PREFACE

Astrobiology is the study of the origin, evolution, distribution, and future of life in the universe. This book offers an analysis undertaken from the perspective of science education, to discuss the nature of the particular challenges faced by those seeking to facilitate public education in the field of astrobiology. The authors also address the question of the formation of a protocell and its function at the system level. It will further deal with the environmental pressures likely present on the early Earth, as they would have influenced the lifetime of unstable or reactive components needed for the start of life. In addition, the method of the transition from prebiotic organic microsystems to the primordial communities of prokaryotes is explored. The authors also explain some aspects related to aqueous interfacial processes in the context of prebiotic chemistry under the point of view of our current experimental results. Moreover, there is considerable interest in astrobiology in investigating icy worlds and the microbial forms that thrive in extreme environments, especially under those cold conditions that can provide a model for some extraterrestrial environments. This book reviews the general trends concerning the biodiversity and ecology of psychrophilic microorganisms and their molecular mechanisms of adaptation and evolution, as well as summarize the latest results on this topic in samples from icy environments. Other chapters summarize the morphological signatures of flowing water, the astrobiological potential of the dunes, and the theoretical modelling background of the presence of liquid water on Mars today.

Chapter 1 - Over recent years the importance of the public understanding of science has been increasingly recognised. Science is not only a core area of culture, but is also a major area of investment from public expenditure. Awareness of the potential of science to develop technologies which can safeguard and extend the quality of life - for example, through medical advances - is matched by knowledge of the role science has played in developing increasingly effective mass weapon systems and in facilitating the non-sustainable exploitation of natural resources. The public has a somewhat ambivalent view on whether science is in general a good thing, and scientific careers are not seen as attractive to many talented young people. Scientists in all fields must therefore engage with the issue of 'public relations' rather than consider their work as only the concern of an intellectual elite. Education for public understanding has become one of the responsibilities of those working in research areas funded from the public purse. Furthermore, spending money on aspects of 'space science' may not seem a priority compared with developing renewable energy technologies, tackling pollution and protecting biodiversity here on earth. Astrobiology has some advantages in this regard, being an area that can readily inspire the public imagination. Conversely, the very familiarity with aliens represented in mass media, may also mean that scientists attempting to explain the nature and significance of their work to the public may often face unhelpful preconceptions. Moreover, it can be argued that the areas of science that astrobiology draws upon (such as chemical, biological and cosmological evolution) are among those where research into science education has identified major learning difficulties. The present chapter offers an analysis undertaken from the perspective of science education, to discuss the nature of the particular challenges faced by those seeking to facilitate public education in the field of astrobiology.

Chapter 2 - Prebiotic chemistry studies the possible origins of the building blocks of living organisms, as well as their chirality. The hypothesis commonly accepted to explain the origin of life is that simple inorganic molecules, for instance, CH_4, CO_2, N_2, NH_3, reacted together in order to form simple organic compounds that then underwent subsequent reactions to yield biologically functional molecules. These compounds self-organized and self-assembled to increase the organization at molecular levels. This succession of chemical processes is considered the most likely pathway for the emergence of the first living organism. Therefore, the first step to verify this theory is to check how the components of proteins and nucleic acids, among others, could be formed under abiotic conditions. Additionally, the chirality of the constituents of these polymers is another important point. A chiral molecule is a molecule that is not superimposable to its mirror image, L and D configuration. All amino acids in nature have L configuration and all sugars are D. To date, the origin of homochirality in nature is still not understood.

The presence of water is considered a fundamental factor for the development of life. Approximately 72% of the surface of the Earth is covered by liquid water in the form of oceans. This huge water pool and the atmosphere are connected by a cycle of evaporation, condensation, and rain. In addition, oceanic organic and inorganic surface products can be transmitted within aerosols to the atmosphere above, where they are then exposed to radiation and electrical discharges in the form of lightning. The terrestrial water cycle and its changes of state and distribution must have played a significant role in the origin of organic molecules under abiotic conditions, as well as in the symmetry breaking.

In this review, we explain some aspects related to aqueous interfacial processes in the context of prebiotic chemistry under the point of view of our current experimental results. We propose a possible role for the cycle of natural aerosols (i.e., from the ocean water pool to the atmosphere and back to the ocean, bubble-aerosol-droplet cycle) and demonstrate the importance of melting-freeze water cycles. These processes may play a relevant role in the synthesis of organic molecules directly related to the first self-organized systems. We also explain a plausible role for the nucleation processes in the solid-vapor interface in the symmetry breaking.

Chapter 3 - The first forms of living system, or protocells, must have been composed of chemical components or subsystems allowing them to ensure their maintenance, growth, and evolution. As such these subsystems must have possessed similar functions to those of present cellular life. However, contemporary cells rely on the interconnected work of information polymers, catalytic polymers, and their compartments, whose design required a long evolution.

To model plausible protocells and their functions, several classes of simpler compounds have been proposed and investigated, such as single chain amphiphiles (e.g., fatty acids) as building blocks of the compartments, polycyclic aromatic hydrocarbons (PAHs) as energy harvesting molecules, and catalytic RNAs (ribozymes) as both information and catalytic components. While very interesting insights in the processes and/or functions of each molecule class have already been gathered, it has become increasingly clear that the study of the protocell as a whole must be carried out to achieve the construction of a truly functional model system.

This review addresses the question of the formation of a protocell and its function at the system level. It will further deal with the environmental pressures likely present on the early Earth, as they would have influenced the lifetime of reactive components needed for the start of life. The capabilities and limitations of protocell functionalities can be elucidated only through understanding the container interactions/interconnected functions with the other subsystems including environmental factors.

Chapter 4 - There is considerable interest in astrobiology in investigating icy worlds and the microbial forms that thrive in extreme environments, especially under those cold conditions that can provide a model for some extraterrestrial environments. After the successful missions Galileo and Cassini-Huygens to Jupiter and Saturn systems respectively this priority has been focused on the research of environments potentially habitable in some icy worlds such as Europa, Encelado or Titan.

On Earth, the recent discovery of cold-tolerant microorganisms in glaciated and permanently frozen environments has broadened the known range of environmental conditions which support microbial life. These microorganisms, known as psychrophiles are defined as organisms having an optimal temperature for growth at about 15ºC or lower, a maximal temperature for growth at about 20ºC, and a minimal temperature for growth at 0ºC or below. The lowest temperature limit for life seems to be around -20ºC, which is the value reported for bacteria living in permafrost soil and in sea ice. Terrestrial models of extraterrestrial icy worlds are being intensively studied. Among them, bacterial communities from Arctic and Antarctic permafrost, subglacial lakes and high mountains are considered representative of these environments in which psychrophile bacteria are the unique inhabitants. When compared to other known prokaryotes, psychrophilic bacteria posses many unique qualities and molecular mechanisms that allow their adaptation to cold environments. In this regard, some psychrophiles have been found to contain polyunsaturated fatty acids in their plasma membranes, which generally do not occur in other prokaryotes. Further, some of them use enzymes that continue to function at near freezing ambient temperatures. And finally, psychrophilic bacteria are able to produce proteins that are stable at cold temperatures such as heat shock proteins (Hsps) and cold shock proteins (Csps). This chapter will review the general trends concerning the biodiversity and ecology of psychrophilic microorganisms and their molecular mechanisms of adaptation and evolution, as well as summarize our latest results on this topic in samples from icy environments.

Chapter 5 - At the polar dunes of Mars branching dark slope streaks emanating from Dark Dune Spots were observed in local springtime on MOC and HiRISE images. They seep downward with an average speed of 1.4 meter/sol when the temperature of the terrain on 3 km spatial resolution is between 180 and 250 K. Theoretical considerations and calculations suggest interfacial liquid-like water has to be present on Mars, and possibly is causing the observed seepage-like features. The thin water lubricated grains may slide over each other, and/or the stress caused by the refreezing of this interfacial water could also produce such markings, as well as the moving front of solid ice / liquid water phase changes. Such an ephemerally wet environment between the dune grains may have astrobiological significance.

Chapter 6 - This chapter is devoted to consideration of the method of the transition from prebiotic organic microsystems to the primordial communities of prokaryotes. During the initial transformations prebiotic organic microsystems acquired the unstable bifurcate state, with its following relative stabilization by means of balanced oscillations around the bifurcation point. Then microsystems of the type converted into the primary living units – probionts, which were characterized with the ability to concentrate free energy and information already. Through the synergy effect probionts were organized into the communities that represented themselves minimum self-sufficient unit of life. The appeared communities of probionts evolved to more complex communities of progenotes (characterized by C.Woese) and then prokaryotes. This earliest biological evolution proceeded through development of the initial nucleoprotein interaction, formation of RNA and then DNA, etc. Emergence of species had led to conversion of the initial communities of probionts and progenotes ("embryos" of ecosystems) into the real ecological systems, which were hierarchically organized of different microbial species.

Chapter 7 - This chapter summarizes the experiences regarding the general knowledge of undergraduate students in astrobiology, and presents methods we used in the education of astrobiology at university level in Hungary. Based on these, we found the following important issues. They have good general knowledge in the fields, which are well known for decades. Liquid water is thought to be widespread by the students, but they lack important information (like oceans inside icy moons) in the recent results. The most important is to develop and improve methods for the students to use the knowledge learned at different subjects more frequent in astrobiology. Useful examples, like the astrobiology- and Drake-matrixes are presented to compare different environments based on numerical values, graphics and tables.

Chapter 8 - The analytical application of Raman spectroscopy to the identification of the survival strategies of terrestrial extremophiles through the characterisation of key biomolecular and biological signatures has provided novel information about the roles of protective chemicals synthesised by the organisms under environmentally stressed conditions. The non-destructive sampling requirement and the ability to discriminate between organic biomolecular spectral signatures and those from the inorganic host matrix in the geological record are essential requirements for the assessment of the survival strategies being employed against low wavelength ultraviolet radiation insolation, desiccation and extremes of temperatures found in terrestrial habitats termed Mars analogue sites (Table 1).

The recent announcement of the inclusion of a miniaturised Raman spectrometer as part of a combined Raman /LIBS instrument for the molecular and elemental analytical characterisation of specimens in the Martian surface and subsurface as a component of the European Space Agency ExoMars life-detection suite has focussed attention on the Raman spectra of key biomarkers of life signatures. To search for indicators of extinct or extant life signatures on Mars serves to highlight the importance of Raman spectroscopic techniques in this astrobiological mission. As a forerunner to the ExoMars mission it is imperative that the Raman spectroscopic data from extremophilic colonies from as wide a possible range of terrestrial sites of relevance to Mars is undertaken. This chapter will address the type of information that is required and which is accessible from these terrestrial studies to adequately prepare the way for the interpretation of analytical scientific data that will emerge from the Mars exploration programme, commencing with the launch of ExoMars in 2013.

Chapter 9 - Europa is the smallest of the Galilean satellites of Jupiter, although it is however a remarkable body and the primary focus of astrobiological interest in the Jovian system. Geological and magnetic evidences, as well as theoretical considerations, strongly suggest that Europa has a thin ice shell, maybe a few kilometers or a few tens of kilometers thick, which floats on an internal ocean of liquid water. Some anomalies have been observed in the huge magnetic field of Jupiter whenever Europa goes through it, which seems to indicate that this ocean is made of conductive water, due to a probable high content of salts. Moreover,the low density of impact craters suggest an surface age of about 60 Myr in average, which is very young in geological terms, indicating that internal activity, driven by tidal heating, is resurfacing the moon at the present time. So, Europa shows an overprint of crisscrossing ridges and linear markings, some extending for thousand of kilometers, which are locally disrupted for chaotic terrains, building a colorful and exotic textured surface. All of these features make of Europa a theoretically good niche for life. Biological organisms might exist in the salty internal ocean, in the icy shell (active or latent) at places such as fractures, veins or liquid reservoirs, on the internal sea floor in hydrothermal vents or submarine volcanoes, or even within the rocky interior.