Life at the edge – a step towards recognizing adaptations of lichens to extreme extraterrestrial conditions

Lichens are specific symbiotic organisms basically formed by a fungus and photosynthetic partner which can be autotrophic algae and/or cyanobacteria. Compared with autonomic fungi, lichens have many peculiar features such as highly variable morphology/anatomy, specific metabolic pathways, and exclusive reproduction methods. Lichens can be found in every major ecosystem on Earth from the poles to the tropics, but only in the most extreme environments, such as hot arid deserts, polar regions and high mountains, they become a significant ecosystem component. In these environments, lichens are subjected to a variety of adverse conditions including extreme temperatures, aridity and high light intensity. The structure and physiology of lichens contribute to their success in the colonisation of environments extremely hostile to life. Due to their ability to adapt and thrive in the most extreme environments on Earth, lichens have become the main focus of astrobiologists who speculated whether they could survive in extraterrestrial environments such as outer space or Mars surface.

The project concerns a comprehensive analysis of the functioning and adaptation of lichens to survive in extreme extraterrestrial conditions. Extremophiles, such as lichens, are perfect candidates to study attributes that contribute to reaching the limits of life. Although there were astrobiological studies in this aspect, majority of them focused on lichen viability after exposure to outer space or in simulation facilities, while the knowledge on anatomical, physiological and biochemical changes and adaptations are lacking. We plan to find answers to key questions about lichen traits that provide greater resistance to stress. The main aim of the project is to identify lichen responses to vacuum, extraterrestrial solar radiation, X-rays, temperature, and their combinations, to determine their adaptations at various levels of the structure and functioning of the thallus: cell viability, morphology, anatomy, physiology and biochemistry. We also aim to assess the regenerative capacity over time after exposure and identify the effectiveness of protective mechanisms by determining the mutual relations between the degree of damage and triggering a response to these damage. The last aim concerns the comparison of resistance limits of lichens to X-ray and extraterrestrial solar radiation in a metabolically active and in a desiccated anhydrobiotic state.

To meet the project aims, the consortium between Jagiellonian University and Space Research Centre was established. The specialists in astrophysics, lichenology, plant physiology and biochemistry, and molecular methods were also invited to the project as co-investigators. Three lichen species were selected, i.e. *Diploschistes muscorum*, *Cladonia uncialis* and *Cetraria aculeata*. The selected species differ in growth form, composition of secondary metabolites and adaptations to specific habitat conditions. They also have different protective mechanisms against extreme terrestrial factors, including heavy crystalline deposit on the thallus, UV-screening secondary metabolites or melanin pigments. We expect that lichen species selected for the study developed specific mechanisms providing them tolerance to extreme extraterrestrial factors; however we expect that they will differ in the tolerance level and capability to recover after exposure to stress. The experiments assume 4 different combination of conditions with regard to solar radiation, X-rays, pressure, temperature, exposition time and the state of thallus metabolic activity (hydrated, desiccated). Simulation facility includes vacuum chamber that will be equipped with Xenon light source with sun-like emission spectrum and X-ray tube and a cooling/heating plate. After each experiment the thalli will be allowed to slowly recover their normal metabolic conditions. The analyses will be performed at different time points: before experiment, 2, 24 and 72h after exposure.

The project is interdisciplinary as it includes the study of lichen responses and adaptations both at the structural and functional levels. Our results will expand the current understanding of how various lichen traits provide them resistance. An innovative element concerns the effect of cosmic rays on lichens since knowledge in this area is very limited. Our research may also provide answers if lichens will be able to survive under global changes caused by different astrophysical phenomena, such as an asteroid impact on the Earth or nearby gamma-ray bursts/supernovae explosion. The results will contribute to broadening the knowledge of astrobiology, lichen ecophysiology and biochemistry. Potential utility of selected lichens in future astrobiological research will be evaluated. Implementation of the project could be important not only from the cognitive point of view, but also can draw attention to the understanding which attributes contribute to reaching the limits of life.