The History and Philosophy of Astrobiology

The History and Philosophy of Astrobiology: Perspectives on Extraterrestrial Life and the Human Mind

Edited by

David Dunér
with Joel Parthemore, Erik Persson
and Gustav Holmberg

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INTRODUCTION

EXTRATERRESTRIAL LIFE AND THE HUMAN MIND

DAVID DUNÉR

… cette curiosité mutuelle avec laquelle les Planetes s'entre-considerent & demandent l'une de l'autre, *Quel Monde est-ce là? Quelles Gens l'habitent?*
—Bernard de Fontenelle,
Entretiens sur la pluralité des mondes (1686)

Conversations on the plurality of worlds

Perhaps, wonders the philosopher in Bernard de Fontenelle's *Entretiens sur la pluralité des mondes* (1686), there are astronomers on Jupiter; and perhaps we cause them to engage in scientific quarrels, so that some Jovian philosophers must defend themselves when they put forward the ludicrous opinion that we exist. Their telescopes are directed towards us, as ours are towards them, "that mutual curiosity, with which the inhabitants of these Planets consider each other, and demand the one of the other, *What world is that? What people inhabit it?*" (Fontenelle, 1701, p. 93; 1767, p. 207)

Human beings have wondered about the stars above since the dawn of the species. Does life exist out there? Are we alone? Questions of life in the Universe can be traced back to antiquity: to philosophers like Epicurus of Samos and authors like Lucian of Samosata. Since then, astrobiological questions have fascinated scientists and philosophers and have been discussed by religious thinkers and utopian authors. These questions have progressed from things of which we could only speculate upon into objects of practical study. When the cosmos was revealed during the scientific revolution of the sixteenth and seventeenth centuries, the super-lunar world – the Universe beyond the Moon – was no longer closed and unchanging but vast and evolving. When Copernicus put forward his heliocentric model in *De revolutionibus orbium coelestium* (1543), Earth was reduced to a planet like other planets. In 1609 Galileo trained his telescope on the Moon and, like the Earth, found it to be rugged and uneven, perhaps even having similar mountains and oceans (Galileo, 1610). Then scientists and philosophers wondered if these celestial bodies could also harbour life. Earth was no longer unique.

On 11 November 1572 when the Danish astronomer Tycho Brahe (1573) saw an extremely bright new star in the constellation Cassiopeia, the sidereal heavens no longer seemed unchanging and eternal, as Aristotelian cosmology had taught. His observation made it possible to think about creation and change not only with respect to the Earth, but also to the Universe. In 1575, as a gift in fief from the Danish king, Tycho received the island of Ven in the strait of Öresund. There he constructed the biggest, most advanced observatory in the world: Stjärneborg (*Stellæburgum*). With its help, he looked to the sky with his naked eye to search for distant stars and other worlds.

Tycho's measurements of the positions of the heavenly bodies (published by Kepler in 1627) were indispensable to his disciple Johannes Kepler's formulation (1609; 1619) of the planetary laws of motion. In turn, Isaac Newton (1687) brought Kepler's laws and Galileo's mechanics together into the gravitational theory of classical mechanics. This enabled the detection of the first exoplanet, 51 Pegasi b, which was announced on 6 October 1995 (Mayor and Queloz, 1995; Perryman, 2012).

In the late eighteenth century, scientists increasingly came to the conclusion that the Earth has had a long history composed of many geological eras. Contributing to the story of modern astrobiology are also the discovery of spectroscopy, Darwin's (1859) theory of evolution, the advent of genetics, the research into the molecules of life, the space programme, and, most recently, the discovery of extremophiles and exoplanets. All of these discoveries contributed to scientifically grounded arguments that the conditions for life need not be restricted to Earth.

Contemporary astrobiology is something more than the results of discoveries and theories. It is the product of societal factors. These include collaborations, institutions, and technological changes and of human inspiration and imagination. This volume captures this distinct history and diversity: the ideas and events that made it possible to think of other worlds and distant life. It traces the history of science and the development of new schools in philosophy. Its aim is to discuss the place of humanity in the Universe.

In 2010, eight scientists and scholars formed a research group at the Pufendorf Institute for Advanced Studies, Lund University, Sweden, under the direction of David Dunér. Two visiting professors joined the group in

2011. The project, entitled “Astrobiology: Past, Present, and Future”, gathered astronomers, geologists, chemists, biologists, historians, philosophers, and other professionals interested in the multidisciplinary field of astrobiology. Research focus was, among other things, on the humanistic side of astrobiology, on the ethics of space exploration, on epistemological questions, and on the historical establishment and development of astrobiology as a scientific enterprise.

Over its first year, the group arranged four workshops and one international conference which addressed the emergence and evolution of terrestrial life, the possibilities for interstellar communication, the search for exoplanets, and the history and philosophy of astrobiology. A conference took place 27–28 September 2011 on Ven (now part of Sweden), a short walk from the remains of Stjärneborg (Dunér *et al.*, 2011). The “History and Philosophy of Astrobiology” conference gathered researchers from around the world to share their results and insights.

This volume is a product of that conference and the previous workshops (see also Dunér *et al.*, 2012). It seeks to establish *the history and philosophy of astrobiology* as a research field in its own right, such that research in the humanities is a necessary contribution to astrobiology and complements ongoing work from biology, chemistry, physics, and astronomy. Cognitive, linguistic, epistemological, ethical, cultural, societal, and historical perspectives on the development of astrobiology are necessary to understand what is meant by “life”, “intelligence”, “communication”, and other phenomena in a universal perspective. It is also necessary to explore what ethical, epistemological, and societal problems are involved in space exploration.

The history and philosophy of astrobiology

What does it mean to speak of the history and philosophy of astrobiology? What lines of research are there and what has been accomplished? (See e.g. Dunér, 2012; Dick, 2012) And why history? Why philosophy? It is true that studies on the history and philosophy of astrobiology do not provide new empirical data on extraterrestrial worlds. Yet, what can be learned is the nature of what it is to be human. The search for life in the Universe touches on fundamental hopes and fears, on the essence of what it means to formulate a theory, grasp a concept, and have an imagination. This book aims to clarify why history and philosophy are important for the self-understanding of astrobiology. It will discuss how it has developed and what deeper fundamental problems it faces. History and philosophy of astrobiology is important for the self-understanding of the humankind itself. What does it mean to be a human being in the true universal sense?

In short, the history of astrobiology is concerned with the evolution of human conceptions of the plurality of worlds (for the history of the debate on extraterrestrial life, see Dick, 1982; 1996; Guthke, 1983; Crowe, 1986; 2008). In order to explain what the history of astrobiology is about, I will give a few examples of historical questions within this field.

Science: Recounting how and why astrobiology emerged and how it has become a respectable, scientific, empirical field of research.

Exploration: This involves the Earth, the Solar System, and extrasolar planets, along with the instruments and technologies that have made this possible. These include the optical telescope, radio telescope, microscope, and spectroscope, as well as manned and unmanned space probes. To a large extent, the history of astrobiology can be considered a history of technological change.

Theories: These include well-renown theories (and hypotheses and models) such as the heliocentric worldview, the theory of gravity, the theory of evolution, and the various theories of genetics. However, controversial and even refuted theories should also be studied. For example, Panspermia, known as the theory that life has spread through its seeds drifting in space, is still an optional explanation of life that has not been completely ruled out (Tirard, 2013, *this volume*; Brandstetter, 2012; Demets, 2012).

Scientific organisation: The organisation of institutions, laboratories, research groups, journals, space programmes, conferences, and international collaborations. The increasing levels of organisation within the last few decades reveal an ongoing institutionalisation of the field, in particular, the increasing number of scientific journals, workshops, university courses, and PhD programmes.

Science and society: Astrobiology does not exist in a vacuum but incorporates such factors which are sometimes regarded as extrascientific, such as politics, economics, religion, and public discourse (Billings, 2012; Race *et al.*, 2012). Since ancient times, debates over the place of life in the Universe have been strongly influenced by religious concerns and they have been equally influenced by the ways in which science is popularised.

Imagination: How human beings perceive the unknown and what they expect of extraterrestrials and distant worlds. Of course, human imagination says little about what actually is “out there”. However, it says a lot about people’s contemporary lives, culture, and world. It is about what was possible to think and the boundaries of their imaginations. Imagination seems to recombine projections of past experience in novel ways. What is entirely outside experience is likewise outside imagination. Studies into imaginary voyages might not be informative for the history and development of astrobiology as a science, but can be considered historically valuable documents in order to understand the dreams and imagination of a specific time period, as a key to the understanding the era they lived in, its conceptions, ideas, and endeavours (see e.g. Bjørnvig, 2012).

Astrobiology raises many other questions for historical research. In this volume we touch just a few questions that we consider most relevant, after all, it covers only one part of a much vaster territory. Much more remains to be said about the history and philosophy of astrobiology, such as how people in different times and places construct their conceptual frameworks, which is to say how they came to a structured understanding of the world around them and how they have used their cognitive capacities to locate the human place in the world and the Universe: a Universe in which the Earth is no longer taken to be the physical centre, but humanity remains very much – and for good reasons – the conceptual centre. This leads naturally into a discussion of the other main theme of this volume. Philosophy of astrobiology is, among other things, about:

Self-understanding: The philosophy of astrobiology is an ongoing, existential exercise in individual and collective self-understanding. That is, what it means to be human, where humankind's place in the Universe is, and how both of these conceptions have inevitably evolved. Since the time of the ancient Greeks, with their philosophers' motto *gnōthi seauton* ("know yourself"), philosophy, in particular the philosophy of the mind, has sought to capture what it means to be a mind, to have a mind, to live as an intentional agent in a seemingly non-intentional world. As Joel Parthemore writes (2013, *this volume*), space is "the ultimate mirror we hold up to ourselves." In confronting the depths of the cosmos, we confront the unseen depths in ourselves. In other words, astrobiology challenges our everyday conception of ourselves as human beings in the Universe.

Conceptual analysis: How to define key terms and frame discussion. Constructing concepts in order to be able to think and talk about the new phenomena encountered is a major task for astrobiological research. The most debated and discussed philosophical question in astrobiology is the concept of life. If we are searching for non-terrestrial life, we ought to know what it is we are looking for and what characteristics it might have. If life is a recipe, what are the essential ingredients and which are optional? Should these criteria pertain to metabolism, entropy, genes, reproduction, or something else? So far, the debate has intuitively employed an Aristotelian conception of definition (Aristotle, *Posterior Analytics*, 2.3.90b30–31), in which a “definition” is a limited list of characteristics that are both necessary and sufficient for something to be of the type of object it is, and from which all the characteristics of the object originate. In our daily lives, however, we make relatively little use of Aristotelian-type definitions and depend much more on prototypes (Rosch, 1975; 1978). Dogs, cats, and horses may seem to be more typical representatives for “life” than arsenic microbes. The debate on the definition of life could benefit from the insights of contemporary philosophy and cognitive science about human categorisation. However, astrobiology deals with categorisation not only with regard to life, but to such concepts as *habitable zones* (see e.g. Kane and Gelino, 2012), *Earth analogues*, *exoplanets*, *gas giants*, and *dwarf planets*. Future discoveries in astrobiology will most likely challenge our categorisations and definitions, that is to say, our preconception of what the world is and not is. So, we should be prepared to re-categorise and redefine our concepts. Future exobiological systematics and taxonomy will face problems concerning categorisation, identification, and description. The taxonomy of future extraterrestrial fauna and flora will be a product of the human mind.

Ethics: The philosophy of astrobiology is a coming-to-terms with basic ethical issues and human values. These are, among others, how we should behave if we find extraterrestrial life, whether we have moral obligations to such life and, if so, which ones (see e.g. Persson, 2012). There is also the question as to whether and under what conditions terraforming is permissible (see e.g. Haqq-Misra, 2012), to what extent inhabited and uninhabited planets should be preserved in their pristine state or whether they could be mined for their resources. If this is the case, then who has the rights to those resources? Do we have an obligation to spread life or to avoid contaminating other worlds with life, including the microbes that we have accidentally or intentionally transported there? Related to the ethical questions of astrobiology are those that include political ideologies and considerations, economical concerns, and distributional justice. Astrobiological exploration is expensive and involves political decisions. Who owns the Moon and future scientific discoveries of astrobiology? Why spend money on astrobiology and the search for unknown life on distant planets rather than using the money on the only life that we definitely know exists?

Epistemology: A rigorous consideration of what is known, what is knowable in practice or in principle, and what is knowably unknown. Epistemology of astrobiology is a less explored philosophical territory concerning the limits of astrobiological knowledge. How long should we search without positive results before we give up? What is possible and not possible? The epistemological problems of astrobiology are somewhat similar to those of other branches of science, but with the exception that the limits of our astrobiological knowledge seem to be much more uncertain.

Semiotics and language: The construction and decoding of interstellar messages raise a number of semiotic and linguistic questions. How can we recognise and decipher incoming messages? This is not just about constructing a vehicle for information transfer. Its concerns are on what is needed for effective communication and the symbolisation of concepts, and the relationship between syntax, semantics, and pragmatics. Interstellar communication (see e.g. Sagan, 1973; Vakoch, 2011) is in fact less of a scientific-technological problem than a communicative-semiotic one. How extraterrestrials might communicate depends on biological and cultural factors, i.e. how their bodies are constructed and how they interact with their environment and how they have evolved through the bio-cultural co-evolution (Dunér, 2011b). The semiotic and cognitive problems of interstellar communication will be further discussed below.

Cognition: What is intelligence and cognition and are there universal laws for the evolution of intelligence? How would the human mind, which is entirely a product of a terrestrial environment, function in extraterrestrial environments? Astrocognition deals with questions concerning the cognitive challenges of the human mind when confronted with the unknown (Dunér, 2011a), and the question of how cognitive abilities emerge through the evolutionary processes in different habitable environments. I will soon return to these questions and go deeper into cognition from an astrobiological point of view.

This volume

The historical and philosophical topics previously discussed are just some of those that to a minor extent have been studied or need to be scrutinised further in the future. Many more historical and philosophical issues are waiting to be explored. In this volume we have gathered a wide range of studies on the thought-provoking, imaginative, and critical questions of astrobiology, and the search for life and intelligence in Universe. The book is divided into three sections: Cognition, Communication, and Culture.

The first section (*Cognition*) focuses on the human mind and what it contributes to the search for extraterrestrial life. It explores the emergence and evolution of life and cognition and the challenges humans face as they reach to the stars. Erik Persson (Chapter 1) introduces some additional philosophical questions for consideration, the ethical dilemmas involved, and asks whether astrobiological research is justifiable at all. Mathias Osvath (Chapter 2) takes a cognitive zoology approach in formulating an astrocognitive theory of the universal principles of intelligence. Joel Parthemore (Chapter 3) considers the limits of human conceptual abilities and posits astrobiology as an entry into what he sees as truly the *final frontier*: “the unmapped territory of the human mind”. Astrobiology research threatens to challenge our cherished conceptual frameworks and provoke a radical re-conceptualisation of what it means to be human. In a similar vein, Per Lind’s (Chapter 4) interest lies with the human mind’s encounter with the unknown (see Dunér, 2011a) and consequent experience of what he describes as *cognitive derailment* and perplexity in front of the unspecified that challenges trusted frames of reference and interpretation. His framework is Pyrrhonean scepticism which establishes irresolvable cognitive conflicts as a means of overcoming dogmatism. Finally, Jean Schneider (Chapter 5) raises classical issues concerning the definition of extraterrestrial life and intelligence.

The second section (*Communication*) examines the linguistic and semiotic requirements for interstellar communication. It considers what is needed for successful communication and if there are universal rules of communication. Michael Arbib (Chapter 6) asks: if space aliens resembled octopuses, how would they communicate? Arthur Holmer (Chapter 7) uses comparative linguistics to discuss the possible features and restrictions of exolanguages. From semiotics, Göran Sonesson (Chapter 8) discusses the problems involved in recognising a message as a message. What does it mean to transfer meaning or decipher symbols? Finally, Maria G. Firneis and Johannes J. Leitner (Chapter 9) reappraise what is perhaps the most famous attempt to construct a logical interstellar language: Hans Freudenthal’s *lingua cosmica.*

The third section (*Culture*) considers the cultural and societal issues involved in astrobiological research. It inquires into astrobiology’s organisation as a scientific discipline, its responsibilities in relation to the public sphere, and its theological implications. Stéphane Tirard (Chapter 10) discusses the panspermia hypothesis, defended by French botanists and plant physiologists in the second part of the nineteenth and the beginning of the twentieth century. Gustav Holmberg (Chapter 11) studies the popularisation of exobiology, and the boundary work going on in science, with particular consideration to the Swedish astronomer Knut Lundmark. Urszula Czyżewska (Chapter 12) takes a sociological perspective on how an increasing number of scientific journals in the field reveal the ongoing institutionalisation of astrobiology. Christopher C. Knight (Chapter 13) and Ludwik Kostro (Chapter 14) discuss the interrelations, incompatible or harmonious, between theology and astrobiology. Finally, Jacques Arnould (Chapter 15) summarises the challenges facing astrobiology, in the present and future, and asks whether astrobiology is the next revolution.

In the remainder of this introductory chapter, I will further examine these three major themes – cognition, communication, and culture. Through addressing these questions on the history and philosophy of astrobiology, let us take the first steps in the exploration of the immense *terra incognita* of extraterrestrial life and the human mind.

Cognition

In the course of everyday events and encounters the human mind has been enabled, through an evolutionary process, to understand, interact, deal with and adapt to the environment of this particular planet and to the minds of other human beings. Thus, the human brain is well adapted to the biological, ecological, and physical characteristics of our planet, as well as the cultural, social, and cognitive characteristics of the tellurian species *Homo sapiens sapiens.* What if we extend this human perspective and turn our eyes towards the starry sky to ask ourselves: are there other thinking beings out there and, if so, what are they thinking? Then, we face the cognitive questions of astrobiology.

The multidisciplinary field of *astrocognition* – i.e. literally the "acquaintance of the stars", from the Greek *astron*, star, and Latin *cognitio*, knowing or acquaintance – was first proposed in 2009 (Dunér, 2011a) and could be generally defined as:

> the study of the origin, evolution and distribution of cognition in the Universe.

…Or, simply:

> the study of the thinking Universe.

This mirrors the 1996 NASA Strategic Plan's definition of astrobiology as "the study of the living Universe" (NASA, 1998; Chyba and Hand, 2005). While astrobiology searches for the necessary and sufficient conditions for life in the Universe, astrocognition goes further and seeks the conditions for awareness and self-awareness. The Universe is not only living, it contains not just self-reproductive entities, but it also has apparently led to self-reproductive organisms that are able to reflect on the Universe they live in, on their place in that world, and their own thoughts and existence. We humans are the only species here on Earth that is able, as we know it, to reflect upon the Universe. Through the self-conscious human being, the Universe can also be considered self-conscious and able to reflect upon itself. It seems, then, that the Universe is not only bio-friendly (Davies, 2007), but also *cogito-friendly*.

Like the astrobiology field of which it is a part, astrocognition requires a multidisciplinary approach which brings together cognitive science, philosophy of mind, animal cognition, semiotics, linguistics, anthropology, cultural studies, history of science, computer science, neuroscience, evolutionary theory, physics, astronomy, and space technology. If the general philosophical, ethical, and theological implications of extraterrestrial discovery have received only minimal discussion (see e.g. Davies, 1998; Jakosky, 2000; Bertka, 2009), then the cognitive implications have hardly been touched on.

The field of astrocognition concerns cognitive processes in space, the origin and evolution of cognitive abilities, and cognition in extraterrestrial environments (Dunér, 2011a; see also Osvath, 2013, *this volume*). In terms of astrocognition, *cognition* can be described as the ability of processing sensory inputs for action in the environment. If we are discussing the existence of extraterrestrial intelligence in space, then I maintain that we must take into account the research within cognitive science and affiliated research areas in order to find answers to these questions: What is needed for higher cognitive skills to evolve? What physical, biological, societal, cultural, and other environmental factors shape cognition? What cognitive abilities are needed for a living organism to be able to manipulate its environment or, in other words, to develop technology?

The astrocognitive paradigm states that exploration of extraterrestrial environments and contact with other forms of life and civilisations, will change our thinking, conceptual frameworks, and belief systems. This condition leads to a discussion of what we can know and cannot know about the extraterrestrial, or, put in another way, the limits of our human-based epistemology and the constraints of our evolutionary history. And further, what cognitive challenges we are likely going to face when we encounter the unknown, and the challenges our Earth-bound perceptual, cognitive, and psychological capacities face in a space context (Pálsson, 2009, pp. 79–80). In this way, as astrocognition reaches outward to the stars and to the minds we hope to find out there, it also reaches inward into the uncharted depths of the human mind. It is both about the human mind in front of the unknown and the evolution of an unknown potential mind in the unknown space. Thus, astrocognition tends to time and space, both temporal and spatial questions, i.e. tries to give answers to i) the origin and evolution of cognition, and ii) the distribution of cognition in the Universe.

Astrocognition concerns time and evolution. It starts from a fundamental, basic premise, *the evolutionary astrocognitive premise*:

> Cognition in the Universe develops through evolutionary processes of adaption to a specific, but changing environment, and the challenges it presents.

Thinking has an evolutionary origin (see e.g. Gärdenfors, 2006), and as such, cognition largely evolves as an adaptation to certain problems that the ancestors of a particular organism had faced during the evolution of the species. That is, the cognitive processor of the organism is adapted to, firstly, the physical and biological environment of their celestial body in order to understand and interpret, interact and deal with, and orientate itself in the particular physical and biological environment, in relation to its specific conditions, such as planetary orbit, gravitation, light conditions, atmosphere, radiation, temperature, chemistry, geology, ecology, and biota. Secondly, the cognition of an organism is also adapted to the mind and culture of its conspecifics in order to understand and interact with other individuals, to understand emotions, thoughts, and motives, etc., in a psychological and sociological interplay that forms that particular exoculture.

Under certain conditions, which we are only beginning to understand, the environmental pressures force the cognitive agent to evolve toward more complex and flexible cognition. On Earth we find that intelligence seems – in the same way as vision, aerial locomotion and other abilities – to have emerged several times, apparently independently, in the course of evolution and in separate evolutionary lines, i.e. convergent or parallel evolution (Seed, Emery and Clayton, 2009). The more intelligent or cognitively flexible species on Earth, such as primates, dolphins, and corvids, share some qualities. Firstly, they are social animals and have a high degree of social complexity. Secondly, they are adaptable to very different environments and diets. If we could better understand the processes behind the rapid brain evolution that began a few million years ago on Earth – the encephalization in the Phanerozoic (Bogonovich, 2011; Carter, 2012) – then we could use this knowledge to formulate astrocognitive theories on the evolution of intelligence in space (see further Osvath, 2013, *this volume*).

Astrocognition concerns space and spatial consciousness. Cognitive science can give clues to how we understand and think about the Universe and reveal new perspectives on human encounters with the unknown. In short, cognitive science studies how we and the external world are represented and how we use cognitive tools for our thinking, such as language, image schemas, mental maps, metaphors, and categories. Yet, it is also how we use and interpret signs, objects, drawings, images, etc., to enhance communication. It is about perception, attention, memory, learning, consciousness, reasoning and other things that we include in what is called "thinking".

Cutting-edge thought in cognitive science portrays the mind as embodied, extended, distributed, and situated. According to the theory of *the embodied mind* (see e.g. Varela, Thompson, and Rosch, 1991; Lakoff and Johnson, 1999; Krois, 2007; Thompson, 2007), the mind is not something independent and detached from the body. There is no "brain in a vat", to borrow a turn of phrase from Hilary Putnam's (1981) famous thought experiment. Instead we think with the body. Therefore, bodies of other kinds and evolutionary backgrounds, like those that might exist on other planets in the Universe will have other minds and ways of thinking. The brain does not only need the body, but also the surrounding world in order to function efficiently. The environment has an active role in driving cognitive processes. According to the *extended-mind hypothesis* of Andy Clark and David Chalmers (1998; see also Clark, 2008), the mind leaks in various substantive ways into the environment. The boundary between self and non-self, self and world, is one that is never fixed but constantly being re-negotiated. In a similar way, *distributed cognition* (Hutchins, 1995) stresses the non-localizability of much of cognition, that we are using our environment and tools for enhancing thinking, and that we place our ideas and memories in things, such as books, computers, etc.

So, where we are in time and space is essential for cognition. What the senses convey have to be interpreted through means of specific cognitive processes. The cognitive agent is never just a passive recipient of images and information from the surrounding world. Instead, the brain actively searches out patterns in what is conveyed to it through the senses and interprets them through a process that is determined by both biological and cultural factors. The world distorts our concepts, and the concepts distort our world. Striking examples of this *epistemic perception* are the maps of Venus and Mars from the seventeenth century and onwards, that delineated the surface of the planets (Dunér, 2013b). We see what we expect to find. In 1877 at the Brera observatory in Milan, Giovanni Schiaparelli recorded a detailed network of canals on Mars. This finding was confirmed by the American astronomer Percival Lowell, who detected hundreds of Martian canals that he interpreted as an artificial irrigation system.

Another cognitive ability is *categorisation* (Lakoff, 1990; Taylor, 2003). All living creatures seem to categorise the environment in terms of edible versus inedible, benign versus harmful, and so forth. Categorisation becomes more complex in humans. The human mind tends to categorise, seeing hierarchies and similarities between things, such as stellar spectra or species and genera in taxonomy (Berlin, 1992; Dunér, 2013c).

From these cognitive theories concerning the human mind we can conclude that encounters with the unknown outer space will: i) change our spatial consciousness; ii) change our thinking, conceptions, categories, belief systems, culture, and meanings of things. What we have come to believe so far through science and human cogitation will face anomalies. The old categories, systems, and beliefs will fall short when we try to understand these new unfamiliar things. Our thinking, science, and belief systems will then have to be revised, which will lead to adjustments, adaptations, and compromises. A task for astrocognition is to search for the limits of our bio-culturally evolved, earthly brains to try to find out what we can know and what we are likely to encounter in the future. As thinking beings we are earthbound and historically constrained. Our intellect does not transcend space. Instead, our cognition is situated in space.

Astrocognition puts discussions of cognition into a wider perspective. We will get further theoretical, scientific knowledge of i) how we encounter the unknown, how the human mind interacts with space and the environment around us; and ii) the evolution and prerequisites needed for cognition to emerge. These achievements will be valuable even though we might never go beyond our Solar System. From this we would learn more about human cognition and how it has been developed here on Earth. But we will also get iii) practical knowledge that will prepare us for future manned and unmanned space missions and terraforming, how to live in an extraterrestrial environment, and how to code and decode interstellar messages. Finally, vi) future comparative research on cognitive processes of extraterrestrial minds can reveal more about how humans think. Then will we know more on specifically human ways of thinking and sense-making, specific or typical characteristics of our species. Are we unique in the Universe? This approach can lead to the development of not just an anthropocentric, but also a cosmocentric perspective on cognition. An astrocognitive inquiry will give indications as to what a human being is from a truly universal point of view. Encounters with other minds here on Earth or on extrasolar foreign planets in deep space among billions of stars and galaxies can give a more universal answer to the question: "What is thinking?"

Communication

This is a message, a message addressed to you constructed in a code-system called English marked with Roman letters in ink on sheets of cellulose, or as liquid crystals on a computer screen. It is here and now, perceived by the senses, being interpreted by a being with a brain, body and history, living in the world. By using this code-system I hope to make myself understood, to awaken thoughts and ideas in the mind of the receiver which are similar to mine when I formulated this message. This hope of mine stems from the fact that we share the same human cognitive abilities that are a product of our common evolutionary history here on Earth, the planet Tellus. However, if we extend this communicational situation beyond Earth, the question naturally arises: how could communication be possible between intelligent beings of different environments that differ physically, biologically, and culturally, and have developed through separate evolutionary lines? This is the *cognitive-linguistic problem of interstellar communication* (Dunér, 2011b).

The circumstances in which we will have no kinship, that we will not share similar bodies or cultures, or even similar physical realities will have far-reaching consequences for how we will be able to construct and interpret messages from distant civilisations. The usual strategy to overcome the problem of interstellar communication has been to try to construct a message that is a universal symbolic information transfer, which is independent of context, time and human nature. This can be called *the universal-transcendental interstellar message objective*. However, this strategy and its requirements are not reconciled with what we presently know about cognition, communication, and evolution. Particularly, it presupposes the universality it is aimed at, and thereby ignores the facticity of evolution, and the situatedness and embodiment of symbolisation. It ignores the context that the living organisms, with their cognition and communication, are planet-bound and constrained by certain physical conditions. It leaves out time and history – the evolution, the phylogenetic, ontogenetic, and cultural-historical development – in which the organisms are evolving. Finally, it ignores the nature of the communicators – that they have bodies and brains evolved in interaction with their environment. Building on the basic observation in cognitive science that our cognitive and communicational skills are embodied, situated in and adapted to our terrestrial environment, we cannot exclude the context, the situation, space, time, and human nature if we would like to construct comprehensible interstellar messages.

In order to solve the interstellar communication problem we need the insights of cognitive science, evolutionary theory, semiotics, hermeneutics, and history. Inasmuch as interstellar communication is thought to be an exercise in coding and decoding signs, then the relevance of semiotics (Vakoch, 1998) should be obvious. Information transfers by means of symbols (or conventional signs), which will be explained below, are probably an ineffective and hopeless way of starting a communicative interaction. Thus, it could be argued that the problem of interstellar communication is not just a problem within natural science, but a true humanistic problem in its true sense, a human problem. It is we humans who will send and receive, and code and decode the messages. The communicative problem also has to do with history, understood on the most basic level, as the interaction of organisms with their environment over time. Our cognition and communication are results of time, of history, both evolutionary history and socio-cultural history. Communication is not something pre-given, but rather evolves in interplay with the environment, in dialogue of agent with agent. In our case, this process took millions of years (Donald, 1993; 2001; Christiansen and Kirby, 1997; Deacon, 1997; Tomasello, 2008). Human communication, whether it consists of lingual, symbolic, or bodily expressions, is dependent on the inner workings of our brains and how humans interact with their physical, biological, and cultural environments. Accordingly, communication is a bio-cultural hybrid, a changing product of the genetic-cultural co-evolution. Communication is therefore a situated practice. It is constrained by its surroundings and is adapted to specific circumstances. This means that we cannot exclude the situation where the message is performed, and the physical, biological, and socio-cultural context of the communicators. We are planet-bound creatures.

Intelligence could be seen as evolved mental gymnastics which is required for a particular organism to survive and reproduce within its specific environment. This includes the capability of representing activities and being able to make inner models of reality. If the extraterrestrials are intelligent then they probably have some kind of symbolisation abilities and abstract thinking detached from the environment, with which they can reason about things that do not exist and things that are not right in front of them, facing their senses, in a specific moment in time. A very effective tool for symbolising thought is our communicational devices. John Taylor (2002) describes language as a set of resources that are available to the language user for the symbolisation of thought and the communication of those symbolisations. It facilitates thinking about that which is not immediately in front of us, engaging with our senses; as well as that which, seemingly, could never exist outside of fiction. It frees us ever further from the here-and-now and lets us better contemplate the might-have-been. It allows us to share ideas and mental states. Yet it rests on the cognitive abilities that are a result of bio-cultural evolution here on Earth.

Like our spoken languages, interstellar communication is intersubjective, a system for sharing information and for socialising. Communication can be regarded as a sharing of mental states and the expression as information about a mental state (Østergaard, 2012). Semantics is based on a "meeting of minds", as Peter Gärdenfors (2013, *forthcoming*) puts it: "the meanings of expressions do not reside either in the world or (solely) in the mental schemes of individual users, but emerge from *communicative interactions* between the language users." The evolution of semantics could be seen as a co-evolution of intersubjectivity, cooperation, and communication (Gärdenfors, 2008a; 2008b). In linguistics and cognitive science, almost no one would deny that intersubjectivity (Zlatev *et al.*, 2008) plays a critical role in the acquisition of language, but in the context of interstellar communication these basic insights have often been overlooked (Dunér, 2013a).

The interstellar communication problem is very much a semiotic problem: how meaning can be transferred and interpreted. As Göran Sonesson (2013, *this volume*) points out, the first problem that arises in a situation of interstellar communication is realising that it really is a message at all. Some regularity and order and finding a repetition in the pattern is not enough. We have to understand that someone has an intention with it that we should understand as a message. Next is the problem of deciphering what the message means. Some kind of vehicle for transferring the mental content is needed. The problem with symbols is that they are conventional, or arbitrary, as Ferdinand de Saussure (1916) called them. They are detached representations and, as such, dependent on culture and human interaction. The sign (the expression) and the signified (the content) have no intrinsic connection. It is not impossible to imagine that the aliens would have certain knowledge about their environment that in its content is similar to our own knowledge of mathematics, physics, or chemistry. However, their expression of it, as Sonesson clearly points out, would most likely be very different from ours. This basic semiotic distinction between expression and content is neglected in most human attempts at interstellar messaging. For all its ingenuity, Freudenthal's (1960) *lingua cosmica* is probably an effort in vain. Sonesson's critical analysis shows the inevitable role semiotics must play in message constructions. How we, and the aliens, transfer meaning in different ways, I would say, is the result of our dissimilar evolutions, bodily and cognitive constructions, and socio-cultural histories. The construction and interpretation of the symbols are dependent upon how our brains work, what our bodies are like, how we interact with our environment, how our sensations are processed and the history of our culture.

So we can conclude that:

> Communication is based on cognitive abilities embodied in the organism that has developed through an evolutionary and socio-cultural process in interaction with its specific environment.

This is the case for human cognition and communication, according to recent research in cognitive science and cognitive linguistics. In other words, our communication is adapted to an earthly environment and for communication with our conspecifics. Our communicational and symbolic skills have evolved through an evolutionary and cultural-historical process here on Earth and are thereby constrained by our human bodies, terrestrial environment, and the socio-cultural characteristics of our species. So our human communication is, in fact, maladapted to interstellar communication. This understanding of human cognition is crucial for future interstellar communication and should be taken into account in order to be able to transfer messages to other minds in the Universe.

Culture

The human desire for exploration and man's encounters with the unknown are a fundamental part of the cultural history of mankind, from the first, stumbling steps on the African plains to the recent explorations of our globalised and urbanised world. From the very dawn of the hominids to the days of the modern man, this ever changing terrestrial being has expanded in ever increasing circles of spatial consciousness, in an endeavour to climb over mountains to the next valley, cross vast oceans, and fly through the air. The next small step for a man, or giant leap for mankind, that of going far beyond the atmosphere and gravity of the Earth to the unknown extrasolar space, is decisive, but that, too, is part of the long history of mankind.

A true universal history includes outer space and not only the human history on Earth, not only the short history of human civilisation but also the immense space, and, as we know it, the long history of matter from the big bang, through the formation of planetary systems and the evolution of life and cognition, to the future speciation and the final big crunch or the ever-expanding Universe and eternity of time. History is crucial in order to understand the perennial enigmas of who we are, where we come from, and where we are going. Historical narratives are essential in order to formulate possible answers to the big questions of science: the origins of the Universe and the development of galaxies, stars and planets, the evolution of life on Earth, the human species and the human mind.

What made astrobiology possible was not only those human cognitive and communicational skills that biological evolution has given us, but also human culture, the ability to learn from others. *Culture* can here be defined (Sinha, 2009, p. 292; see also Tomasello, 1999) as:

> the existence of intra-species group differences in behavioural patterns and repertoires, which are not directly determined by ecological circumstances and which are learned and transmitted across generations.

Characteristic of human social interaction is this ability to learn from others, i.e. culture, the transmission of learned behaviour and knowledge that is not biologically encoded, or in other words, the ability to transfer information from generation to generation that does not use the genetic code for the transfer but is learned, taught, and transferred by a multitude of communicative and cultural devices and artefacts, like language, signs, pictures, sounds, objects, etc. Accordingly, culture presupposes enduring joint beliefs or common knowledge.

Culture made technological change possible. It has given us the increasing capability to manipulate the environment in order to make it easier to live in it and to adapt the environment to fit us, instead of adapting ourselves to the environment. Technology could be described as ways of manipulating the environment, using objects in the environment outside the body in order to strengthen our genetically given capacities, such as body strength, perception, and cognition. Culture also enabled science. Astrobiology as a science is not something isolated from the living world, from culture, society, beliefs, imaginations, communication and interactions with other thinking, believing and feeling minds. The chapters of this book show the intense interactions going on in astrobiology, between mind and environment, between science and culture. Without social interaction, joint beliefs, intersubjectivity, information transfer – in one word, without culture – science and technology would not have arisen on this planet.

One day we might encounter another living planet. The travelogues and descriptions of these new worlds will inform us more about ourselves and our place in the Universe, how we interpret and understand the "reality" around us, than about the "real" or "objective" extraterrestrial world. An independent world outside us might exist, but we will never be able to reach it without filtering it through our minds. Anyhow, future discoveries and experiences of other worlds will change us and our culture forever.

The unknown

There are things we know. Even though life might not exist out there, it is we human beings with our brains, bodies, and cultures who are searching for it. The history and philosophy of astrobiology is centred on humans, or more specifically, the scientific endeavour's dependence on the human mind and the human culture. Astrobiologists have brains, for sure; they are using cognitive tools that are a result of the bio-cultural co-evolution of human cognitive abilities. Certain cognitive processes are at work when astrobiologists encounter unknown things, when they interpret their observational data, and when they gather and classify it. This does not go on in subjective isolation. Astrobiologists live in a culture, in a certain time in history, in a specific research environment, and collaborate with other thinking beings.

Through the history of astrobiology we find a certain common form of argumentation: the analogy, from what we know to what we do not know (Dunér, 2013b). An analogical argument could be explained as a search for similarities, i.e., a way of selecting features in the source domain that are to be mapped onto the target domain, and of transferring relevant properties from the source to the target. The challenge is then to select the correct and relevant salient features from an infinite number of possible ones in the source domain, which features will then be transferred to and mapped onto the target domain. In the *Sidereus nuncius* from 1610, Galileo showed, based on his telescopic observations and analogical reasoning, that the Moon had mountains and therefore had the same solid, opaque, and rugged nature as the Earth (Spranzi, 2004). In some sense, astrobiology as a whole is one single, great analogy. Starting from the one particular type of life we happen to know something about, namely life on

Earth, we proceed to search for life on other planets. We predominantly look for life as we know it: something needing oxygen, liquid water, being based mainly on carbon, inhabiting a planet of a certain magnitude that revolves at a certain distance from its sun and which in turn has to be of a certain size and capacity, and so on. Logically speaking, analogical arguments are invalid. However, in providing us with some point of departure, they still might hold some heuristic advantage in the search for life. What we are actually looking for is something that reminds us of ourselves, something similar to us. In fact, we are searching for ourselves. Though, life might be very different from what we imagine. The history of science is actually a history of surprises. The world we are living in turned out to be very different from what we first thought: richer, more complicated, more advanced, more peculiar and more astonishing than what we could dream of. This will also be true for astrobiology. Future discoveries in astrobiology will surprise us completely.

If we find extraterrestrial life, we can be sure that this will change our way of thinking and how we perceive the world and our place in the living Universe. It will change our culture and science. It could be said that this book is not on the *history*, but on the *prehistory* of astrobiology. Should the day arrive when we find extraterrestrial life on another planet in our Solar System, or on an exoplanet or exomoon orbiting another star, then that shall begin the new history of astrobiology. That occasion will be a historical turning point in our persistent search for life. The greatest discovery of all for a human in her life and for mankind itself in the history of its civilisation, would be the encounter with another thinking being.

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