Exploration of Space to attain scientific breakthroughs in biology for a sustainable future

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Summary

Organisms adapt to changing environments using their amazing flexibility to remodel themselves by a process called evolution. The interactions between organisms and the environment are the basis of evolution because these determine the general developmental tendencies. Changing environments can cause strong selective pressure, leading to genetic and phenotypic shifts for adaptations. Stress plays a significant role in facilitating adaptation by allowing better modifications, maintenance, and functioning of organismal systems to ever-changing environments. Extreme environmental stress can cause extinction but may also lead to rapid evolutionary changes and the origin of new species adapting to new environments. Extinction succeeds when organisms fail to change and adapt to the constantly changing stressful environment. Evolution can be used to increase tolerance of organisms to stress (biotic or abiotic), improve cell performance, improve utilization of a target substrate, improve the production of compounds, or produce new natural chemicals. Evolutionary engineering is emerging as a promising natural approach for the development of desired traits or phenotypes and the production of novel biomaterials through the imposition of one or more selective pressures.

Life on Earth has always developed within the boundaries of gravity (1g). Space provides a unique environment of stressors (weightlessness and the accompanying changes in the physical reality and radiation) that organisms have never experienced on Earth. Cells in microgravity reorganize and develop or activate a range of molecular responses to raise their survivability. We anticipate that space attributes dramatically changes gene expression, leading to the evolution and adaptation of cells or organisms in a new environment. Thus, by subjecting cells or organisms to artificial stressors in microgravity in space, we can develop novel varieties of organisms and biomaterials significantly more efficiently than on Earth. For instance, we can generate natural crop varieties with higher nutrition and yields and improved features, such as resistance against high and low temperatures, salt stress, microbial and pest attacks, drought, and other stresses. Introduction of plants to artificial stressors in microgravity will activate the expression of dormant genes, change the global systemic organization of plants, and improve their recovery processes in subsequent stresses, like the ability to adapt rapidly to a disease-causing organism. Furthermore, real microgravity conditions are needed to unveil some key physicochemical aspects like the natural movement of colloids that experiments made on earth, in the presence of gravity may mask, alter or simply hinder.

Here we review how the space environment can be used as a tool to accelerate the development of new varieties of crops or other species and novel substances addressing major challenges of climate change. We discuss the molecular machinery and mechanisms that may lead to the adaptation and evolution of living organisms to stressors in the space environment. We consider the effects of the environment (additional biotic and abiotic stressors combined with space-distinctive factors), constrained selection process, unrestricted and enormous gene expression, mutation, and epigenetics on the biology, adaptation, and evolution of organisms in space, which we term as "self-guided evolution." By providing a comprehensive review of this currently unfolding space research discipline, we intend to illustrate organisms' responses to the space environment, enlighten a new understanding of biology, and recognize the potential of the space environment for boosting biological research in the pursuit of new solutions for the future of agriculture and health on Earth.