Resistance of bacterial spores to space radiation – from wow to how?

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Introduction: Spores *of Bacillus subtilis* have been used extensively as biological indicators for industrial purposes such as sterilization or decontamination. Spores have also been shown to be suitable dosimeters for probing terrestrial and extraterrestrial ionizing radiation in environmental and astrobiological studies. Synergistic radioprotective effects of core components, including small acid-soluble spore proteins (SASP), dipicolinic acid (DPA), core water content, and a network of different DNA repair mechanisms are important in preventing DNA damage generated by UV or ionizing radiation.

Methodology: Spores of the different *B. subtilis* strains were individually exposed, either as air-dried spore layers or spores in suspension to different types of UV or ionizing radiation (e.g., X-rays, protons, heavy ions).

Results and discussion: Understanding bacterial spore resistance to radiation, vacuum, heat and chemicals is important in the areas of astrobiology, sterilization and space exploration. Spores of the *B. subtilis* are monogenomic, thus there is no protection provided by duplication of genetic information. Spore radiation resistance results from mechanisms of two types: those which (i) prevent DNA damage in the dormant spore and (ii) repair DNA damage during spore germination. During sporulation, spore DNA is saturated with a group of unique proteins called α/β-type small, acid-soluble spore proteins (SASP). SASP binding to DNA changes the DNA from the B-like to the A-like helix conformation, promoting spore photoproduct (SP) formation and suppressing formation of cyclobutane pyrimidine dimers (CPD) in UV exposed spores. DNA reactivity to a variety of other DNA-damaging agents is also dramatically lowered when DNA is bound by α/β-type SASP. Several additional key factors in the spore core (e.g. lowered pH and water content, and the presence of dipiciolinic acid (DPA)) are also involved in preventing DNA damage in dormant spores. However, despite the protection mechanisms provided by the components of the dormant spore, potentially lethal or mutagenic damage can still accumulate in the spore DNA. Germinating spores activate a number of DNA repair pathways dedicated to the removal or repair of induced lesions. Among these are the SP-specific enzyme SP lyase, the generalized base excision repair (BER) and nucleotide excision repair (NER) pathways, recombinational (REC) repair, and non-homologous end joining (NHEJ) pathway for repair of double-strand DNA breaks. Here, results from physiological and genetic studies regarding spore resistance to UV and ionizing radiation (from protons, X-rays, and heavy ions) will be presented. The identification of transcriptional and biochemical changes occurring during sporulation and germination has contributed substantially to our understanding of the unique resistance of bacterial spores towards the extreme conditions in space.

References:

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