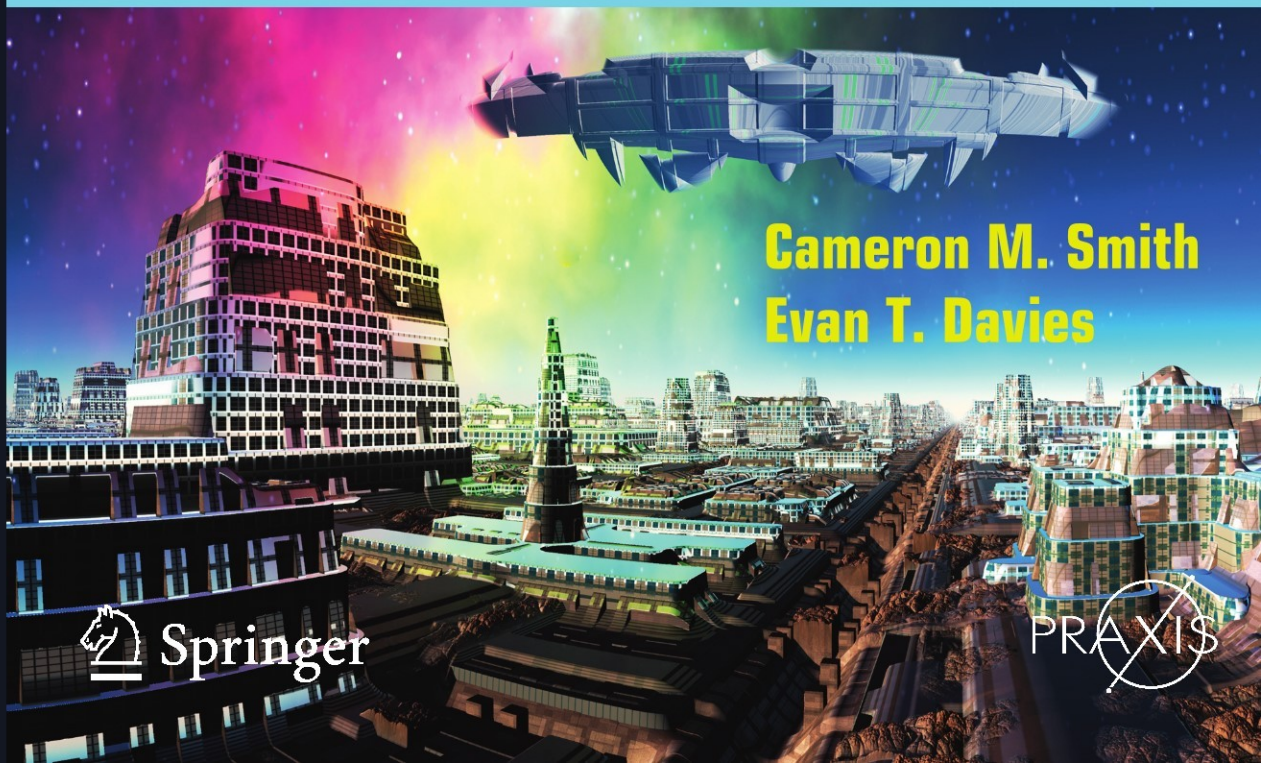


EMIGRATING BEYOND EARTH

Human Adaptation and Space Colonization



Cameron M. Smith
Evan T. Davies

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encouraged his students at Cornell to think critically, to always maintain a healthy skepticism, and keep an eye towards the day when we might leave the cradle and venture from our home world, and to the memory of my childhood friend Joji "George" Mochizuki; who left this Earth far too soon.

"... promises to keep."

Finally, the authors wish to dedicate their effort to every person who chooses to read this book. We hope that our species survives itself; we hope that our children live to see the dawn break on another world, we hope that we ultimately realize our fullest potential as humans, and that one day, our descendants look back from afar on the Earth with gladness, knowing that we made the right choices in our time.

About the Authors

Cameron M. Smith, Ph.D., teaches human evolution and prehistory at the Department of Anthropology at Portland State University in Oregon. His professional training began as a student of Harvard University's early human archaeology field school at the Leakey research station in northern Kenya. After a year at the University of London's Institute of Archaeology, Dr. Smith earned a Joint Honors BA in Anthropology and Archaeology at Durham University before completing graduate degrees in the US and Canada. His courses emphasize adaptation and evolution as structuring factors of human prehistory. Dr. Smith has been widely published in both scientific journals and popular science magazines, including the *American Journal of Physical Anthropology*, *Structure and Dynamics,* the *Journal of Field Archaeology*, *Scientific American MIND*, *Scientific American*, *Evolution: Education and Outreach, Archaeology*, *Hang Gliding and Paragliding* and *Spaceflight*. He has written about evolution in books and magazines including *The Top Ten Myths About Evolution* (Prometheus, 2006) endorsed by the National Center for Science Education and the American Library Association, and *The Fact of Evolution* (Prometheus, 2011), endorsed by *Science Daily* and recently picked for the *Scientific American Book Club*. Away from his office, Dr. Smith is an active Scuba diver and paraglider pilot. He is a fellow of both the Royal Geographical Society and the Explorers Club of New York.

Evan T. Davies, Ph.D., began his academic training in archaeology at Cornell University and has conducted fieldwork throughout the United States, Europe, sub-Saharan Africa and the South Pacific. He completed his graduate studies in cultural anthropology at Rice University, where he focused on land use among traditional hunter-gatherer societies in Central Africa. He serves as a defense attaché, African area expert and imagery scientist in the United States Navy. In 2007 while deployed on a combat tour with the multi-national forces in Iraq, Dr. Davies became involved with efforts to preserve Iraqi antiquities and archaeological sites. His experiences in Iraq led him to pursue medical studies and in the coming years he intends to work in wilderness and expedition medicine as well as continue anthropological research into indigenous pharmaceuticals and

healing practices. Dr. Davies is a fellow of both the Royal Geographical Society and the Explorers Club of New York and his popular science writing has appeared in Wiley publications as well as *Spaceflight* and *Archaeology* magazines. He has held a lifelong interest in space exploration.

Preface

Discussions of the idea of human space colonization often quickly diverge in one of two ways. Either people agree that it is an interesting and worthwhile endeavor, or they disagree, with the most common argument against it being that humanity has other pressing problems on its hands at the moment, and that space colonization would be callous and immoral because it would consume effort and resources that could be used to address those problems. This is one reason why Gerard K. O'Neill's 1976 book on space colonization, *The High Frontier*, contains large sections dedicated to showing that space colonization would materially benefit people on Earth. We do not feel that such a justification for human space colonization is necessary; the benefit, as we aim to show in this book, will be the preservation of our species itself, by the ancient methods of adaptation and evolution. While we of course believe that human problems on Earth must be addressed, our justification of human space colonization is not that it will immediately or materially help the people of Earth, but that it will provide a greater return: that it will be an insurance policy for our civilization and our species. Considering the dangers to humanity – non-human, such as asteroid impact, or human, such as warfare and the collapse that archaeologists have documented in every civilization of the ancient world – colonizing space would be the act of a mature civilization, and perhaps the only intelligent way to ensure that what humanity has built over the past few millennia will not be lost. Of course, civilization has built horrors as well as libraries, and it can also always be argued that colonizing space would only move human problems off of the Earth. We prefer to be optimistic, however, and we have good reason to believe that this will not be the case.

For many reasons, the first substantial off-Earth colonies will probably be on Mars, and the first colonists to arrive there will look on a world where not a single bullet has been fired, where not a single bomb has ever fallen from the sky. We think early colonists will be very aware of this. They might well prohibit such weapons entirely. Of course, we will still be human, and prone to the same fears and emotions that have governed many of our less-moral choices and actions in the past. But in a pristine world, we think, people will be determined not to repeat old madnesses, and they may be extremely intolerant of even the seeds of division, violence, and waste. In ancient Iceland, murderers and other criminals were banished to the wilderness, where life was nearly impossible. Similar rules may be enforced by early off-Earthers. And if things go badly in off-Earth colonies, for example on Mars, there would remain the solution that has been used by various human groups on Earth for millennia: social fission. In many cultures, it has been customary to relieve tensions by splitting up, an option almost impossible on Earth today. To paraphrase the science fiction writer Robert

Heinlein, *When things get so crowded that you need an ID, it is time to move*. The great thing about space travel is that it has given us somewhere to move. For a long time after the first colonists begin to settle the Red Planet, Mars will offer large landscapes for expansion; places to go if things turn badly.

And, of course, Mars is no end; one of our points in this book will be that human space colonization cannot be thought of as an end, like landing on the Moon nearly 50 years ago. Rather, what we write about in this book is a beginning. What we as anthropologists have learned from the study of human evolution is that as humanity has evolved, it has continually expanded outward, finding new places to live. Evolutionary adaptation to such a wide range of environments as inhabited by our species is the force that has shaped both our biological and cultural evolution. Just as humans on Earth have explored and settled in new environments throughout prehistory, eventually, people of Mars will want to move farther on; in fact, considering what we will describe in this book, that seems both natural and inevitable, while challenging it seems unnatural. We feel that other places in the Solar System, and perhaps some day even the galaxy, and even other galaxies, will all be explored, and some settled. Humanity, by this method of continual expansion, will have aligned itself with the nature of the Universe, which is change. There is no final utopia, because conditions change, and humanity itself changes. If there is a constant it is change and the evolution itself that adapts to that change. But for humanity to engage with this reality, we have to begin somewhere, and we argue that we should begin now. There will never be a best time to begin; it will always be argued that we have more pressing immediate concerns. But remaining focused on those immediate concerns could, in the end, cost us everything. In our daily lives, we invest heavily to protect our future, by buying insurance and minding our doings. Colonizing space will be nothing less than an insurance policy for our species and civilization. It is worth the both the cost and effort.

In addition to arguing that human space colonization is necessary, we argue that it will not be a technocratic endeavor, focused on rockets and robots, but on human beings. Space colonies, after all, will be for people, communities, and cultures. In this way, they will be a continuation of humanity's many adaptations over the last few million years. That the environments we choose to colonize in space will not be much like Earth environments is somewhat immaterial. This is because establishing colonies – and, over time, new branches of humanity – off of Earth will be *adaptation*, the fitting of a life form to a new environment. While human evolution has significant differences from the evolution of many other species in the past few billion years of Earth life, it is still evolution. For this reason, we also argue in this book that the study of evolutionary adaptation will be central to making a success of human space colonization, and near the end of the book we apply the lessons of adaptation in sketching out an adaptive framework for human space colonization.

This book is our attempt to shed new light – derived from understanding evolution and adaptation – on the ages-old dream of human space colonization. We feel that the best way to make it a success will be to use the adaptive lessons

of billions of years of Earth life to humanity's next adaptation: the *extraterrestrial* adaptation, extra- referring to outside of or beyond, and terrestrial referring to the planet Earth.

The most recent book to treat our subject from an anthropological perspective was *Interstellar Migration and the Human Experience*, a volume of papers, some written by anthropologists and others with interests in evolution, published in 1985 by anthropologist Ben Finney and Eric M. Jones. That book tackled serious evolutionary issues associated with human space colonization, and remains a good introduction to them, but some of its elements can now be revised with more recent understanding. For example, it was published before the concrete evidence for planets beyond our own Solar System (which are being discovered monthly, now), and several decades of genomic research have vastly improved our understanding of even basic evolutionary principles, and on the macro scale we have new bodies of theory to help understand evolution as well. We also know that the 'dark matter' theory proposed in the volume has been verified, and there is a significant shift today – perhaps unimaginable in the mid-1980s – away from a vision of government-driven human space colonization, and towards private space colonization. Our worries and concerns today also differ from those of the 1980s, at least in part; today climate change is a major concern, having edged out nuclear annihilation, though we have new worries about nuclear terrorism. And while biology and computing were both largely the tools of science in the past, today they are rapidly becoming the tools of a burgeoning biotechnology industry and the 'gaming' entertainment industry, respectively, with numerous and specific attendant effects. In all of these ways, and others, we live in a different world than that of 1985.

Still, many of our suggestions have been offered in the past; in the 1920s, the Russian scientist Konstantin Tsiolkovski was publishing freely about humans living off of the Earth, in space. But in this book we present new arguments for a collective course of action that could ensure the survival of humanity, and, most importantly, we sketch out an evolutionary and adaptive philosophy for space colonization that is informed by the lessons of anthropology and evolution. In part, our book is an attempt to update what was paved out by the authors and editors of *Interstellar Migration and the Human Experience*. But we also write for a new audience, asking them to believe in a course that many will call impossible, and to support the real efforts of small companies and independent researchers who are preparing for the next major adaptive episode of human evolution, which we call the Extraterrestrial Adaptation.

Most space colonization literature has been written by astronomers, engineers and others in the 'hard sciences', and much that they have written has been somewhat technical. But it is equally important to add a human dimension to the discussion of space colonization because space colonization will ultimately be about humanity. Technology must be a tool, not an end.

In this book we are introducing a philosophy of humans-in-space that emphasizes long-term adaptation and evolution, in great contrast to the necessarily short-term, exploratory character of human-in-space activities of the past half

century. We comment on occasion on technologies, but our focus is on what we can learn from our own evolutionary background that can be applied in making a success of human space colonization. Overall, our goal is to help shape a philosophy of space colonization rather than to—at this point—define any specific courses of action, such as population sizes for off-Earth colonies, or their cultural and biological composition. Rather, we are suggesting a new character to the concept of humans in space as subtle, but important, as the difference between, say, crossing an ocean by sailboat rather than with a motorized boat, or between climbing a mountain with a small and nimble team as opposed to climbing it with sherpas, supplemental oxygen and so on. The differences are important.

To structure the introduction of humanity to the space colonization literature, we employ the field of anthropology, the evolutionarily-based scientific study of the human species, both biologically and culturally.

We begin by introducing anthropology, showing how it is structured as a discipline, how it generates knowledge, and why it will be significant to the successful human colonization of space. We then discuss arguments for and against space colonization, arguing that it is important, and that we should begin now, and we conclude by sketching out an adaptive framework for human space colonization. Overall, we wish to establish the foundations of a human-centered, evolutionary paradigm for space colonization. Our book is organized in three main sections.

In Part I, *The Context and Uniqueness of Human Evolution and Adaptation,* we place humanity in the larger context of evolution and show why humanity is well-suited for adaptation to space.

We begin with Chapter 1, *The Extraterrestrial Adaptation: Humanity, Evolution and Migration Into Space*, in which we introduce the field of anthropology, describe why and how it will be significant to successful space colonization, and begin to build a framework for thinking about space colonization in terms of evolutionary adaptation.

In Chapter 2, *Stardust: the Origins of Life, Evolution and Adaptation* we summarize the evolutionary history of the genus *Homo*, noting that it is characterized by adaptability.

In Chapter 3, *The Adaptive Suite of the Genus Homo: Symbolism, Language and Niche Construction,* we outline how humanity has adapted to Earth environments throughout prehistory, not because of our biological constitution, but in fact despite it, using the tremendous power of our symbolic, language-using minds to actively alter and construct ecological niches for our own habitation. We also describe the evolution of modern civilization, showing exactly what it is and dispelling the illusion that it is a pinnacle or end to human evolution, and that – as has happened in the past – it could collapse.

In Part II, *Arguments For and Against Human Space Colonization,* we review the arguments for and against human space colonization, concluding that it is not simply an option, but necessary for the survival of our species, or, at least, the survival of civilization, which we feel is worthwhile.

In Chapter 4, *A Choice of Catastrophes: Arguments for Human Space Colonization*,

we argue that a number of threats to humanity make it important to begin colonizing space now as an insurance policy for the human species.

In Chapter 5, *Common Objections to Human Space Colonization* we consider the most common objections to space colonization – including that it is too costly, a technocratic stunt, an elitist or escapist endeavor – and recast space colonization as a responsible investment for the future of our species.

In Part III, *Human Adaptation to Space: Lessons from the Past and Shaping the Future,* we reveal an adaptive framework for planning and carrying out human space colonization – informed by evolution at large and the human colonization of difficult environments to date – and discuss some possible future homes for humanity.

We begin with Chapter 6, *Starpaths: Adaptation to Oceania* in which we use an astounding example of human and adaptation in the ancient world to remind readers that human colonization of essentially alien regions is not a new and outlandish endeavor – or one focused on technology – but a natural continuation of millions of years of human adaptation and evolution.

In Chapter 7, *Building an Adaptive Framework for Human Space Colonization*, we outline an evolutionarily-informed, adaptive framework for human space colonization, based on all we have learned about evolutionary adaptation in the last 3+ billion years of Earth life, including human biological and cultural evolution discussed throughout this book.

We conclude with Chapter 8, *Distant Lands Unknown: Informed Speculation on the Human Future in Space*, in which we allow ourselves some informed speculation and offer a vision of how humanity might successfully begin to colonize our Solar System, and how this process would begin to change our species. We examine some of the latest concepts in extra-solar-system travel and interstellar propulsion, ponder the latest evidence of the multitude of worlds that lie beyond our own Solar System, and imagine what, and maybe even who, we might find there.

At the end of each chapter we include notes that often provide interesting details regarding points in the text, and/or references to technical reports, academic journal articles and other material we used to research this book.

Part I

The Context and Uniqueness of Human Evolution and Adaptation

1 The Extraterrestrial Adaptation: Humanity, Evolution, and Migration into Space

> *"... it is a long way from sailing canoes to interstellar arks. But ever since our ancestors started using tools to survive and eventually flourish in new environments, the pattern of evolution by cultural as well as biological adaptation has been underway. Although the prospect of traveling and living in space might seem 'unnatural' to many, it would represent a logical extension of the technological path our ancestors have been following ..."*
>
> Ben R. Finney and Eric M. Jones[1]

This is a book about humans migrating into space, why we believe such migration is important, and how the lessons of anthropology – the study of the human species – will be important to the success of human survival beyond Earth. We have three essential premises.

Premise 1: Human space migration is not optional, but necessary to avoid the extinction of our species.

This premise argues that human space migration must not be considered an option, but mandatory, at least in the long run. We will see in this book that most life that has ever evolved on Earth – up to 99% by some calculations – has become extinct. Numerous threats to humanity's long-term biological survival can be divided into two main classes: extraterrestrial and terrestrial threats.[2]

Extraterrestrial threats include Earth impact by extraterrestrial bodies, such as the comets or bolides that impacted Earth around 292 million years ago and about 65 million years ago; each of these events (the End-Permian and K-T events, respectively) resulted in mass extinctions and ecosystem disruptions that

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1 Finney and Jones (1985): 335.

2 Isaac Asimov reviews a number of possible disasters for humanity in *A Choice of Catastrophes* (Asimov 1979), as does Sir Martin Rees in *Our Final Hour: A Scientist's Warning* (Rees 2003). We review the topic in Chapter 4 of this book.

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today would extinguish the human species.[3] Terrestrial threats include nuclear war, pandemics and ecosystem collapses.

Whatever their source, threats to humanity can be classified according to their impact. Some might extinguish our species, others might extinguish a substantial portion of our species, while others might leave much of humanity alive but bring about structural disintegration of civilization, for example, by disrupting the agricultural backbone of civilization. We feel that the disintegration of modern civilization (examined in detail later) would be a vast loss for our species; while modern civilization is beset with problems, many of its own making, we consider it nonetheless worth saving because its benefits outweigh its detriments.

Premise 1, then, argues that there exist real threats to humanity as a species and to modern civilization, and that, in the long run, the only solution is to continue with the exploratory, expanding nature of most successful species, so that migration from the surface of the Earth results in viable extraterrestrial human populations that are ecologically, biologically and culturally independent of Earth.

Premise 2: Human migration into space will be the continuation of the natural processes of evolution.

By this we mean – as we show throughout this book – that humans and our ancestors have a 4-million year legacy of migration, and that there is no logical reason to differentiate ancient migrations across Earth habitats from migration off of Earth. Placing human space migration in the terminology of human adaptation and evolution, we argue, is both appropriate and will be important to both its acceptance and its success.

By 'human', in this book we mean any member of (or the entirety of) the biological species *Homo sapiens* (sometimes the subspecies *sapiens* is also added). Later we will show that anthropology differentiates between anatomical and behavioral modernity when considering what it is to be human; for the moment, though, we simply mean modern humans; any member of our species, *Homo sapiens*.

By 'space', we mean any environment beyond Low Earth Orbit ('LEO',[4] here defined as being less than 2000km from Earth's surface). Space, then, is widely defined here, to include the Earth's Moon; other planets and their moons; orbits around those other planets and moons; space objects such as asteroids; and

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[3] Palaeontologist David Raup reviews these and other extinction events, pointing out that "... no species of complex life has existed for more than a small fraction of the history of life. A species duration of ten million years is unusually long ..." but also that "widespread species are hard to kill." (Raup 1993): 192–193. We comment on these issues later in this book.

[4] Our definition of LEO is from NASA's Global Change Master directory engineering guide: see http://www.gcmd.nasa.gov/User/suppguide.

open-space habitats such as planetary 'Lagrangian libration points' (L-points) where free-floating enclosed habitats (commonly thought of as 'space colonies') can remain in place without orbiting a body (other than the Sun in the case of our Solar System). Having said this, we agree with many authors that Mars is most likely the first off-Earth place that humanity will colonize in substantial numbers.

By 'migration' we mean purposive, permanent movement of humans from Earth to other habitats where they can survive as biologically, materially, philosophically, culturally and politically independent populations. By specifying purposiveness in human migration to space we indicate that this migration must be carefully planned and proactive, rather than hastily planned and reactive, as in the case of an emergency; in Chapter 3 we will introduce the concept of *niche construction* to identify this uniquely-human proaction, which has, ultimately, allowed the survival of our genus and species so far.[5] By specifying permanence in this migration, we are speaking not of 'tethered' explorations planned and carried out to return humans to Earth – though those will of course continue for some time – but 'untethered' movements in which migrants to do not return to Earth. Those humans who do not return to Earth will first be considered colonists, because they will have some dependencies on Earth or near-Earth supply. After some time, however, these humans would be considered entirely new, independent human populations: extraterrestrial populations. They will, naturally, diverge from humans of Earth both biologically and, more so, culturally.

By using the word *adaptation* in this premise, we mean that human migration to space is properly considered adaptation in the same way that ancient human migration into the Arctic region, for example, was a natural process that can be understood at least partly in biological terms as adaptation. Adaptation, as a verb, indicates any adjustment to an environment to increase survival. As a noun, *an* adaptation is a specific biological or cultural structure or process that increases ones' probability of survival.[6] A hummingbird's long, slender beak, for example, is an adaptation to the environment in which it lives, which includes

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[5] Moving populations of humans to new habitats would have effects on culture as well as biology, and must of course be carefully considered; an evacuation is different from purposive colonization. It has been shown that encountering new conditions can stimulate cultural innovation (Barnett 1953). Regarding biology, migration is one of the most significant drivers of genetic population dynamics and evolution of any species, which is why it is included as a factor in the well-known Hardy–Weinberg model of gene pool equilibrium; see Minkoff (1983): 146.

[6] As we will see, an adaptation is, to paraphrase biogeographer Geerat J. Vermeij, any variation that allows an organism to live and reproduce in an environment where it probably otherwise could not survive (see Vermeij 1978). A little more narrowly, and closer to the level of the individual organism, an adaptation can be considered anything, such as a physical characteristic, that improves fitness.

flowers whose nectar is only available deep inside long, slender tubes of petals. The traditional Arctic ethos, in which injured individuals voluntarily commit suicide during hard times to increase the likelihood of survival of the rest of the group, is an example of a cultural adaptation.

In sum, Premise 2 holds that human migration into space will be a continuation of human evolution rather than an outlandish, science-fiction fantasy of space 'conquest' or a soul-less, technocratic endeavor focused on machines – both common conceptions among those who oppose human space activity. Rather, human space migration will be the same thing migration has been on Earth: people in search of new homes, using both biological and cultural adaptation to survive and, eventually, thrive.

Premise 3: Anthropology – the scientific study of the human species, in all its aspects from biology to culture – will be critical to successful human migration into space.

This premise holds that if humanity is to succeed in migration to extraterrestrial habitats, the endeavor will have to be strongly informed and conditioned by what humanity knows about itself. The study of humanity is in Western science known as anthropology, *anthropo* referring to humanity and *logy* referring to 'the study of'.

Anthropology is the only academic discipline that has systematically studied the human species at large; sociology and psychology take rather narrower views, normally focusing on Western, industrialized cultures, whereas anthropology examines all humanity in space and time. Anthropology is traditionally subdivided into four subfields. *Physical anthropology* has studied the human species as a biological phenomenon, and since biology is structured by the process of evolution, physical anthropology is deeply involved in the study of human evolutionary history. This includes the search for, discovery, and analysis of fossil remains of our ancestors and near-relatives, the study of the entire Primate order (of which *Homo* is one of many genera) and – largely in the last 30 years – the genetics and genome of our species. Another major division of anthropology, *archaeology*, studies the human past via the material remains of human lives; artifacts, from entire ancient cities to individual stone tools that reveal the long-term story of what we and our ancestors did in the past. A third major field, *cultural anthropology*, studies living human groups, referred to as cultures, to understand how humans organize themselves, communicate, engage in conflicts and mediation, and so on. Finally, *linguistic anthropology* studies the unique human communication system called language, from its origins to how it is used among living cultures. In sum, these studies have provided humanity with a Western scientific understanding of its origins, story, and current state.

In Premise 3, then, we argue that if humanity is to succeed in migrating to space, that migration will of course have to be structured on what humanity is, and how humanity changes through time. Since anthropology is the only Western academic field that has studied what humanity is and how it has