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The Astrophysical Context of Life—Summary

SPACE STUDIES BOARD

Background

In 1997, the National Aeronautics and Space Administration (NASA) formed an entity, the National Astrobiology Institute (NAI), to coordinate and fund research into the origins, distribution, and fate of life in the universe. A National Research Council (NRC) 2002 study of that program, *Life in the Universe: An Assessment of U.S. and International Programs in Astrobiology*, raised a number of concerns about the Astrobiology program. In particular, it concluded that areas of astrophysics related to the astronomical environment in which life arose on earth were not well represented in the program. In response to that finding, the Space Studies Board requested the original study committee, the Committee on the Origins and Evolution of Life, to examine ways to augment and integrate astronomy and astrophysics into the Astrobiology program.

Findings and Recommendations

Current Status Astronomy topics most relevant to astrobiology are those that directly influence the origin, evolution, and distribution of life. Funding decisions about astronomical research for astrobiology should be based on this “life-focused” connection. This connection might be broad and show up in unanticipated ways.

A review of astrophysical research funded in NAI and the Office of Space Science’s Origins program indicates the roadmap goals of the two programs overlap extensively. NASA may need to review this overlap to achieve greater mission clarity. In addition, while a significant amount of astronomy research is underway or is being proposed by NAI, many of the topics are or will be studied at multiple centers leading to possible redundancy. A diverse set of astrophysics research topics should be supported by astrobiology and there should be continued coordination with other NASA programs. Finally, the astronomy-related research supported in the NAI should be interdisciplinary in that it is fully integrated into the other astrobiology research efforts.

Research Areas for Augmentation and Integration There are several astrophysics research areas that should receive additional attention within the astrobiology context. They include the Galactic environment, the radiation/particle environment, bolide bombardment, interstellar molecules and their role in pre-biotic chemistry, photochemistry and its relation to photosynthesis, and molecular evolution in an astronomical context.

In order to address the question of whether there is a Galactic habitable zone, it is necessary to characterize the **Galactic environment** and how it affects life. Of interest is whether cosmic rays affect climate and the evolution of life by inducing mutations. NASA should support the study of cosmic ray effects over long periods on Earth and other bodies that might host life.

The astronomical environment provides an influx of **optical, ultraviolet, and ionizing radiation** that had a significant effect on the early stages of evolution of life on Earth. Characterization of this radiation and the particle flux incident on an evolving planet should be carried out. Also required is understanding of the origins, nature, and control of UV and ionizing radiation damage and repair of DNA under conditions appropriate to the astronomical environment as it might have varied over the history of life on Earth.

Large scale **bolide** impacts can have important effects on the evolution of a planet and on the organisms living there. Erasure of the early Earth's crust, lack of definitive ages for many large lunar impacts, and none for Mars makes research on bolide impact difficult. More work is needed to identify ejecta material in the rock around large impact basins.

There are interesting questions about the transport of organic material from the interstellar medium and protostellar disks to planet surfaces. Research about the chemistry of accretion disks evolving from molecular clouds should be pursued. Also, there is a need to understand better the complexity of interstellar and circumstellar chemistry as it might relate to the origin of life.

A major question in **prebiotic chemistry** is whether astrochemistry is a contributor or detriment to the origin of life. Efforts to resolve this question should be undertaken. Improved understanding of how photochemical carbon, nitrogen, and sulfur cycles might work on a prebiotic planet is also desirable. In this context, missions to asteroids, comets, and moons such as Titan to analyze surface organic chemistry are needed. A better understanding is also needed of how those cycles work on a prebiotic planet with an ocean and incident photons and particles. Abiotic **photochemistry** should be studied to determine if it is a possible source of organic compounds.

While it is impossible to predict what life would be like elsewhere, it might be possible to define the basic principles it would obey. Of fundamental importance is an understanding of what level of disturbance—e.g., bolide impacts and irradiation of surfaces, oceans, and atmospheres of planets and moons—is beneficial for the origin and development of the complexity of life. Examination of the **evolution** of Earth-like organisms and those with other coding that are subject to thermal and radiation environments of planetary systems orbiting stars of varying masses and ages should be undertaken. In addition, the importance of stochastic variability of the environment on **evolution** of life should be studied.

Integration of Astronomy and other Astrobiology Disciplines There are several challenges that must be overcome to integrate these two disciplines more effectively:

establishing a common language, goals, and interests; and providing motivation and incentives for expanded integrative activities. NASA should encourage the NAI to institutionalize education and training in Astrobiology. It should also establish Astrobiology a Graduate Student Fellowship program. NASA should encourage the NAI to foster cross- and inter-disciplinary training opportunities for graduate students and faculty. Programs that permit students and faculty to spend time in areas outside their own should be established. NASA must ensure that astrobiology will be a fruitful, long-term career path for students entering the field.

For Further Information

Copies of the complete report, *The Astrophysical Context of Life*, can be obtained on the National Academy Press Web site <<http://books.nap.edu/.html>>.

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