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CULTURAL IMPLICATIONS OF THE SEARCH AND EVENTUAL DISCOVERY OF A SECOND GENESIS

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Abstract. This chapter addresses two important questions that intersect the natural sciences and the humanities, specifically philosophy: firstly, what are the implications of a search for a 'second genesis' (defined herein as "the emergence of biological complexity elsewhere in the universe"), and secondly, what are the implications of an eventual discovery of such a phenomenon. Astrobiology is introduced as the transdisciplinary science that is most likely to contribute to not only the discovery of a second genesis elsewhere in the universe, but also the research effort that, due to its multi-faceted composition of scientists and philosophers, will be able to help the world adjust to a potential discovery of such a magnitude. We refer to the English physicist C.P. Snow's concept of the "two cultures" (i.e., the sciences and the humanities) and imply that the transdisciplinary science of Astrobiology is the key to bridging the gap between them, and also an excellent opportunity for promoting interest in science and technology in our society. We then review relevant evidence for why we might expect to find life, for instance on Europa, a typical biofriendly body such as those that could be found in exoplanets. These speculations are made all the more exciting and timely by the new discovery of over 1,200 new planets, some of which are hypothesized to be habitable-zone candidates. We further address the implications of the (possible) discovery of a second genesis which might be possible with the use of landers, rather than manned spacecrafts. We reject "biogeocentrism", namely the notion that life is exclusive to the Earth. We believe that if Darwinian principles hold here on Earth, they can be reasonably expected to hold elsewhere in the universe, and that, at the very least, discovery of eukaryotic life elsewhere in the universe would strengthen the case for the eventual discovery of intelligent life elsewhere in the universe too (since according to Darwinian evolution, simple life must precede more complex life). Discovery of intelligent life would have greater implications in the humanities than would the discovery of very simple microbial life on some distant planet.

1. Introduction: Implications of a second genesis elsewhere in the universe

The question we wish to address in this chapter concerns one of the most rewarding scientific and cultural activities that are possible at present. The frontier of science and the humanities is the exciting territory we will discuss in this chapter. The fast development of technology has allowed us to address the issue of a possible "second genesis" interpreted as the emergence of biological complexity elsewhere in the universe (McKay, 2001). The origin of life is not fully understood. However, the general outline of chemical evolution of the precursors of the biomolecules has greatly advanced. The outline includes the likely pathways that nature may have followed during the molecular evolution that preceded the Darwinian evolution of the living cell. The seminal work of Charles Darwin in the 19th century established the basis for the second stage in the discussion of astrobiology. Two questions emerge out of the pioneering work in astrobiology: Firstly, we consider the implications of *the search* for a second genesis: Since its search is already a fact, its implications are already observable in different aspects of our culture, such as in science, philosophy and technology. Secondly, in this chapter, in a second stage we shall later discuss the implications of an eventual *discovery* of a second genesis. If the search for a second genesis is a fact, its eventual discovery is only a possibility, but a scientifically sound possibility, which places the study of its implications in the domain of speculation of high heurist interest.

Regarding the second stage of our discussion, we recall that the theory of Darwinian evolution is not a predictive theory. In order to get further insights as to what can be the eventual destiny of life in the universe that might not be evident from our current knowledge of biology, we should search for alternative manifestations of the living process. Having assumed that Darwinian evolution is a universal process, we may argue in favor of the inevitability of the origin and evolution of life, including intelligence.

2. Cultural Implications of the Scientific Search of a Second Genesis

2.1 THE PLURALITY OF INHABITED WORLDS: FROM SPECULATION TO SCIENCE

The debate in Western philosophy on the existence of other inhabited worlds goes back, at least, to the early Greek philosophers, being carried on since that time up to the middle of the twentieth century in the realm of speculation. Only in the last few decades we have begun to dedicate effort, knowledge and resources to settle this question through observation and experiments. Astrobiology emerges from such undertakings.

In other occasions we have discussed extensively the scientific bases of astrobiology. We have reached the conclusion that, either by the nature of its assumptions and its theoretical framework, astrobiology, understood as the search for a second genesis is indeed a valid scientific research (Aretxaga, 2006, 2008; Chela-Flores, 2003, 2006, 2008). What was originally a question in the realm of philosophy now has been shifted radically to the centre of science. One example that will be discussed below illustrates our point: astrobiology can explore in strictly scientific terms the possibility of whether the evolution of intelligent behavior is inevitable in an evolving cosmos. This change of point of view experienced by the question of the plurality of inhabited worlds in our culture for the first time in history we face the possibility of giving a definite answer to one of the most fascinating questions ever formulated.

2.2 ASTROBIOLOGY AS A TRANSDISCIPLINARY SCIENCE

It is not unusual to consider astrobiology as an intrinsically multidisciplinary, or more precisely interdisciplinary activity. It is well known that its study requires a collaboration of knowledge and methods of a diversity of disciplines, in order to tackle its diverse relevant questions, so that astrobiology forces upon us to bring together different areas of knowledge that often are far apart from each other. Nevertheless, some scientists maintain that astrobiology implies a deeper level of interaction between different disciplines: *transdisciplinary investigations*. This means a new approach to conceive the research activity, as well as its results.

Transdisciplinary science (TDS) has been defined as the integration of theoretical and methodological perspectives drawn from different disciplines, in order to produce new pathways for the investigation of a specific problem from a novel point of view (Stokols *et al.,* 2003). In this sense astrobiology is an outstanding example, since the problem of the search for a second genesis may be approached in order of increasing complexity by different disciplines.

According to the Spanish engineer J. A. Rodríguez-Manfredi, astrobiology exploits the synergy generated by different underlying disciplines, in order to create its own methods, procedures and objectives. In this manner, it goes beyond the mere exchange of information between different fields of specialization, since research requires the learning of a common language and learning new mental approaches that were initially foreign to the separate disciplines. Consequently, astrobiology is contributing to the progress of scientific research with new challenges (Rodríguez-Manfredi, 2008).

To sum up, astrobiology besides transforming the question of the plurality of inhabited words from philosophy to science, is now contributing to a new way of doing science, by taking advantage of transdisciplinarity.

2.3 THE SEARCH OF A SECOND GENESIS AS A PROMOTER OF COLLABORATION BETWEEN THE TWO CULTURES

Ever since the 1959 Rede Lecture by Charles Percy Snow (Snow, 1993), the suggestive term "two cultures" has called attention to the wide gap between Science and Humanities. These two intrinsically different cultural activities largely address the same questions. For this we should all persevere in establishing a constructive dialogue. Biologist Edward Osborne Wilson has attempted to bridge the gap between "the two cultures" with his seminal 1998 book "*Consilience: The Unity of Knowledge"* (Wilson, 1998). In this book, Wilson discusses methods that have been used to unite the sciences and might in the future unite them with the humanities. The term *consilience* describes the synthesis of knowledge from different specialized fields of human endeavor.

The difficulty in finding a common dialogue is deep in our culture: Giordano Bruno was a pioneer in this inter-cultural dialogue (Bruno, 2000). In 1584 he wrote his first three Italian dialogues during a visit to England. These writings were stimulated by debates at the University of Oxford. In his third dialogue: "*On the infinite universe and worlds*", Bruno introduced concepts that are still at the centre of astrobiology.

The lesson that we may draw from both history and our present experience is that the progress of human knowledge cannot be achieved neglecting either of the "two cultures" that were pointed out by Snow. Astrobiologists themselves often have requested the presence of humanists in this field, so as to achieve together better and deeper insights in the scientific search for a second genesis.

2.4 ASTROBIOLOGY AS A PROMOTER OF A NEW VISION OF REALITY AND THE HUMAN BEING

The Spanish engineer Rodríguez-Manfredi considers the consequences of the following remark: the instruments for observation model reality through its interaction, so that the aspect of a phenomenon will depend of the kind and stage of development of the artefacts employed for its observation - as in the case of the double nature of light: corpuscular and wave-like (Rodríguez-Manfredi, 2008). He concludes that astrobiology in so far as it contributes to new technologies and methods is already contributing to a change of perception that could lead to a revised version of both 'life' and 'universe'.

Mayz-Vallenilla has gone somewhat deeper in this question. The Venezuelan philosopher considers that the human being has access in a natural manner to reality through a cognitive pattern elaborated with categories modeled predominantly by the spectrum of visible light (*optical-luminous logos*). Nevertheless, there are artifacts of a 'meta-technical' nature, such as radio telescopes, scanning microscopes or particle accelerators that are in contrast to traditional telescopes and microscopes. The latter have been invented by outstanding minds (*meta-technical logos*). The fact that astrobiology amongst other branches of modern science, requires for its implementation such advanced models, methods and techniques (*meta-technical* technologies), implies that the basic concepts such as 'physical universe' (*physis*) or 'life' (*bios*) are profoundly transformed (Mayz-Vallenilla, 2004).

Taking the importance of these concepts in the elaboration of other equally fundamental for the construction of a culture, such as that of mind, body or intelligence, we could assert that its transformation shall reflect itself on the very definition of culture. To such a transformation we could assign the label 'Copernican'.

Just as our perception from time immemorial of the Solar System was radically transformed due to Copernicus and Galileo, also astrobiology is making it possible to conceive the reality of living organisms from a new point of view, which earlier we have called *sub specie Universorum*: under this category, life appears as a phenomenon intimately connected with the universe, as a natural tendency of its matter-energy substratum. The immediate consequence of this new conception is that the word "life" no longer refers to an *exceptional* phenomenon, to signify a local episode, a special case of a universal phenomenon (Aretxaga, 2008). This is the central problem of astrobiology, namely to investigate whether life on Earth is but one example of a ubiquitous phenomenon.

Today we are aware that both Copernicus and Galileo were correct (at least partially), and that their discoveries transformed profoundly human thoughts and feeling reality (knowing and experiencing it), as well as thinking and feeling in it (to know oneself and to live in it). As a result of that change, our lives continue to evolve, without being aware of it, in a world constructed on its consequences in a wide spectrum: science, art, literature, ideas, projects, in our daily lives. In the same way, we can foresee that confirming our view of life *sub specie Universorum* by an eventual success in the scientific search for a second genesis may have consequences when we consider related phenomena, such as mind, intelligence and even other aspects of our general knowledge. We can even imagine that all of these changes will, in turn have an effect in altering how we conceive the world (*Weltanschauung*), including the perception that we have of ourselves, of our position in the tree of life and of our place and responsibility in the cosmos. As pointed out by Lederberg out of all the objectives of space exploration "the study of life beyond the earth, which we term "exobiology", is the most subtle and demanding, for it insists: 'Know thyself'" (Lederberg, 1963).

2.5 THE SCIENCE OF ASTROBIOLOGY AND SCIENCE COMMUNICATION

Even though the debate in the Western world related to the plurality of inhabited worlds goes back at least 2,500 years it only started to become popular topic of discussion in the 19th century. There were several causes that contributed, for instance the observations and speculations of some astronomers — Schiaparelli, Lowell, or Flammarion — or the rising popularity of science fiction that encouraged by the possibility in principle of interplanetary travel, discovered in the topic of alien life a source of inspiration.

A key fact for understanding the rise in popularity of the search for extraterrestrial life during the 20th century was the creation of NASA in 1958, during the cold war. Soon after its foundation the American space agency created the *Office of Life Sciences* in 1960. This action demonstrated to the public opinion the priority that politicians and scientists granted to the relation between the studies of the origin of life and the technological challenge represented by interplanetary exploration. This intriguing relation between both of these fields, now formally established contributed to a general perception that extraterrestrial life and its scientific quest began to be perceived socially as a serious effort within culture, but at the same time the search began to excite popular imagination, occasionally excessively on this particular research line.

The socio-cultural context in which astrobiology was born encouraged a constantly fluid and mutually beneficial interaction between this discipline and science fiction, but at the same time it contributed to many misunderstandings as to the true nature and possibilities of such research.

At present, even at the level of the school curricula, much confusion arises due to a misconception of the real limits of science and the humanities. Indeed, science is an activity that is essentially experimental and supported by a reasonable theoretical background that is often presented in detailed mathematical language that is not easily understood by everyone. The discussion of astrobiology with the general public requires a detailed knowledge of science, philosophy, and theology. It is difficult for single individuals, either scientists, or humanists, to be able to approach reliably all aspects of contemporary culture. But it is nevertheless desirable to take additional modest steps in this challenging direction. Some experience in all aspects of culture is essential for a constructive, comprehensive and interdisciplinary discussion that dare to consider the implications of science in philosophy and religion; for a mutual understanding, yet another chapter on the popularization of science would be justified.

On the other hand, the close temporal proximity between the emergence and acceptance of astrobiology as a new science turns this subject into an excellent playground to analyze and better comprehend the inevitable clash of interests and interactions between science and technology, as well as between the latter two and other sectors of human knowledge. These additional areas of influence included also the humanities and theology, not excluding the relation of astrobiology with other areas of influence, such as the social, cultural, political, or economic ones. Due to the technologic challenges and its sense of adventure, astrobiology presents an excellent opportunity to advance in several fronts: pedagogical, science communication and new technologies (Alcibar, 2008).

3. Cultural Implications of the Discovery of a Second Genesis

3.1 WHAT CAN BE REASONABLY EXPECTED TO BE DISCOVERED

Often astrobiologists have to face the criticism of doing science without a subject matter. Currently, we do not have a definition of life that is unanimously accepted. This is in fact an open question in both philosophy and science. However, our present knowledge of life on Earth allows us to elaborate a reasonably well-accepted explanatory model. Putting these remarks together with our recent insights into life in extreme environments induce us to think that a similar phenomenon—life—could have taken place elsewhere in the universe in the favorable conditions that the increasing repertoire of exoplanets begin to suggest.

Extrapolating elsewhere in the universe our present understanding for the emergence of life does provide us with an object for astrobiology, since it allows us:

a) To set some theoretical bases for the possible existence of the main object of our research (a second genesis).

b) To suggest the elaboration of a coherent and realistic strategy, namely with possibilities of success, of the search and obtaining reliable data of extant, extinct life or simply the identification of reliable biomarkers.

Consequently, astrobiology can be understood as the *scientific exploration* of the universe searching for a second genesis (Aretxaga, 2008).

We are gradually discovering other places in the universe where such conditions exist suggesting that it may be possible to detect the presence of bacterial life. As a consequence of the exciting discoveries of Cassini that come more than a decade after the epoch making discoveries of the Jovian moons by the Galileo mission, our general view of the conditions favorable for a second genesis in our own Solar System, our cosmic backyard, have been greatly enhanced. The conditions for habitability are more widespread than were thought to be possible at the end of the 20th century.

In our Solar System there are several cases of some interest, where life can reasonably expected to be discovered:

• Europa may be a typical biofriendly body amongst extra-solar planets. The main problem is how to select appropriate experiments in situ, after surface landers are able to filter melt water from Europa's frozen surface.

• Evolutionary tests are also suitable in potential water sources under the Martian surface, such as in its north pole. These environments may contain microorganisms, an exciting possibility that was raised by the Allan Hill meteorite. Although the possibility of having detected life in this meteorite was not subsequently confirmed, it was nevertheless an important contribution that stimulated discussion about the possibility of life elsewhere in our Solar System. Cases of possible habitability to test in the future have been discussed in the literature (Chela-Flores, 2010).

From the above examples we have learnt that searching for a second genesis is feasible in the foreseeable future. The ultimate aim of a biology experiment in Solar System exploration is to develop robotic tests that are compatible with the necessarily reduced dimension of landers. In the case of a Martian mission to subterranean pockets of liquid water we find a possibility that has attracted wide attention both by scientists and by the popular press. For this purpose miniaturization of instrumentation is essential. Many difficulties though are inherent in the eventual design of a test that would intend to identify microbes, robotically, in any extraterrestrial environment. This question begins to be important, in view of the decisions that have to be made in the selection of biological experiments that should be performed in situ on Europa and on Mars.

The discovery on Earth of unicellular microorganisms (eukaryotes) in an analogous habitat to Mars—the Tinto River, Spain—suggests the possibility of the presence of eukaryotic microorganisms elsewhere in our Solar System. Since there is no evidence for inhibiting the origin and evolution of such microorganisms beyond the Earth in analogous habitats, it seems reasonable to discuss the hypothesis of the universality of eukaryogenesis (Chela-Flores, 2003). Finally, eukaryoticity seems to be a necessary condition for the emergence of a neuron (with the capability of setting up a series of action potentials that characterize it) and eventually multicellular complex nervous systems seems inevitable. The lowest multicellular organisms where action potentials have been documented are the eukaryotic sponges (Villegas, 2000). In multicellular prokaryotes, such as stromatolitic colonies of cyanobacteria action potentials seem unnecessary, and in fact have not been detected to the best of our knowledge. These arguments reinforce the hypothesis that has been assumed anyway by radioastronomers that there will be other intelligences that would give away their presence by radiowaves emitted from some exoplanet or exomoon (the SETI project).

3.2 THE BIOLOGY OF THE POSSIBLE: ARTIFICIAL LIFE?

We should not rule out other possibilities, and indeed some further possibilities have been discussed by Dick, such as postbiological entities (Dick, 2008). In this context, artificial life is a terminology used to refer to attempts at developing systems with the properties of all biological organisms, for instance, just to name a few, self-reproduction, homeostasis, adaptability and mutational variation. The term is often associated with computer simulation of artificial life. This term has gained support since unlike robotics it emphasizes reprogramming, and other digital characteristics (Langton, 1990). In common with astrobiology this line of research can attempt to answer the question: "what is the simplest possible living system?"

3.3 RELEVANCE AND IMPLICATIONS OF THE DISCOVERY OF A SECOND GENESIS

Both the implications and the degree of importance of the eventual discovery of a second genesis will depend on the type of life that is discovered. Considering our human condition, the discovery with the largest impact and relevance at all levels of our society would be the discovery of intelligent life, especially if it were technologically advanced. But the majority of scientists would be of the opinion that the discovery of the simplest extraterrestrial microbial life would be an event of historic proportions. In the present work we shall distinguish implications at different levels.

3.3.1 Straightforward consequences if life is discovered

In this context we have two different aspects:

a) The setting up of different protocols for our actions to be taken for communicating the news to society in general, as well as preventing undesirable ethical, political, or scientific consequences, both for life on Earth as well as for the life that would be discovered (Race, 2008).

b) Confirming the universality of biology, sharpening the definition of life, and the fall of biogeocentism: The sharp distinction between chance (contingency) and necessity (natural selection as the main driving force in evolution) is relevant for astrobiology. For this reason, it is important to document the phenomenon of evolutionary convergence at all levels, in the ascent from stardust to brain evolution.

The universality of biochemistry suggests that in Solar System missions, biomarkers should be selected from standard biochemistry. Given the importance of deciding whether the evolution of intelligent behavior has followed a convergent evolutionary pathway, and given the intrinsic difficulty of testing these ideas directly, we can alternatively begin testing the lowest stages of the evolutionary pathway within the Solar System. Within a few years we will be in a position to search directly for evolutionary biomarkers on Europa, the Jovian satellite.

We have considered that if extant microorganisms were to be encountered, a possible set of evolutionary biomarkers may be considered. In addition, if only landers are possible in the foreseeable future, it is possible with the help of available techniques in biogeochemistry to decide on the possible biomarkers by sampling regions of the icy surface of Europa where there is abundant presence of non-ice elements such as, for example, sulfur (Chela-Flores, 2010).

Testing evolutionary biomarkers clearly lies in the distant future. However, we expect that technology will allow us to be in a position to undertake a variety of experiments *in* situ on the surface of other solar system bodies, such as the Jovian moon Europa. Given the length of time before we can test reliable biomarkers directly, a full discussion at the present time of the feasibility of carrying out a proper test is timely. In this sense the discussion of biomarkers is reasonable at the present stage, since the Galileo mission has already provided us with a wealth of information about the chemical non-water-ice elements on the icy surface. The careful interpretation of such information might conceivably lead us to reliable biomarkers without actually penetrating Europa's icy surface. Testing directly the Europan icy surface with a lander is a possibility that can be taken into account.

The discovery of other solar systems suggests that their formation seem to be analogous to ours. This is compatible with the current extensive knowledge of interstellar matter. From the assumed universality of biology it seems inevitable that intelligent behavior will emerge in the cosmos, provided certain conditions favorable to the presence of continuous life on a given planet (or satellite) are maintained. One of these conditions is that early stages in the formation of a solar system are characterized by a heavy bombardment period.

This period would end after a few hundred million years. Consequently, planetary conditions over geologic time are likely to allow the continuous presence of life, as it has already occurred on our own planet, once the heavy bombardment ceased. Observational techniques continually improve (the Terrestrial Planet Finder and the large telescopes of the European Space Observatory are now under construction). These new instruments will allow us to estimate the duration of the initial heavy bombardment in other solar systems, as well as the subsequent life-favorable quiescent period. These future observations should give us a more precise idea of the temporal constraints that allow the continuous presence of life on a given planet. In our own solar system the most attractive site for the search for life has already been explored.

The Galileo mission to Jupiter and the Galilean satellites completed an eight-year period of continuous exploration in the year 2003. This mission focused our attention on Europa. In the 17th century Galileo discovered Europa together with three other satellites Io, Ganymede and Callisto. However, Europa remains the leading contender for being the host of an independent evolutionary line. A second genesis could, in principle, be brought to our attention in the foreseeable future if the funding of the space agencies allows this technical possibility.

Ganymede is the largest satellite in the Solar System, bigger than the planets Mercury and Pluto). In fact, the Galileo mission already has given us data to suggest that Ganymede, Callisto and Europa may harbor large oceans underneath their icy surfaces. Not only is there strong evidence for the internal oceans in the Jovian system, but also Jupiter's large icy moons appear to have three ingredients essential for the origin and sustained evolution of life, namely, water, energy and the necessary chemical molecules.

It is still premature to attempt the exploration of extraterrestrial oceans of the Jovian system by means of submersibles. But for learning whether a second genesis has occurred, probably a lander may be sufficient. We should recall some aspects of the icy Europan surface: it is possible that matter from the interior of the satellite may be raised to the surface itself. The Galileo mission has led to the discovery of a phenomenon called "lenticulae" that are interpreted as surface areas on Europa, whose origin is matter from its deep interior. A lander, without penetrating the icy shell, may be sufficient to retrieve information that might shed some light on its subsurface ocean that may be pregnant with life.

Although there are still many questions to be answered, at present it seems possible (although not an easy matter) to probe the oceans of the iced Galilean satellites, even if indirectly, by reaching their icy surfaces with landers or micropenetrators.

The preliminary steps taken by science, philosophy and natural theology assumed that humans had a privileged position in the cosmos. With Copernicus geocentricism was abandoned. Natural theology has incorporated this view, after an initial opposition to Galileo's inexorable conclusions. After Darwin's theory of evolution was formulated, anthropocentrism was abandoned, although more than a century of research was needed, culminating with the solid genetic bases of neo-Darwinism. Natural theology is also beginning to incorporate this second step into its discussions. We have called, for lack of a better word in the English language, 'biogeocentrism' the concept that life is exclusive to the Earth (Aretxaga, 2004; Chela-Flores, 2001, 2009).

The underlying difficulty for many scientists arises from a confrontation between the physical and biological sciences. Firstly, everyone agrees that the Newton's theory of gravitation can be extrapolated without any difficulty throughout the universe, except for the small corrections required by Einstein's theory of relativity. One example regards the orbits of Jupiter-like planets. Secondly, the case of extrapolating the theory of biological evolution throughout the cosmos requires more care and is still an open problem. Arguments against the hypothesis of biogeocentrism can now be formulated thanks to progress in our understanding of Darwinian evolution (cf., Section 4). The role of randomness has to be qualified since Darwin's time. Although chance is implicit in *The origin of Species* and Monod captured the essence of Darwinism with the suggestive contrast between chance and the necessary filtering of natural selection, we have also seen that molecular biology greatly constrains chance. Convergence will be a further factor to take into account. To sum up, Darwinian contingency is constrained and evolution tends to converge on similar solutions when natural selection acts on similar environments. Cosmochemistry and planetary science suggest that the environments where life can originate are limited. We already are gathering information on a significant number of Jupiter-like planets around stars arising from protonebulae that are likely to grant them an array of satellites. In our outer solar system this can be confirmed. Each of our giant planets has a large number of satellites.

Such is the case in the outer Solar System. Factors giving rise to atmospheres in Jovian satellites are known. Titan, for instance, has an atmosphere produced by outgassing, combined by seeding of volatiles by comets carrying a fraction of water ice. Evidence is leaning in favor of the existence of Jovian planets with masses larger than Jupiter; hence tidal heating responsible for Io's volcanic eruptions, could be even more efficient in other solar systems. On Europa it is not clear that tidal heating may produce hydrothermal vents capable of giving rise to life, unlike the case of satellites orbiting around large Jupiter-like planets. To sum up, natural selection will be working on a finite number of similar environments. According to cosmochemistry, similar chemical elements will enter into pathways of chemical evolution. We have also learnt that there are no laws in chemical evolution that are specific to the Earth; it is reasonable to hypothesize that biological evolution will follow chemical evolution. Today Darwinism cannot be seen as a simple dichotomy between chance and necessity, but rather we must build into its fabric constrained chance and convergent evolution. Thus, in environments similar to Earth, we expect analogous pathways that lead from chemical evolution to the evolution of intelligent behavior.

These speculations are made all the more exciting and timely by the new discovery of over 1,200 new planets, some of which are hypothesized to be habitable-zone candidates. The Kepler mission of NASA was launched in March 2009 (Friedlund *et al.,* 2010). Kepler can remain pointed toward the same point in the sky for years and it is expected to make observations for a period of 3–4 years having the potential to detect small long-period planets. The observed star field is in the constellations Cygnus and Lyra. With a significant field of view, it will follow about 100,000 stars. Six planets were discovered early made of a mix of rock and gases orbiting a yellow dwarf star (2,000 light years away), known as Kepler-11 (Lissauer *et al.*, 2011). This is an extraordinary solar system in which five inner planets have orbital periods less than 50 days around the dwarf star, while an additional one has a period of 118 days. We are witnessing these extraordinary discoveries, but must wait for a revision of the data to establish, or refute, one of the major discoveries in astrobiology. With these results the catalogue of known exoplanets is expected to explode way beyond the preliminary 500 that were known in the first decade of the 21st century.

3.3.2 Consequences of the specific nature of exolife

The consequences and implications of the specific nature of life to be discovered elsewhere in the Solar System, or eventually on exoplanets or exomoons are the main topics of this section. They shall depend on the type of life and the stage of the evolution of the life to be identified (Race, 2008). Taking as a point of reference the terrestrial model, we can conceive the following possibilities: unicellular life (both prokaryotic and eukaryotic), multicellular life, multicellular life capable of coordination via the emission of action potentials, multicellular life that has reached the stage of intelligent behavior, and possibly a stage further where the intelligent behavior manifests itself at the social and cultural levels which we commonly associate with civilization. We should not rule out other possibilities. Indeed, Dick has discussed some further possibilities, such as postbiological entities (Dick, 2005).

While the discovery of eukaryotic microorganisms would confirm the hypothesis of the universality of eukaryogenesis, reinforcing the possibility of the existence of intelligent life elsewhere in the universe, the detection of technologically advanced civilizations would have more profound consequences, for instance the incorporation of the category of *person* assigned to deserving beings different from humans (Aretxaga, 2006). We should also consider the possibility that the messages received by Earth-bound radio telescopes could provide information on other forms of thinking and comprehending reality in its multiple aspects, such as science, philosophy, art or religion that would induce us to revise our theories and knowledge related to the origin, structure and function of mind and intelligence, not forgetting the origin, evolution and contents of its most significant creations: society and culture (Billingham, 1994; NASA Technical Memorandum, 2000; Tough, 2000). Faced by these possibilities, the Spanish theologian E. Miret-Magdalena (Miret-Magdalena, 2008) recommends an open mind in searching all the positive common elements that might be learnt after the discovery, especially including the idea of the new beings of God, and other ideas of religious significance. These reflections led him to suggest a cosmic ecumenism. In this context it is also worth mentioning the concept of *cosmotheology* (Dick, 2000, 2005).

4. Discussion: Some of the larger philosophical issues arising from a second genesis

Although astrobiology is far from reaching its maturity, it lies squarely within the frontiers of traditional research. Some of the deepest questions raised within astrobiology lie close to those raised within the humanities. From the point of view of philosophy and theology, it is conceivable to view conventional science as one aspect of a wider empiricism that would take into account such facts as the intelligibility of the universe. Some humanists feel that it is possible that a search for a rich empiricism could bring within human rationalization what lies beyond the scientific approach.

The implications of a second genesis are likely to be relevant, not only to astrobiology, but also ethics and especially for philosophy and theology. Such a discovery would provide significant additions to our insights on the intelligibility of nature. Intelligible means the capability of being understood, or comprehended. Alternatively, intelligible can signify to be apprehensible by the intellect alone. A third aspect of intelligible, closer to the significance of the term in the context of the present work, is related to something that is beyond perception. An "intelligible universe" can be the starting point of a prolonged and systematic discussion amongst astrobiologists, as well as philosophers and theologians (Chela-Flores, 2009).

The Belgian Nobel Laureate Christian de Duve, at the end of a review on the origin and evolution of life, asks himself the question: "*What does it all mean?*" not only in science (De Duve, 2002), but also in philosophy (Dear, 2006) and in theology (Russell, 2001). The intelligibility of the universe raises questions that lie on the frontier between science and the humanities; and we need an open all-embracing approach.

Considerations of intelligibility return to the often quoted, but less frequently debated statement of Steven Weinberg, the American Physics Nobel Laureate: *The more the universe seems comprehensible, the more it also seems pointless* (Weinberg, 1977). Such pessimism seems to leave no room for a first genesis on Earth as a special case of a wide and meaningful phenomenon of second genesis elsewhere. We should clarify that the quoted statement reflected a specific philosophical trend, or attitude, characteristic of the first half of last century. Hence, if that were the case, the statement should not discourage the general dialogue at the frontier of science and religion. The common approach from both ends of the academic discourse to discovering a second genesis anywhere else in the universe should contribute, as we shall see below, to the progress of the philosophy and theology. Reciprocally, the questions raised in any field of the humanities arising from the discovery of a second genesis could, in turn, enrich the search for the place of humans in the universe. The above quotation can be best understood in the context of a philosophical trend called Existentialism.

We should ask: Which role would astrobiology play in the systematic search for meaning beyond Hegel's Absolute Idealism? In other words, what would be the implications of a new philosophical approach for the meaning of human life?

The eventual success of astrobiology in its search for life elsewhere in the universe would force upon us a reconsideration of the question of intelligibility and comprehension of nature, a subject that is the very nucleus of Western thought.

From this new perspective we could profit by returning to concepts that can be retraced to Lawrence J. Henderson, especially those of fitness and biocentrism: The fitness of the cosmos for the origin and evolution of life is discussed in Henderson's *"The Fitness of the Environment"* (Henderson, 1913), where the shift form two separate discussions, one for the cosmic evolution, and the other for biological evolution (Darwinism) begin to merge. This influential book was published almost a century ago, not as a response to the crisis in the systematic search for meaning that we have attempted to review in this chapter. Henderson was a graduate of Harvard and a professor of the University (Chela-Flores, 2007). Henderson's main interests ranged widely: he was a physiologist, chemist, biologist, philosopher and sociologist. He discussed the question of teleology in biochemistry to give some rationale to the question of fitness of the environment for the evolution of life. For many chemical compounds he discussed the difficulties that the evolution of life would have encountered had these compounds not been freely available in the environment. Water was one example. Its search, even today, is a main objective of the exploration of the Solar System. Henderson concludes at the end of his book that:

> *"The properties of matter and the course of cosmic evolution are now seen to be intimately related to the structure of the living being and to its activities; they become, therefore, far more important in biology than has been previously suspected. For the whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric."*

Today we should search the roots of Henderson's "biocentrism" at the molecular level. In fact, fine-tuning in biochemistry is represented by the strength of the chemical bonds that gives rise to the "dictionary" that contains the correspondence between amino acids and the monomers of RNA. This dictionary is called the genetic code. Both transcription and translation of the messages coded in RNA and DNA would not be possible if the strength of the bonds had different values. Hence life, as we understand it today, would not have arisen.

We have argued in favor of fitness of the cosmos for the origin and evolution of life without touching on the question of teleology. In this sense, we approach the subject without restricting ourselves exclusively to biological evolution in the universe, but rather we also include the evolution of the structure of the cosmos itself.

The existence of different views on the intelligibility of the nature, or universe, in Western thought claims the need for philosophical understanding of meaning with fresh approaches in philosophy at the frontier of astrobiology. We need especially to understand the influence of philosophical doctrines that will tend to encourage any future constructive dialogue between the new physical sciences and the humanities—especially philosophy—pointing towards unified two-culture knowledge, aiming at consilience (with the Edward Wilson fortunate choice of word).

5. Chart of the implications of a second genesis elsewhere

I. Cultural implications of searching for a second genesis (Secs. 1-2)	*From speculations to science*
	Astrobiology as a transdisciplinary science
	Collaboration between the two cultures
	Towards insights into reality from the point of view of astrobiology
	To promote societal interest in science and technology
II. Cultural Implications of finding a second genesis (Sec. 3)	*Straightforward consequences*
	Implications that depend on the nature of what is discovered
III. Deeper philosophical issues (Sec. 4)	*Ontological issues*
	Towards the end of biogeocentirsm

6. References

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