“Think small to be big”: addressing the relevance of studying microbial response to spaceflight conditions

Ralf Moeller*
German Aerospace Center (DLR e.V.), Institute of Aerospace Medicine, Radiation Biology Department, Space Microbiology Research Group, Cologne (Köln), Germany.
(*email: ralf.moeller@dlr.de, phone: +49(2203) 601-3145)

The complex space radiation environment, which includes Galactic Cosmic Rays (GCR) composed of high-energy protons and high-energy charged (HZE) nuclei, and Solar Particle Events (SPE) containing low- to medium-energy protons, has been considered as one of the main hazardous components of space for any biological system staying for extended periods of time in this vast realm of space. This pertains to astronauts, the cabin microflora and accompanying bioregenerative life support systems during long-term exploratory missions as well as to any microorganism accidentally traveling through space after being ejected from its planet’s surface by a meteorite impact, as described in the scenario of lithopanspermia. Exposure to this particulate radiation in space causes a wide range of different types of genomic lesions, e.g., single and double strand breaks, abasic sites, modified (mainly oxidized) bases or interstrand crosslinks with consequences of gene mutations, chromosome exchanges, cancer induction and cell death.

In a variety of space experiments, spores of *Bacillus subtilis* have been used as valuable biological test organisms. Spores of the Gram-positive bacterium B. subtilis are highly resistant to inactivation by environmental stresses, such as biocidal agents and toxic chemicals, desiccation, pressure and temperature extremes, and high fluences of UV radiation and are a powerful biodosimetric system for terrestrial environmental monitoring and astrobiological studies. Onboard several spacecraft, e.g. Apollo 16, Spacelab 1, LDEF, D2, FOTON, ISS EXPOSE spores of *B. subtilis* were exposed to selected parameters of space, such as space vacuum and different spectral ranges of solar UV-radiation and cosmic rays, applied separately or in combination. Bacterial spores have since been recognized as the hardiest known form of life on Earth, and considerable effort has been invested in understanding the molecular mechanisms responsible for the almost unbelievable resistance of spores to environments which exist at (and beyond) the physical extremes which can support terrestrial life. Understanding bacterial spore resistance to radiation, vacuum, heat and chemicals is important in the areas of astrobiology, sterilization and space exploration.

In my talk, I will present results from physiological and genetic studies regarding spore resistance to UV and ionizing radiation (from protons, X-rays, and heavy ions) as well as data from the transcriptome analyses of germinating *B. subtilis* spores, which were exposed for 1.5 years to space and simulated Martian conditions in the spaceflight experiment EXPOSE-E Experiment PROTECT. The identification of transcriptional and biochemical changes occurring during sporulation and germination has contributed substantially to our understanding of the unique resistance of *B. subtilis* towards the extreme conditions in space.