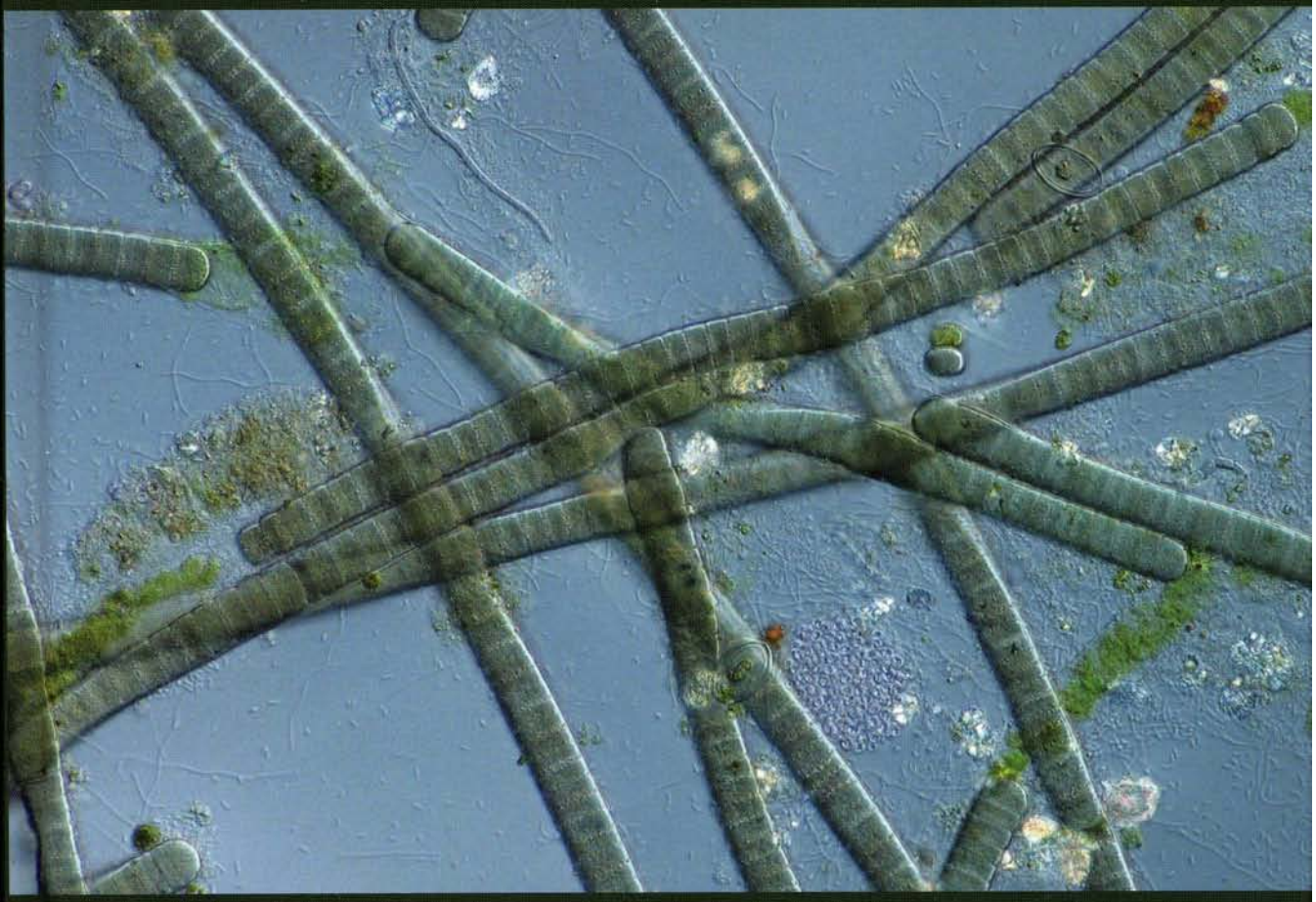
CAMBRIDGE Astrobiology

Origins and Evolution of Life

An Astrobiological Perspective



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CAMBRIDGE **Astrobiology**

Devoted to exploring questions about the origin and evolution of life in our Universe, this highly interdisciplinary book brings together a broad array of scientists. Thirty chapters assembled in eight major sections convey the knowledge accumulated and the richness of the debates generated by this challenging theme. The text explores the latest research on the conditions and processes that led to the emergence of life on Earth and, by extension, perhaps on other planetary bodies. Diverse sources of knowledge are integrated, from astronomical and geophysical data, to the role of water, the origin of minimal life properties and the oldest traces of biological activity on our planet. This text will appeal not only to graduate students, but also to the large body of scientists interested in the challenges presented by the origin of life, its evolution and its possible existence beyond Earth. Colour versions of many of the book's illustrations can be viewed at www.cambridge.org/9780521761314.

The **Cambridge Astrobiology** series aims to communicate recent advances in astrobiology and to foster the development of scientists conversant in the wide array of disciplines needed to carry astrobiology forward. Books in the series are at a suitable level for graduate students and researchers and are accessible to scientists working in a range of disciplines.



Cover illustration (front): micro-organisms thriving in a suboxic shallow pond. Photo by Purificación López-García.

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Foreword

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Astrobiology, also known as bioastronomy or exobiology, is the study of the origin, evolution and distribution of life in the Universe. These are subjects which have been of interest to mankind throughout recorded history. Although questions of origins have most frequently invoked divine beings, non-supernatural speculation on these fundamental issues dates back at least to the Ionian school of pre-Socratic Greek philosophers. Anaximander, the successor to Thales, is reported as saying that all living creatures arose from the moist element (water) through the action of the Sun (Freeman, 1966), a prescient insight given current ideas that life as we know it requires water, that radiation acting on inorganic matter can produce the molecular components of life (amino acids, nucleic acids, etc.) and that the Sun is the ultimate energy source for almost all life on Earth. In fact, Anaximander seems to have gone further and suggested that human beings arose from fish-like creatures (presumably a natural result of life having originated in water).

Speculation about life beyond the Earth has also had a long tradition. Although Pythagoras himself is not known to have recorded his teachings, his school (in particular, Philolaus, *ca.* 400 BCE) is said to have written that the Moon appears Earth-like because it is inhabited with animals and plants (Dreyer, 1953). At roughly the same time the atomist school of Leucippus and Democritus taught that the Universe is infinite and contains innumerable worlds. Since Democritus is quoted as saying that 'There are some worlds devoid of living creatures or plants', presumably he believed some are in fact inhabited, and this view was explicitly stated by his later follower Epicurus (*ca.* 300 BCE). The atomist ideas are best known from the Roman poet and philosopher Lucretius (*ca.* 99–55 BCE), who firmly embedded the idea of an infinity of worlds in the atomist tradition. Also during Roman times Plutarch, better known for his biographies, raised in an essay the distinction between habitability and the actual presence of life; a distinction of fundamental importance in modern astrobiology (Dick, 1982).

Aristotle's rejection of the atomist theories ended most Western discussion of life beyond the Earth for the next millennium, although some medieval scholars such as William of Ockham (of the famous razor; *ca.* 1280–1347) argued that the omnipotence of God certainly allowed for the possible existence of other worlds like ours. Then, as the Renaissance began, Nicholas of Cusa (1401–1464) argued that 'Rather than think that so many stars and

parts of the heavens are uninhabited and that this earth of ours is peopled ... we will suppose that in every region there are inhabitants'. Subsequently Johannes Kepler, arguing on the basis of its newly discovered moons, 'deduce[d] with the highest degree of confidence that Jupiter is inhabited' (Dick, 1982).

Islamic science had a considerable history of speculation about the evolution of species. Al-Jahiz (real name Abu Uthman Amr ibn Bahr al-Fuqaimi al-Basri) (*ca.* 780–*ca.* 869), an Afro-Arab descendant of an African slave, wrote that the effect of the environment can cause animals to develop new characteristics and can thus lead to new species (Sarton, 1975; Bayrakdar, 1983). Later, Nasir al-Din al-Tusi (born in 1201 in what is now Iran) apparently held an atomist-like view of the origin of life and also propounded ideas on the evolution of species (Alakbarov, 2001). Fakr al-Din al-Razi (1149–1209, in Iran) was an atomist as well and proposed that there are possibilities for other beings and other universes (A. Ragab, Harvard University).

In modern times ideas concerning extraterrestrial life have been expressed by many, including Huyghens and Fontenelle, while Percival Lowell built the Lowell Observatory in the USA primarily to investigate Mars, where he was convinced that the 'canals' were the work of an intelligent species. Modern scientific study of the origin of life perhaps began with the theoretical work of Oparin and Haldane and the laboratory experiments by Miller and Urey. Governmental funding for what was initially called exobiology was initiated in the USA shortly after the formation of NASA in 1958, with the aim of exploring the origin, evolution and distribution of life, and life-related molecules, in the Universe. The Exobiology Program included the Viking missions, intended specifically to search for evidence of life on Mars. At present the International Astronomical Union has a Commission (51) on Bioastronomy, there is an active International Astrobiology Society (ISSOL) and astrobiology societies or institutes exist in Spain, the USA, Japan, the United Kingdom, Australia, France, Italy and more generally in Europe.

Modern astrobiology encompasses the search for extant life, evidence of past life or evidence of prebiotic chemistry on Solar-System bodies; the search for and characterization of planets around other stars; the study of biologically relevant molecules in the interstellar medium and in primitive Solar-System objects such as comets, undifferentiated asteroids and some meteorites; the study of the origin, evolution and environmental constraints for life on Earth; and the search for intelligent signals of extraterrestrial origin. This book addresses all of these questions except the last one and also probes the complex issue of the definition of life. The authors are experts in the field, so that their work here will be a valuable resource for both students and established scientists in the many disciplines which contribute to astrobiology.

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