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POLYEXTREMOPHILES.
SUMMARY AND CONCLUSIONS

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The search for extraterrestrial life is encouraged by a comparison between organisms living in severe environmental conditions on Earth and the physical and chemical conditions that exist on some Solar System bodies. Astrobiology raises the possibility of life elsewhere in the Solar System (cf., the chapter by Joseph Seckbach: *Life On The Edge And Astrobiology: Who Is Who In The Polyextremophiles World?*.

The extremophiles that could tolerate more that one factor of harsh conditions are called poly-extremophiles. There are unicellular and even multicellular organisms that are classified as hyperthermophiles (heat lovers), psychrophiles (cold lovers), halophiles (salt lovers), barophiles (living under high pressures), acidophiles (living in media of the lower scale of pH). At the other end of the pH scale they are called alkaliphiles (namely, microbes that live at the higher range of the pH scale). Thermo-acidophilic microbes thrive in elevated thermo-environments with acidic levels that exist ubiquitously in hot acidic springs.

Most of the organisms that we know thrive in normal environments that we consider to be ambient habitats. Extremophiles are among the microorganisms living on the edge of life under severe conditions. In recent years microorganisms have been discovered living in extreme environments, such as very high temperature (up to 115° C) (cf., chapter by Bizzaco Richard: *The impact of two or more stresses on the growth and physiology of cyanobacteria and micro-algae*. Survival is also particularly relevant for very low temperatures (~ minus 20° C, as discussed from various points of view in the chapters by V. Edgcom et al: *Protsit community structure and dynamics in a seasonally anoxic fjord: Saanich Inlet British Columbia;* Hanhua Hu*: Adaptation of Antarctic green algae to the extreme environments*; Jacquline Whyte Lyle – Goordial et al: *Cryophilic microbial life at low water activity in polar cryoenvironments*; Leya Thomas' *Snow algae: adaptation strategies to survive on snow and ice*.

In addition, polyextremophiles can also withstand a variety of stresses; amongst them we mention both ends of the pH range; very strong acidity vs. high alkalinity; saturated salt solutions and high hydrostatic pressure (Kawarabayasi Yutaka's *Living under thermoacidophic extreme conditions* and Minegeshi Hiroaki's *Halophilic and acidophilic prokaryotes*). We know that life exists on Earth in almost every ecological niche. One of the prerequisites for life is the availability of liquid water, sources of energy and a reasonable supply of organic molecules. From our experience with the Earth biota, wherever there is water, there is a good opportunity of finding living organisms.

In hypersaline areas (such as the Dead Sea, Israel) we find halophilic bacteria and algae that can balance the osmotic pressure of hypotonic external solutions (cf., the three well-documented chapters by Aharon Oren: *Two centuries of microbiological research in the wadi natrun, egypt: a model system for the study of the ecology, physiology, and taxonomy of haloalkaliphilic microorganisms; High salinity and divalent cations, chaotropic ions and Hofmeister series* and finally, *Life at high salt and low oxygen: how do the halobacteriaceae cope with low oxygen concentrations in their environment*? In addition this book covers this topic in Helga Stan-Lotter 's *Survival strategies of halophilic oligotrophic and desiccation resistant prokaryotes*. Halophilic bacteria were further discussed in the chapters by Stoeck Thornsten et al: *Microbial eukaryotes in hypersaline anoxic deep-sea basins,* as well as by Banciu Horia's *Adaptation mechanisms in haloalkaliphilic and natronophilic bacteria*.

Recently, the segmented microscopic animals tardigrades, (0.1 – 1.5 mm) have been under investigation (Horikawa Daike's *The case of Tardigrades*). These “water bears” are polyextremophilic, and are able to tolerate a temperature range from about 0 °C up to + 151°C (much more that any other known microbial prokaryotic extremophile). But even low Earth orbit extreme temperatures are possible: tardigrades can survive being heated for a few minutes to 151°C, or being chilled for days at – 200 °C, or for a few minutes at -272°C, 1° warmer than absolute zero. These extraordinary temperatures were discovered by an ESA project of research into the fundamental physiology of the tardigrade, named TARDIS. Tardigrades are also known to resist high radiation (the chapter of Jocelyne Diruggiero further discusses the tolerance of high radiation in her chapter: *Extremophilic adaptations leading the ionizing radiation resistance*), while Gusev Oleg & Takashi Okuda discuss another polyextremophile that will survive outside the Earth's atmosphere: *An anhydrobiotic midge Polypedilum vanderplanki: Morphological, Genetical and Biochemical Tricks for Survival in Outer Space*. The question of microbial life in outer space has also been reviewed in the chapter by Lynn Rothchild: *Poly-dimensional niche space for life*.

To conclude, many other valuable chapters make up this timely and comprehensive volume that demonstrate the current relevance of subject of polyextremophiles in a wide range of subjects that the readers will discover by themselves supplementing those that we have listed above, as well as other topics from the space sciences, biochemistry, genetics, ecological situations and in human activities. But from our personal point of view the most striking and appealing aspect of this work is the fact that life on Earth is evidently ubiquitous and it suggests how life may emerge and adapt itself in other worlds (Chela-Flores, 2011).

This argument is particulary compelling, especially now that we have a highly developed NASA robot on Mars, *Curiosity*, capable of searching for extinct microorganisms that according to our viewpoint would be some kind of polyextremophiles (Mars Science Laboratory, 2012) . The argument in this book is in addition significant, since with two major probes, the current Kepler Mission (Batalha et al., 2012) and FINESSE (to be lauched by NASA, FINESSE, 2016) we will be able to begin probing if some of the Kepler worlds in our galactic neighbourhood would be in habitable zones of their stars and if they have produced unusually high fractions of biogenic gases, as cyanobacteria were able to pump out since the Archean. After the new abundant gas from photosynthesis, oxygen, was able to saturate surficial ferrous compounds (banded-iron formations), the Earth was transformed from an oxygen-poor atmosphere to oxygen-rich one: "the great oxidation event" took place around 2.4 Ga before the present.

An alternative name to the oxigenation of the atmosphere was given by the late Lynn Margulis and Doron Sagan (Margulis and Sagan, 1987), who called this atmospheric phenomenon the "great oxygen holocaust" from the point of view of those ancient polyxtremophiles that were anaerobic and could not survive on a world that was rapidly transforming itself into a multicellular-friendly environment from the surviving aerobes.

The present book is a treasure trove for microbiologists, but especially for astrobiologists that need to anticipate what sort of organisms may have evolved elsewhere.

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