Astrobiology: The future of life and the search for life in the universe

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Abstract

Astrobiology is defined as the study of the origin, evolution, distribution, and future of throughout the universe. Astrobiology is a systems-level science utilizing data from a wide range of disciplines. A systems approach indicates that astrobiology science is the integrative study of the interactions within and between the physical, chemical, biological, geologic, planetary, and astrophysical systems as they relate to understanding how an environment transforms from nonliving to living and how life and its associated environment coevolve. This puts the origin and evolution of life in an environmental context, and how life and its environment subsequently change and evolve together (i.e., the evolution of a system is the study of ecology through time). This means that habitability is a continuum-that an environment may transition from abiotic to biological over different spatial and temporal scales as a function of planetary and environmental evolution, the presence of life, and the feedbacks between related complex physical, chemical, and biological parameters and processes. Evidence from major transitions in environmental conditions from early Earth to today, and an understanding of how they occurred, is critical for the search for life in the Universe. To understand the future of life and to search for life in the universe we must understand how life interacts with the various temperature, pressure, radiation and gravity regimes in the space environment and on solar system bodies. Within the last 50 years, space technology has provided tools for transporting terrestrial life beyond the protective shield of Earth in order to study, *in situ,* their responses to selected conditions of space. Microbes have flown in space since the early 1960's and nearly all organisms exposed to the space environment were killed except *Bacillus subtilis* spores. With the development of ESA's BioPan and EXPOSE facilities as well as cube satellites systems many more types of organism have been flown, illustrating that UV radiation and not space vacuum is not the primary cause of cell death during the short term. From a biological perspective applicable to organisms ranging from humans to microbes, the two most influential physical changes experienced onboard an orbiting spacecraft are the state of near-weightlessness created by the vehicle's freefall trajectory and the increased radiation exposure incurred as a consequence of being outside Earth's protective atmosphere. Other environmental factors, such as space vacuum, thermal extremes, solar ultra-violet (UV) radiation and the presence of high-velocity micrometeoroids and orbital debris, are mitigated by spacecraft design in order to provide internal conditions conducive to sustaining life. Data from the ISS and MIR illustrate that space station habitats are conducive to fungal growth. In fact, microbiome analyses have identified fungi (e.g. *Aspergillus* and *Penicillium*) among the main colonizers of the ISS. For ISS organisms, microgravity has been shown to alter microbial growth and metabolism

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in a variety of ways. Data gathered from exposure to the space environment and exposure to microgravity in the ISS provides a better understanding of the potential implications of forward contamination of extraterrestrial environments during interplanetary missions, and a better understanding of the physiology of the organisms and their stress responses. Understanding how a variety of Earth microbes and microbial communities behave in space will facilitate our understanding of the type of systems we should search of on other bodies in the solar system. Examples of potential future experiments and their significance will also be presented.