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Rebecchi Lorena[1]; Guidetti Roberto[1]; Altiero Tiziana[1]; Rizzo Maria Angela[2]; # Bertolani Roberto[1]
Lorena Rebecchi[1]; Roberto Guidetti[1]; Tiziana Altiero[1]; Maria Angela Rizzo[2]; # Roberto Bertolani[1]

[1] Univ. Modena and Reggio Emilia; [2] Univ. Milan
[1] Univ. Modena and Reggio Emilia; [2] Univ. Milan

Organisms living in extreme habitats, being subject to strong stresses such as drying and freezing, have evolved specific adaptations to survive. Tardigrades, together with rotifers and nematodes, are the only metazoans able to survive to extremes carrying out cryptobiosis at any phase of their life cycle, including egg. Cryptobiosis is a form of quiescence, which includes anhydrobiosis, a highly stable state of suspended animation due to complete desiccation pending recovery by re-hydration. Cryptobiosis also includes cryobiosis, a phenomenon often verified in tardigrades, but not yet studied from a molecular point of view. The ability to withstand desiccation in tardigrades (and in other desiccation tolerant organisms) is a complex phenomenon that takes place at every level of the biological organization. Morphological, physiological, biochemical, and molecular constraints are involved in tardigrade anhydrobiosis. These factors can allow a long-term resistance in a desiccated state. The anhydrobiotes also show a particular resistance to chemical and physical extremes, suggesting that some of the mechanisms underlying anhydrobiosis might contribute to the resistance to those stresses, other than desiccation. This ability, and especially the radiation tolerance, has lead to propose tardigrades as suitable model in space research. A natural exposure to space environment provides a more realistic evaluation of mechanisms allowing anhydrobiotic organism to survive space than simulated tests on the Earth. Our preliminary data on tardigrades that have flown in space within the facility Biokon (by Kayser Italia) in the recent Mission LIFE on Foton M3 (September 2007; TARSE project) reveal a high survival rate, more in desiccated than in hydrated animals. The related molecular aspects are still under study. Our future studies will be particularly addressed to molecular aspects of anhydrobiosis.

In general, studies are still necessary to better understand the mechanisms by which anhydrobiotes are able to tolerate the total suspension of metabolism due to the complete desiccation and the evolutionary meaning of life without water. They should be devoted to understand repair mechanisms of damages to biological structures and molecules (especially to DNA) induced by desiccation, and to characterize genes and their proteins, which allow dehydration without death. The identification of such mechanisms should allow us to use this evolutionary advantage to engineer desiccation tolerance in cells, tissues or animals not naturally anhydrobiotic. Recently acquired knowledge of trehalose properties represents a new stimulus to continue the basic research to discover other bioprotectants that allow life without water.