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Excerpt
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Introduction

At the time of writing, NASA has announced that the *Kepler* observatory – a small, man-made satellite trailing the Earth on its orbit around the Sun – has made the first discovery of five terrestrial-size planets around other stars in the Galaxy, as well as a planetary system (provisionally named Kepler-11) containing no less than six planets.[1] While this newsflash may not sound revolutionary in isolation – have we not grown accustomed to many spectacular 'firsts' coming from new astronomical instruments? – it may mark, in retrospect, an important milestone in the scientific and intellectual movement, bringing the question of life and intelligence in their general cosmic context to the forefront of scientific research. This development, dealing with sometimes surprisingly old questions, is embodied in a new discipline – astrobiology. After several hundreds of planetary systems have been discovered in the last two decades, which include planets around pulsars, planets in the halo of the Milky Way, and possibly even planets in *another galaxy*,[2] we are now witnessing a clear convergence towards a Galactic set of habitable, Earth-like planets.

This book investigates several philosophical and methodological issues related to the ongoing 'astrobiological revolution' (*c.*1995–today), and the surge in both professional and public interest in the search for life and intelligence beyond Earth. We are lucky enough to live in an epoch of great progress in this nascent discipline, which deals with three canonical questions: How does life begin and develop? Does life exist elsewhere in the universe? What is the future of life on Earth and in space?

A host of fascinating discoveries has been made during the last two decades or so, some of the most important being: a discovery of a large number of extrasolar planets; the existence of many extremophile organisms, possibly comprising the 'deep hot biosphere' of Thomas Gold; the discovery of subsurface water on Mars and the huge ocean on Europa, and possibly also on Ganymede, Callisto and Enceladus; controversial evidence concerning Martian methane and microfossils in the Martian meteorite ALH84001; the unequivocal discovery of a large variety of amino acids and other complex organic compounds in meteorites; modelling organic chemistry in Titan's atmosphere; the quantitative treatment of the Galactic Habitable Zone; numerical elucidation of astrobiologically relevant ecological models, such as James Lovelock's 'Daisyworld'; the development of a new generation of panspermia theories, spurred on by experimental verification that even terrestrial microorganisms easily survive conditions of an asteroidal or cometary impact; elucidation of mass extinction episodes in Earth's history; rapid progress in understanding biogenesis, etc. In addition, there is a great deal of activity on the organizational, managerial and public outreach level, reflected in the setting up of new specialized institutes and university programmes at both undergraduate and graduate level, launching of several new research journals (*Astrobiology*, *International Journal of Astrobiology*, *Planetary Science*, etc.) and monograph series, coupled with the reorientation of some of the older publishing outlets, as well as a host of popular journals, web portals and blogs, maintaining vibrant interest in astrobiological topics both inside and outside of academia.

The epistemological and methodological basis of astrobiological studies presents us, however, with a hornet's nest of issues that have not been, with few exceptions, tackled in the literature so far. It is not surprising, therefore, that seemingly paradoxical situations and controversial conclusions arise from time to time, as is usual in young scientific fields, coupled with confusion which does not always stay limited to the lay public. Thus, the aim of this book is to frame the relevant questions about philosophical and methodological aspects of the astrobiological enterprise, rather than to provide answers. Perhaps it is too early even for speculative and tentative answers; but as in the prototypical case of the dog which did not bark, even the absence of answers tells us something very important about the puzzle itself.

The composition of the book reflects a symbolic shift both (1) from the 'origins' (distant cosmological past, large spatio-temporal scales) towards the present-day and near-future practice of astrobiology, and (2) from the abstract and theoretical towards issues that are more empirical. I will try to demonstrate that in a young field, as astrobiology certainly is, foundational philosophical and methodological questions can play a very stimulating and inspirational role. This parallels the development of physical cosmology since Einstein, especially in the crucial and formative 1929–1965 period; in my view, astrobiology is today in a position similar to the one cosmology was in at the time of Friedmann, Eddington, Hubble, Lemaître or Hoyle. The overarching analogy – recognizable, for instance, in the title of Steven J. Dick's seminal study *The Biological Universe*[3] – is useful both in heuristic and metaphoric terms; it may further the already huge popular appeal of astrobiology as well. Therefore, after introducing the astrobiological revolution since 1995 and some of its foundational concepts (Chapter 1), I consider the relationship between cosmological and astrobiological enterprise through various puzzles that bridge the gap between these realms. Some of them have been resolved (or only noticed *post festum*), like Dirac's large-number coincidences or the Davies–Tipler argument, others are still very much with us (Fermi's paradox), while fresh ones have been unearthed only through recent and excessively complex research (like the problem of Boltzmann's brains). Such amalgamative problems present not only research opportunities, but also point toward wider scientific synthesis, or consilience. One of the central themes of this first part of the book (Chapters 2–4) is the concept of observation selection effects, which helps us not only to resolve some of the encountered conundrums, but also dispels further confusions and controversies, like the ones surrounding anthropic reasoning. In particular, the notion of the astrobiological landscape, introduced in Chapter 3, offers a convenient platform for unifying the (Earth-) specific and the (universe-) general. Conversely, the leitmotif of the second part of the book (Chapters 5–8) is the *continuity thesis*: roughly speaking, the idea that physical, chemical, biological and perhaps even cultural, evolutions are parts of the same evolutionary continuum. Here, a tradition of thought starting in its modern version with J. B. S. Haldane has already brought about important insights; for example, as Iris Fry has persuasively shown in several articles and a brilliant monograph, *The Emergence of Life on Earth*,[4] some variant of the continuity thesis is necessary for the scientific consideration of biogenesis. In a generalization of this thesis, a proper response to many popular arguments of the opponents of astrobiological and the Search for ExtraTerrestrial Intelligence (SETI) studies can be found, as will be repeatedly discussed in the book. Notably, the generalization will include the undermining of gradualism, the old-fashioned view that the 'present is the key to the past' in terms of the tempo and mode of evolutionary processes. A new perspective on the classical anti-SETI arguments follows, like the argument from biological contingency, Fermi's paradox, and Carter's 'anthropic' argument – and this new perspective is more optimistic as far as the practical aspect of SETI searches is concerned. In addition, astrobiology provides us with potentially powerful insights into the nature of *terrestrial* biological evolution itself, as well as the antidote to the Popperian scepticism (too often misused by creationists and other pseudo-scientists) towards the contingent or 'lawless' nature of evolutionary biology. The concluding chapter will offer a glimpse of what we could expect in terms of synthesis if the expanding trend of multidisciplinary effort centred on astrobiology continues.

But danger also lurks in bringing such philosophical perspectives to the fascinating issues of contemporary astrobiology. One should be wary of an almost reflexive tendency in works of philosophy to present them as though the authors believe them to be the final word on their subject. This comforting illusion would be self-indulgent, even in much better developed fields than astrobiology is at present; sadly, this has not prevented some authors from writing in this way, and we shall encounter such negative examples later on. In my view, the very *openness* of the subject cannot be overemphasized. Thus, the present book should be understood, in the literal sense, as a *philosophical exploration* of perplexing issues arising from contemporary research on the origin, existence and future of life in its widest cosmological context. Conceptual completeness is overrated, anyway, even in well-established realms of knowledge. Half-baked ideas that cohere in tone and attitude have more often been fruitful seeds of novelty and sources of inspiration than heavy volumes of well-developed 'grand systems' – and no apology should be sought for that. Those who insist on completeness in the tangled reality of the history of ideas look, more often than not, akin to Shigalyev, a tragicomic character in Dostoevsky's *Demons*: a disturbingly persuasive fool, who argues that if people do not devote exactly ten weeks to listening to his universal theory of society and liberty, they can go home and forget about political activism, since there can be no viable alternative to his programme.

Consequently, some of the views I present are still crude sketches, far from being polished and refined, or incorporated into a complete and elegant whole. As the analogy with cosmology will show, this remains in the future, even for more advanced fields of study. Nevertheless, if there is no place for the last word in this field, there is still ample place for the first words to be said on many issues, including not only the main line of argument, but many leads and side issues as well. Philosophical quest starts with an idea about the destination, but it necessarily changes all the time; instead of misplaced zeal for perfect, streamlined consistency, I believe the fluid nature of the quest simply enriches its flavour.

The same strategy applies to the level of technical complexity of the book. As emphasized by Sir Arthur Eddington long ago – and yet sorely misunderstood by scientists on the one hand, and science writers and journalists on the other – science writing evolves (just like everything else):[5]

> Science has its showrooms and its workshops. The public to-day, I think rightly, is not content to wander round the showrooms where the tested products are exhibited; the demand is to see what is going on in the workshops.

Nothing is new under the Sun. It cannot be overemphasized how much the old myth of clear, sharp, antiseptic division between scientific research writing and popular science writing has long ago been debunked by intellectual giants of Eddington's calibre. While the scientific research discourse may – and should – be entirely logical, fair-minded and based on careful empirical and/or theoretical analysis, it is still fashioned as rhetorical, persuasive discourse. And yet, this myth remains perniciously influential today, exercising its impact in a particularly repulsive form in science education and fundraising. It is incumbent on us scientists to fight what Stephen Jay Gould, another fine stylist in contemporary science, labelled scientific selection for poor writing.[6] While it is certainly more difficult to correct for than other selection effects discussed in this book, it is certainly rewarding to try. While some parts of the book (in particular Chapters 3, 4 and 7) may look superficially more technical, a reader can skip the mathematical or tougher philosophical parts and, if interested, return to them at a later time. Some suggestions for further reading and points of entry into the existing literature are clearly indicated in the notes. Throughout the book, I use illustrative and graphically marked scenarios, either as thought experiments or examples from the literature (both fictional and discursive).

A final note on the use of history. On the pain of anachronism, I give some of the concepts and phenomena their modern labels for the sake of compactness and better understanding. This is a book about astrobiology and not a history of science, although, of course, historical scholarship has a large role to play in this youthful realm. Therefore, I label Alfred Russel Wallace's 1903 study 'astrobiological', although astrobiology clearly did not exist as either a word or a concept in the first years of the twentieth century. Let the purists of 'anti-Whiggish' historiography or postmodern relativists be offended, but it is exactly an illustration of the fact of scientific progress that is at (epistemic) stake here and offers the best prospect for understanding the astrobiological synthesis that is crystallizing as we speak. No apology for progress is ever necessary. As a great poet of idealistic optimism wrote almost two centuries ago:[7]

> The lightning is his slave; heaven's utmost deep
> Gives up her stars, and like a flock of sheep
> They pass before his eye, are numbered, and roll on!
> The tempest is his steed, he strides the air;
> And the abyss shouts from her depth laid bare,
> Heaven, hast thou secrets? Man unveils me; I have none.

1

Astrobiology

'The Colour Out of Space?'

And what shall I love if not the enigma?

Giorgio de Chirico

In April 1897, *Pearson's Magazine*, a rather influential London literary publication, although launched only about a year earlier, published one of the eeriest prologues ever to appear in the world of *belles lettres*. The author was a 31-year-old former cloth retailer and biology student by the name of Herbert George Wells, who two years before had created a mini-sensation with his first novel, *The Time Machine*, controversial for both its outrageously speculative scientific premise and for its radical social criticism. Now, he did it again, having started the new novel, *The War of the Worlds* (to be published in book form the following year), with this dramatic warning:[1]

> No one would have believed in the last years of the nineteenth century that this world was being watched keenly and closely by intelligences greater than man's and yet as mortal as his own; that as men busied themselves about their various concerns they were scrutinised and studied, perhaps almost as narrowly as a man with a microscope might scrutinise the transient creatures that swarm and multiply in a drop of water. With infinite complacency men went to and fro over this globe about their little affairs, serene in their assurance of their empire over matter. It is possible that the infusoria under the microscope do the same. No one gave a thought to the older worlds of space as sources of human danger, or thought of them only to dismiss the idea of life upon them as impossible or improbable. It is curious to recall some of the mental habits of those departed days. At most terrestrial men fancied there might be other men upon Mars, perhaps inferior to themselves and ready to welcome a missionary enterprise. Yet across the gulf of space, minds that are to our minds as ours are to those of the beasts that perish, intellects vast and cool and unsympathetic, regarded this earth with envious eyes, and slowly and surely drew their plans against us.

The famous progressive rock version by Jeff Wayne produced in 1978, gives an even more fascinating introduction by condensing Wells' second to sixth sentences into 'Few men even considered the possibility of life on other planets' – rather frightening in the superb narration of Richard Burton.[2] It is even more pertinent from the point of view of the present book. In *The War of the Worlds*, Wells, once a pupil of Thomas Henry Huxley, the legendary 'Darwin's bulldog', struck a perfect balance between dramatic and philosophical discourse. The then reigning Kant–Laplace theory about the formation of the Solar System predicted that the planets' ages correlate with their distance from the Sun, so Mars was considered older than the Earth, which would, in turn, be older than Venus, and so on. The Copernican principle – and naturalism regarding biogenesis! – suggested that, if Mars is habitable at all (and many influential astronomers thought so), it is likely to be the home of a biosphere older in comparison to the terrestrial one. The same Copernican principle, coupled with naturalism with regard to the origin of intelligence (or *noogenesis*), led Wells to assume the existence of Martians as an intelligent species older then humans. The hallmark Victorian belief in progress in both biological and cultural domains led Wells, and many other thinkers of his day, to translate this greater age into greater intelligence and into greater capacity for manipulating nature, i.e., more advanced technology. However, more advanced technology needs not, and here Wells parted company with many of his optimistic contemporaries, pacify essentially biological – or *socio*biological – aggressive instincts of a dominant species. Coupled with the climatic and ecological degradation of their home world (also stemming from the Kant–Laplace theory conjoined with the dominant paradigm of Lyellian gradualism), these instincts led the Martians to undertake the interplanetary expansion and colonization of the nearest habitable ecosystem – our Earth. As noticed by Wells' protagonist, who is perpetually torn between paralyzing fear and an irrepressible curiosity, while Martian invaders brought horrible destruction and death to humans, they did not seem to act any more irrationally than humans do when clearing a forest in order to cultivate land or irrigating a swamp to build housing. Such actions are not regarded as obviously morally repugnant even today, in this epoch of heightened ecological awareness. In the end, the invasion from Mars fails, but not due to any action of humans – supposed pinnacles of the terrestrial evolution. Instead, the Martians, who are of course well adapted to their own biotic and abiotic environment, are defeated by the simplest terrestrial life forms – bacteria to which they had evolved no resistance, bacteria that have lived on our planets for billions of years, thus prompting again the question whether it is sensible to talk about progress in the context of biological evolution.[3] Consider how deep is the gold mine of philosophical issues (and I mention just the most obvious ones) contained in what is still occasionally – and ignorantly – dismissed as 'just' a science-fiction thriller![4] And it is a contingent fact of history that as a consequence of Wells' writings more than a few men have hitherto 'considered the possibility of life on other planets'.

In contrast, consider the plots of recent movies – also *fin de siècle*, as was Wells' novel – like *Smilla's Sense of Snow* (1997) or *X-Files: Fight the Future* (1998): a prominent role in both is played by an ancient meteorite that fell to Earth in times past and brought microscopic alien life forms to our planet (both influenced by Robert Wise's 1971 classic *Andromeda Strain*, based on the 1969 novel by Michael Crichton). This has been for quite a long time, since Lord Kelvin and Svante Arrhenius, known as the panspermia hypothesis, one of the hotly debated topics in contemporary astrobiology. Now microorganisms, bacteria and viruses, are the invaders from space, if anything more threatening than before. The details of science are, of course, wrong (an interesting question for science, technology and society studies: why is it *so* difficult to get the science right in any major film?), but the general idea is the same as the one underlying the current efforts of researchers, technologists, and even politicians, to institute efficient planetary protection protocols. The famous Article IX of the Outer Space Treaty, adopted by the United Nations in 1967, explicitly puts the same fear and caution in legalistic terms, by proposing that parties to the treaty[5]

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

This admirably non-anthropocentric statute (it lists adverse consequences for other celestial bodies first and those for the Earth after; with good reason we shall return to it in Chapter 6) is just as useful a gauge of our thinking as are the motion pictures mentioned above. Like the discussion of extraterrestrial life at the end of the nineteenth century, in the cultural context it was unavoidably framed by the Schiappareli–Lowell 'discovery' of Martian canals, as well as debates on Darwinism vs. other theories of evolution and, last but not least, the late-Victorian anxiety about the conflict of civilizations, so analogous discussions at the end of the twentieth century are coloured by our fear of deadly pandemics, as well as the post-Cold War anxiety about the conflict of civilizations. The difference – and a very real one – consists of the ongoing *astrobiological revolution*, which has opened wide prospects for an objective assessment of the perennial questions about life and intelligence in their cosmic context.[6] Scientists are understandably reluctant to talk about revolutions in what is usually perceived as day-to-day research work. But an avalanche of both observational and theoretical results from various fields, starting about 1995, being incorporated into a wider synergistic whole, together with large-scale organizational changes and restructuring, give any observer at least some indications that we are living through a real revolutionary epoch. That the revolution could become even more radical, as more and more fields and themes are involved and interconnected, is one of the central topics of this book.

The Canonical Three

But what is astrobiology in the first place? One should not seek a formal definition for many reasons, some of which touch upon philosophical issues, and others are similar to the famous US Supreme Justice Potter Stewart's statement on obscenity: 'I know it when I see it.'[7] Is astrobiology a research activity recognizable on sight? Some of the standard textbooks avoid the question of definition entirely, and pass on to the exposition of a circle of topics that certainly belong to the field.[8] The rationale here is quite clear: after all, the formalization of knowledge – which includes giving precise definitions – usually comes at the *end* of the original research in a given field, not at the very beginning. The history of science is full of examples: consider why we feel Euclid's definitions ('a point is that which has no part', 'a line is a breadth-less length') amusing, even laughable, today. The reason for such a reaction of ours – and, indeed, even of Euclid himself, who did not use the definitions at all in the further discourse on geometry! – is that a definition is useless if it does not reduce a more complex concept to a simpler one. Since, for example, the concept of a 'part' is arguably not simpler than the concept of a 'point', Euclid's definition does not help our understanding at all. Because it is clear that simplification cannot proceed indefinitely, it turns out – and the history of philosophy and mathematics confirmed this long ago – some concepts need to be left undefined, as 'primitives' of any formal system. Similarly, the proper definition of many other important concepts – even if they can be properly reduced to simpler entities – has had to wait for a long time before the adequate *theory* of simpler entities was developed. A particularly illuminating example is the concept of *number*, which was properly defined in the modern sense only after the development of axiomatic set theory in the first decades of the twentieth century – which obviously does not imply that Archimedes or Fermat or Gauss or any other mathematician of old did not know what they were working with. Contrary to the sad prejudice which is forcefully instilled in primary and high-school pupils, formal strictness is much less important in 'real' science than in its cardboard (or too often, textbook) version.

In the realm of astrobiology, the strength of the dilemma can be appreciated when we realize that there are literally dozens of definitions of *life* – which, after all, has been the subject matter of biological sciences for centuries, if not millennia.[9] Like the concept of number, life seems so familiar to us that an intuitive view of it is satisfactory for the vast majority of practical problems. One of the most brilliant minds of modern science, the Austrian physicist Erwin Schrödinger, put it in the title of his epochal 1944 booklet: *What Is Life?*[10] In contrast to mathematical entities, in the case of life it is the complexity of associated phenomena that causes difficulties for the definitional enterprise. The road Schrödinger and most subsequent researchers took is, therefore, to state the list of properties a system needs to possess in order to be called alive: biochemistry based on polymers such as proteins, metabolism, imperfect reproduction, etc. However, these 'list definitions' are, as in other fields, vulnerable to counterexamples, so that a significant amount of the ongoing discussion has been caused by questions such as, 'Are viruses alive?' 'Are prions?' 'Are mineral assemblages?' In order to surmount this difficulty, the so-called 'NASA definition' adopted at one of the first astrobiological scientific meetings in 1994, states simply that *Life is a self-sustaining chemical system capable of Darwinian evolution*.[11] This has been criticized on the basis that it presumes a theory of life (for instance, excluding life based on the strong force, which was speculated about in the fictional context), and presupposes a complete understanding of processes comprising 'Darwinian evolution'. Both are serious criticisms, closely connected to the issues I shall repeatedly address in the present book, notably the need to fight anthropocentrism. While Wells' invading Martians are legitimately alive according to the NASA definition, at the very end of this chapter we shall encounter a fictional example of a life form that eminently defies this definition. The normative justification offered by practising astrobiologists is that the exclusion of non-chemical or non-Darwinian entities aspiring to the status of being alive is justified by a constructive belief that such life forms are not possible. This, in turn, motivates some of the critics of the entire astrobiological endeavour, such as biologist Jack Cohen and mathematician Ian Stewart, to charge astrobiology with being narrow-minded and conservative.[12] However, it is generally accepted that the NASA definition and any particular refinement are *necessarily provisional*, and will evolve as the underlying theory evolves.

The general lesson is that only when it comes to life in a sufficiently novel and strange context – such as when we are discussing biogenesis (the origin of life), or artificial life, or life on other worlds – that the definitional questions come to the fore. Similar reasoning (but understandably more loaded with wider practical, societal and political baggage) applies to the philosophical enterprise of defining *intelligence*: until the advent of fields touching upon foundational issues, such as artificial intelligence and SETI, few people even paused to ask what, exactly, if anything, is that thing we call intelligence (or consciousness or self-awareness or any number of similar high-level mental phenomena). Thus, we are likely to run into trouble if we try to define astrobiology through a second-order definition, since the concept of life itself is problematic in this respect.

Happily enough, this has been widely recognized in research circles (although not as often or as easily amongst science writers and journalists), and the mainstream approach is nowadays to try to build the understanding of the nature of astrobiological endeavour around wide questions that endeavour is supposed to answer. That is the strategy adopted by NASA in producing its famous 'Astrobiology Roadmap', the first version of which was drafted in 1998, and