Translating physics to microbiology: spore resistance to terrestrial and extraterrestrial extremes

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Spore-forming bacteria are of particular concern in the context of planetary protection because their tough endospores are capable of withstanding certain sterilization procedures as well as harsh environments. Spores of *Bacillus subtilis* have been shown to be suitable dosimeters for probing extreme terrestrial and extraterrestrial environmental conditions in astrobiological and environmental studies. During dormancy spores are metabolically inactive; thus substantial DNA, protein, tRNA and ribosome damage can accumulate while the spores are incapable of repairing and/or degrading damaged DNA and proteins. Consequently, damage to essential components of spores poses a unique problem, since damage repair does not occur until the processes of spore revival. Spores appear to have two possible ways to minimize deleterious effects of environmental extremes: (i) by protecting dormant spore macromolecules (in particular the spore DNA) from damage in the first place and (ii) by ensuring repair of damage during spore outgrowth. In our research, we used spores of different genotypes of *B. subtilis* to study the effects of various extraterrestrial conditions (e.g., planetary conditions as present on Mars or low Earth orbit (LEO)) for astrobiological purposes. Spores of wild-type and mutant *B. subtilis* strains lacking various structural components were exposed to simulated Martian atmospheric, galactic cosmic and UV irradiation conditions. Spore survival was strongly dependent on the functionality of all of the structural components, with small acid-soluble spore proteins, coat layers, and dipicolinic acid (DPA) as key protectants. In addition, the interaction of several DNA repair mechanisms (e.g., non-homologous end joining (NHEJ) and spore photoproduct (SP) lyase) was identified as crucial for surviving environmental extremes in space or Martian surface (i.e., exposure to solar UV and galactic cosmic radiation. The ultimate goal is to obtain a complete model describing spore persistence and longevity in harsh environments.