Introduction

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A mission statement for astrobiology is: "Study the origin, evolution, distribution, and future of life on Earth and in the Universe." It addresses the profound questions "How did life originate?", "Are we alone in the Universe?", and "What is the future of life on Earth and in the Universe?" The wide range in the contents of this volume indicates the rich and exciting subject matter of this field. Much of this content can be grouped into three major components.

First, we know that life exists and, therefore, it must have originated; the first component is the study of how life began and evolved to its present form, with an emphasis on the early evolutionary processes.

Second, we don't know if life exists somewhere other than on Earth, and therefore the second component is to test the hypothesis that there is life elsewhere. To do this we must create models to test against the data that has been and will be collected at locations remote from Earth. The only observationally derived model for life that is available is life on Earth and, therefore, it is the model for the hypothesis-testing process. We fully expect that this model may be rejected to be replaced by another currently unknown model that is difficult to even imagine at our present level of knowledge. The major targets for the search for life in our solar system – Mars, Europa, Ganymede, etc. – are more similar to early Earth, i.e. the Earth that existed soon – say, within a billion years or so – after life began. Hence, the model for the search for life elsewhere is the life that existed early in the history of our home planet. The conditions at that time were extreme compared to the conditions in the regions that most animals currently occupy. As a consequence, there is a major program in astrobiology to study contemporary life in extreme environments: geothermal sites; regions with low and high temperatures; arid regions; regions with high or low pH, high or low salinity, low oxygen, and high or low pressures; and deep subsurface areas under the ground and under the bottom of the sea. The areas in and adjacent to impact craters are also of interest since impacts that could have affected life were more common in early Earth and on Mars and elsewhere in the solar system where life might now exist or have existed in the past.

There is also a model that unites the first two components. Life may have originated somewhere other than on Earth and may have been transported here in a comet or meteor, on "cosmic dust particles", or, possibly, as free-floating living material. An additional view is that the basic chemical components that make up life – prebiotic chemistry – arrived from elsewhere and that life was subsequently formed here.

The third component deals with the future of life on Earth and, if it exists, elsewhere in the Universe. It includes the study of changes in the Earth's environment and its inhabitants that may influence the existence of life, and of the conditions on Mars or elsewhere that could have destroyed or diminished life if it existed in the past. Independent of the existence of life away from Earth, this component relates to the broader question of how earthly life, including humans, can survive and explore away from the home planet, in near-Earth orbits and distant from Earth during interplanetary – particularly Martian – and deep-space travel. It connects at this level with the issue of astronaut and cosmonaut health and the basic science questions related to long trips through space and survival on distant planets and moons. The futuristic concept of terraforming, transforming places like Mars to be more like Earth, and colonization of distant planets could be included in this rubric.

In testing a hypothesis, for example that life exists elsewhere in the Universe, it is important to maintain an unbiased view on the outcome. If this is not done, there is a danger that data that is collected will be interpreted to support the favored result. It is easier to maintain an unbiased view if both outcomes, support or rejection, are interesting. Many people, including scientists, have an intuitive belief that the Universe is life-rich and that, in its immensity, there must be other inhabited places. However, when acting in the scientist mode, it is important to maintain objectivity in the evaluation of the data. The discovery of life elsewhere is obviously very interesting as it will open a vast area for exploration and research and radically change our perceptions of self and how we fit into the Cosmos. The rejection of the model will be difficult to do. More and more planets around stars other than our own Sun are being discovered and it is possible that life may exist on one or more of these. However, if the search is conducted for, say, 100 years, and life is not discovered, then it would decrease the probability that life exists elsewhere. We would have to consider that we are alone in this vast space. This also would have a profound effect on our perceptions of our role in the Universe and the future of humans in the Cosmos. It would reverse the concept of Copernican mediocrity, that we are the inhabitants of a relatively minor planet in a solar system that is one of billions situated somewhere away from the center of the Milky Way galaxy that itself is only one of billions in a universe that may not be unique. The realization of aloneness would profoundly change our attitudes.

Arising from these three components is an overriding question, "What is life?". Studying the origins of life on Earth and testing the hypothesis that life exists elsewhere will raise questions on its definition. For example, when does "prebiotic" chemistry become biology? Does the answer reside in the complexity of chemical interactions resulting in an emergent order that satisfies a definition of life? What are the differences between living bacteria themselves and the effects they have on rocks? This is illustrated in the ongoing investigations on the composition of the Mars meteorite ALH 84001. (The acronym and numbers indicate that the meteorite was the first found during the 1984 collecting season in the Alan Hills region of Antarctica.) Does it contain evidence of previous life? Are the very small ordered structures found in the rock the fossils of ancient Martian organisms or are they artifacts of geological or experimental origin? Does the magnetite in the meteorite originate from biological material or is it a non-organic structure? If it is biological, when did it stop being living matter and become mineral, i.e. what are the distinctions between life and non-life?

Astrobiology requires extensive international cooperation in order to be successful. A single nation cannot hope to alone accomplish this mission that is a quest of importance to all humankind. The United States National Aeronautics and Space Administration (NASA), to help advance the field, established the NASA Astrobiology Institute (NAI). It is structured to recognize and serve the specific requirements of astrobiology. I will describe the organization and early history of NAI to illustrate these characteristics. In the mid-1990s there was an increased interest in origins of life for the overall NASA program. It was fueled by several scientific reports, including the MARS satellite images that indicated that water might have been common early in the planet's history, the Jupiter Galileo probe, and, in particular, the discoveries related to ALH 84001. The NAI is a virtual institute, in the sense that several teams are located great distances from each other, but, despite this, they are expected to act as if they were members of a single organization. The NAI Mars Focus Group is helping in site selection of interest to astrobiology and is taking a major role in Mars Mission planning. The NAI Mission to Early Earth has assembled geologists, paleontologists, molecular biologists, and planetary scientists, to probe the nature of the earliest forms of life on Earth, as a model for the search for life on Mars and elsewhere in the Universe. The NAI Europa Focus Group is starting the astrobiological planning for a series of missions that are planned to take place during the next few decades. There are also Focus Groups, either in place or planned, for research on earthly meteorite impact sites, the study of Mars meteorites, mixed evolutionary genomics, the evolution of oxidation, and other topics. This has resulted in mutual cooperation between the teams and expanded the value of the NAI to each of the teams and to the field in general. Much of the work in astrobiology is focused on field trips, both on Earth and in the more elaborate and visionary field trips into space.

Concurrent with the activities of the NAI, European scientists interested in the various fields of astrobiology have established a European Exo/Astrobiology Network, that combines the astrobiology activities of different national groups. It had its inauguration assembly during the 1st European Workshop on Exo/Astrobiology, held from 21 to 23 May 2001 at ESRIN, Frascati, Italy. The current European member countries are Austria, Belgium, Denmark, France, Germany, Italy, Portugal, Spain, Sweden, Switzerland, The Netherlands, and the United Kingdom. The addition of other countries, such as Russia, is under consideration. Several European national groups, as well as the Australian astrobiology group, are in the process of entering into affiliations or associations with NAI. Hitherto, the Spanish Centro de Astrobiologia and the UK Astrobiology Forum have concluded agreements with NAI.

Although astrobiology stresses the importance of interdisciplinary research, it is also attempting to establish a new scientific field. There has been remarkable progress in this respect. Several journals dedicated to astrobiology and related fields are being established, there are astrobiology sections meeting in several of the related professional societies, graduate and undergraduate programs in the field are being established, and there is growing interest among younger scientists in entering the specialty. Astrobiology, and indeed most of space science, is a very long-term proposition. For example, under present conditions it will take 10 years or more for a round-trip mission to Europa, and the planning itself may take many years; a program to test a crucial hypothesis may take decades. A scientist in mid-career, planning a space astrobiology mission, may not be scientifically active long enough to allow the personal evaluation of the results of his or her experiment. It is necessary to think and act generationally, to be able to dedicate oneself to an activity that will be carried on and concluded by our scientific and, possibly, actual children. Space science is similar to the building of the medieval cathedrals that often took centuries, and required the passing on of skills from one generation of skilled workers to another.

There is a strong sense of mission in astrobiology. It will affect the currently planned missions of NASA, ESA and other space agencies and will lead to the design of missions that are generated mostly by the needs of the field. There are exciting prospects in the immediate future for addressing the questions on the origins and future of life on Earth and in the Universe, fundamental to human questing, that can be answered, in part, by the applications of the scientific process. The contents of this book will show how far the field has advanced and how it may proceed in the future.