European Planetary Science Congress 2008. (A cooperation between the European Planetary Network and the European Geosciences Union). Westfälische Wilhelms Universität, Schloßplatz 2, Münster, Germany21 – 26 September 2008.

THE EXTREME ENVIRONMENTS AND THEIR MICROBES AS MODELS FOR EXTRATERRESTRIAL LIFE

Joseph Seckbach[1], Aharon Oren[2] and Julian Chela-Flores[3]
The Hebrew University of Jerusalem, Home: Mevo Hadas 20 [P.O.Box 1132] Efrat, 90435, Israel. [2]Department of Plant and Environmental Sciences, The Institute of Life Sciences, and the Moshe Shilo Minerva Center for Marine Biogeochemistry, The Hebrew University of Jerusalem, 91904 Jerusalem, Israel, and [3] The Abdus Salam ICTP, Strada Costiera 11, 34014 Trieste, Italia, and Instituto de Estudios Avanzados, IDEA, Caracas 1015A, República Bolivariana de Venezuela

Life exists almost everywhere on Earth. Presence of liquid water is a prerequisite for life (Oren, 2008). Living organisms are not only found in ‘normal’ habitats (from the anthropocentric view). Many types, especially of microorganisms, not only tolerate harsh environmental conditions, but even thrive in them. Such organisms that resist very severe physical and chemical conditions in their habitats are termed ‘extremophiles’. Some extremophilic microorganisms are able to overcome more than one type of extreme conditions in their environment. For example, some ‘polyextremophiles’ grow under hundreds of atmospheres of hydrostatic pressure (barophiles) and at very low, or alternatively at very high temperatures. In many hot springs there are acido-thermophiles that tolerate elevated temperatures and very low pH levels (e.g. the *Cyanidium caldarium* group, see Seckbach 1994). Members of *Cyanidium* are able to thrive in pure CO_2, a condition not tolerated by most algae (Seckbach et al. 1970). Some thermophilic Archaea grow at temperatures up to 113^0C and possibly even higher. In the Arctic and Antarctic regions and in the permafrost region in Siberia there are cold-loving microorganisms (psychrophiles) which are able to grow at -20^0C. Many types of Bacteria and Archaea tolerate extreme dryness, and spores of *Bacillus* and relatives that have been encapsulated within salt crystals may have survived in a dormant state for thousands and even millions of years, and still can be revived today. Other extremophiles tolerate salt concentrations up to saturation. Halophilic microorganisms such as found in the Dead Sea or in the Great Salt Lake have developed different strategies to cope with the high osmotic pressure of their environment. Some (e.g. the unicellular green alga *Dunaliella salina*) balance the salts in their medium by accumulating organic compounds such as glycerol. Others (halophilic Archaea of the order Halobacteriales, as well as a few representatives of the Bacteria such as the aerobic *Salinibacter ruber* and the anaerobic members of the Halanaerobiales) use KCl to provide the necessary osmotic balance. Some of these extreme halophiles possess light-driven proton pumps (bacteriorhodopsin, xanthorhodopsin) and chloride pumps (halorhodopsin) that enable them to use photons to drive energetically expensive reactions (Oren, 2002; Oren, 2008).

Extremophiles can serve as models for extraterrestrial microbes that may live in celestial bodies. The most promising among these to contain habitable areas are Mars (where the Phoenix Lander recently discovered water) and the Jovian satellite Europa; also Titan (the moon of Saturn) has some features that resemble those that may have existed on Earth during its earliest stages.

From the characteristics of extremophilic microorganisms found on the present-day Earth, we can derive some insights on the question of habitability of other planets, and learn about possible bioindicators that may be suitable when searching for extraterrestrial life (Seckbach and Chela-Flores, 2007). Compounds such as methane on Mars or traces of sulfur on Jupiter's moon Europa may have been of biogenic origin and may possibly have been endogenic (Chela-Flores, 2006; Chela-Flores and Kumar, 2008). Biogeochemical tests have been proposed for missions that are in the planning stages, such as LAPLACE (Blanc et al., 2008), a mission to Europa and the Jupiter system by ESA's Cosmic Vision Programme.

The finding of elemental sulfur on Europa may be of special interest. One possibility is that such traces of sulfur might have originated from the metabolism of extremophilic sulfur-reducing microorganisms. Radiation may damage traces of biogenic sulfur deposited on the surface. The stopping depth for ionic radiation in the Jovian magnetosphere is expected not to exceed 1 cm (Greenberg, 2005; Dudeja et al., 2008). Thus, organic molecules would not be destroyed below such a thin layer. Penetrators are instruments in the process of development that would impact planetary bodies such as the Moon and bury themselves into the surface. Based on to the preliminary results of the British Penetrator Consortium (Smith et al., 2008), a modest penetration depth of penetrators into the (icy) surface of Europa would be sufficient to obtain samples that can be used to correctly interpret isotopic abundances of sulfur that in the presence of putative S-reducing microbes would show measurable anomalous deviations (a biomarker) without radiation interference.

References

Blanc, M. and the LAPLACE consortium (2008). LAPLACE: a mission to Europa and the Jupiter System, Astrophysical Instruments and Methods, in press. (The LAPLACE Consortium: http://www.ictp.it/~chelaf/ss164.html).

Chela-Flores, J. (2006). The sulphur dilemma: Are there biosignatures on Europa's icy and patchy surface? International Journal of Astrobiology 5: 17-22.

Chela-Flores, J. and Kumar, N. (2008). Returning to Europa: Can traces of surficial life be detected? International Journal of Astrobiology, in press.

Dudeja, S., Bhattacherjee, A.B. and Chela-Flores, J. (2008). Manuscript in preparation.

Greenberg, R. (2005). Europa - The Ocean Moon. Springer and Praxia Publishing, Chichester, 328 pp.

Oren, A. (2002). Halophilic Microorganisms and their Environments. Kluwer Scientific Publishers, Dordrecht, 575 pp.

Oren, A. (2008). Life at low water activity. Halophilic micro-organisms and their adaptations. The Biochemist, in press.

Seckbach, J. (1994). The natural history of *Cyanidium* (Geitler 1033): past and present perspectives. in: Seckbach, J. (ed.), Evolutionary Pathways and Enigmatic Algae*: Cyanidium caldarium* (Rhodophyta) and Related Cells, Kluwer Academic Publishers, Dordrecht, pp. 99-112.

Seckbach, J., Baker, F.A. and Shugarman, P.M. (1970). Algae thrive under pure CO_2. Nature 227: 744-745.

Seckbach, J. and Chela-Flores, J. (2007). Extremophiles and chemotrophs as contributors to astrobiological signatures on Europa: a review of biomarkers of sulfate-reducers and other microorganisms, in: Hoover, R.B., Levin, G.V., Rozanov, A.Y. and Davies, P.C.W. (eds.), Instruments, Methods, and Missions for Astrobiology X. Proceedings of SPIE Vol. 6694, 66940W.

Smith, A., Crawford, I. A., Gowen, R.A., Ball, A J., Barber, S.J., Church, P., Coates, A.J., Gao, Y., Griffiths, A.D., Hagermann, A., Phipps, A., Pike, W.T., Scott, R., Sheridan, S., Sweeting, M., Talboys, D., Tong, V., Wells, N., Biele, J., Chela-Flores, J., Dabrowski, B., Flannagan, J, Grande, M., Grygorczuk, J., Kargl, G., Khavroshkin, O. B., Klingelhoefer, G., Knapmeyer, M., Marczewski, W., McKenna-Lawlor, S., Richter, L., Rothery, D.A., Seweryn, K., Ulamec, S., Wawrzaszek, R., Wieczorek, M. and Wright, I.P. (2008). LunarEX – A proposal to cosmic vision. Experimental Astronomy Journal, submitted for publication.