ASTROBIOLOGY – THE NEW SYNTHESIS. T. Simon[1] and A. Sik[2]. [1]Department of Microbiology (simon.tamas@axelero.com), [2]Department of Physical Geography (sikandras@ludens.elte.hu), [1,2]Eotvos Lorand University, H-1117, Pazmany Peter setany 1/C, Hungary.

Background: In connection with the complex planetology-education in Hungary [1] we have compiled an Astrobiology coursebook – as a base of its teaching in universities and perhaps in secondary schools as well. We tried to collect and assemble in a logical and thematical order the scientific breakthroughs of the last years, that made possible the fast improvement of astrobiology. The followings are a kind of summary of these.

Introduction – The ultimate science: Astrobiology is a young science, searching for the possibility, forms and places of extraterrestrial life. But it is not equal with SETI, because do not search for intelligent life, just for living organisms, so SETI is rather a part of astrobiology. And an extremely important statement: we can search for life-forms that similar to terrestrial life in physiology so we can recognize it as life.

Astrobiology is one of the most dynamical-developing sciences of the 21st century. Determining its boundaries is difficult because the complex nature of it: astrobiology melt into itself lot of other sciences, like an ultimate science.

The fundamental questions are very simple [2]: When, where and how converted the organic matter into life?; How does life evolve in the Universe?; Has it appeared on other planets?; How does it spread in time and space?; and What is the future of terrestrial life?

However, trying to find the answers is quite difficult. So an astrobiologist has to be aware of the basics of astronomy, space research, earth and planetary sciences, and life sciences (mainly ecology, genetics, molecular and evolution biology). But it is not enough – the newest results of these at least as important as the basic knowledge.

Part I. – Astro:

1. Exoplanets

1995 was a particular year in astronomy: we have found the first planet out of the Solar System. Since that time the discovery of exoplanets progress quickly: nowdays more than 80 examples are known and just 6 years passed [3].

The detailed analysis of these distant objects has verified and solidified our theories of planet-formation. The places of this process are contracting clouds of gas and dust, like Orion Nebula. In these star-birth clouds we can observe clusters of matter in which the temperature and pressure reach a limit and a new-born star begin to "function", or rather radiate. Around the star, the remnant matter settle into a plane, forming a protoplanetary disk. It has different zones: heavy elements nearer to the star, light elements farther from it. The planets are taking shape from these zones – perhaps rocky types and gas giants as well.

To see so much example we can state that planetary system-formation is an absolutely normal, everyday process in the Universe. As a consequence there are a lot of planetary system near to our Earth, with planets orbiting around stars.

Though, the known exoplanets are not too Earth-like objects. Most of them seem to be lonely gas giants (with mass bigger than Jupiter) nearer to their star then rocky planets to our Sun. The only known multiple exo-system is around Upsilon Andromedae [4]. Probable the reason of this difference is the weak capability of our instrument and not the speciality of our system. By using advanced methods and instruments (like Next Generation Space Telescope or Terrestrial Planet Finder spacecraft, planned to launch in 5 years [5]) rocky-like planets will be found as well.

2. Water in the Solar System

Looking closer, the knowledge of our Solar System has increased intensively during the last years of the 20th century – due to the planetary spacecraft missions, like Lunar Prospector, Mars Pathfinder, Mars Global Surveyor, Galileo and NEAR-Shoemaker. The most important discovery, that liquid water is quite general in our local cosmic environment. And as we think this is the most important condition of life.

First and foremost, the most hopeful is Planet Mars. By reconstructing the surface evolution of our outer neighbor it seems that in the past, more billion years ago it had global ocean, the depressions were filled with seas and lakes and rivers had carved channel-systems. Though in the present the surface dry and cold, the pressure is very low so H_2O is stable only in ice or gas form [6]. A significant amount of water had been blown off or had escaped, the remnant of the ancient water-reserve is freezed out at the poles or into the megaregolith's pores, respectively [7]. Well, it is possible that life began on the red planet in the past but after these dramatical environmental changes became extinct. Or it might survived and exists today but we are unable to find it. If this is the case, 2004 is our next time, when 3 lander (and 2 orbiter) arrive to Mars, searching for the sings of life.

An other exciting object is Europa, moon of Jupiter. Based on its drifting ice-like surface morphology and the electromagnetic measurements of Galileo spacecraft it is accepted that under the icy crust there is a water-ocean (or at least a slushy layer of H_2O). And other Galilei-moons, Ganymedes and Callisto seems to have similar inner structure as well. So the Europa Orbiter will be a notable mission, planned within 10 years [8].

Saturn's moon Titan is also an interesting target. It is the only moon with significant atmosphere, mainly composed from nitrogen and smaller amount of methane [9]. This reductive conditions are similar to the young Earth's ecology where life had began approximately 3,8 billion years ago. We will know more about this environment in 2004, when the Cassini-Huygens spacecraft will arrive to Saturn and the Huygens probe will land on Titan's surface [10]. Water can be found in the icy cores of comets as well. Sometimes they called dirty snowballs because of their material and structure. Besides the matter of comets is very ancient because they were created few after the birth of the Solar System and a comet's core did not take part in any planet-forming process. Finally, complex organic molecules have been found in the interstellar matter, signing that chemical evolution can start without solid surface. So the first steps of the path leading to life perhaps can be done in the space.

3. Meteorites from Mars

Back to Planet Mars, the most popular topic of astrobiology was the ALH84001 Martian meteorite in the past five years. Since 1996, when researchers announced that they found sings of ancient, primitive, microbiological Martian life in a meteorite here on Earth, intensive research has started and arguments has arisen for and against it as well [11]. But the final word will be said not earlier than 2004, after the arrival of the mentioned spacecrafts to Planet Mars.

(An interesting relation of this discovery is with panspermia-theory. Its essence that life, for example in the form of bacterium-spores, can travel between planets, so bring life from one to an other. So the findings in ALH84001 can be the evidence of this theory which have important influence on the origin of terrestrial and/or Martian life [12].)

Part II. – Bio

1. The champions of bearing: extremophile organisms

The other parts of recent breakthroughs in astrobiology come not from space but from the Earth itself. Terrestrial life namely proves more persistent, flexible and adaptable than previously thought. Places that were considered unbearable for life some years ago recently known as home of a diverse ecosystem – mainly primitive, bacterial life forms. The organisms, that prefer the extreme ecological conditions of these niches called extremophiles. These life forms can be found in thermal springs, hydrothermal vents and black smokers, in the water of isolated lakes under polar ice sheets, in the frozen soils of permafrost terrains, in chemically special places and – most surprisingly – they flourish in rocks as well, deep below the surface.

However some extremophile species have known for more then 50 years, the list of them longer and longer from year to year. Their research intensified for more reason: by analyzing their biochemistry and genetics we can get closer the understanding of formation and early evolution of life; their special enzymes ("extremozymes") have more and more significant scientific and industrial applications [13]; and terrestrial extremophile-analogies can help to understand the possible extreme ecosystems of other planets or moons.

Most of the extremophiles are bacteria (eubacteria and archaea-bacteria as well) but in some extreme ecosystems eukaryotes also can be found. The base of their classification is the environmental factor that is tolerated extremely.

– *Thermophiles and hyperthermophiles:* the best known group and probably the most important in the understanding of life. Mainly prokaryotes that tolerate temperatures higher than 45°C (if this is higher than 80°C, the organism is hyperthermophile). However the first hyperthermophile was an archaea-bacteria (Sulfolobus acidocaldarius). After 1970 a lot of other species was found near to black smokers, so today approximately 50 hyperthermophiles are known. The record is 121°C (Pyrodictium occultum) and the upper limit of tolerable temperature-range is uncertain yet, but 150°C is the estimated value.

– *Psychrofiles:* they can live in the polar ice layers, in glacier-ice and in permafrost soils also.

– *Acidophiles:* pH-tolerance between value 5 and 2, lot of them are hyperthermophiles as well and lives in black smokers. The most ancient genome sequences are from these organisms indicating that the first terrestrial organisms were acidophiles-hyperthermophiles.

– *Alkaliphiles:* life functions above 9 pH value, general in soda-lakes. Together with the acidophiles their way of life is not to let acids and alkalis into their cells.

– *Halophiles:* these species are identified from salt lakes, salt mines and salt crystals (some of these are 250 million years old). The salt concentration of their cytoplasm is extreme high so the outer salt can not enter.

2. Extremophiles and evolution

The research of extremophiles has important evolution aspects, because there are a lot of archaea-bacterium among them. Traditionally, living organisms can be divided into two domain: bacteria and eukaryotes. Though at the beginning of 1980's this theory started to change, based on the comparative sequence analysis of 16S rRNS (one of the most conservative molecular structure of living organisms). It turned out, that the separation of archaea-bacteria is reasonable at the highest taxonomy level so that these organisms belong into a separate domain. Furthermore, the result of genome sequencing examinations indicate that some genes of archaea-bacteria can be found only in eukaryotes and most of their genes are unique [14].

According to the newest theories eubacteria and archaea-bacteria originate from a common ancestor, eukaryotes in turn developed from archaea-bacteria [15]. So archaea-bacteria probably the closest living fossils of this ancestor (called LUCA from words Last Universal Common Ancestor). LUCA was the first organism after the ribo organisms of RNA world in which proteins and DNA had the same function as recent. So by analyzing an archaea-bacteria we can deduce for the surface conditions of the very young Earth – as it was about 4 billion years ago.

The diverse extremophile ecosystems discovered deep in the crust foreshadow that our traditional theory about LUCA is not correct: it was not born in a warm pond on the surface, rather originate from below the surface. From hot volcanic vents, where it was able to live by using sulphur, iron, hydrogen and carbon. The genetical evidences confirm it: the thermophiles seem to be the nearest relatives of LUCA [16].

The Synthesis: Based all the above mentioned things, by detailed examination of terrestrial extremophiles we can choose the objects in Solar System on which it is hopeful to search for signs of life. Besides they can help to determine the essential features of life (morphological, geochemical and biological) that general enough and can be detected with absolute certainty. So they can help very much to construct appropriate instruments for these purposes and for finding life out of the Earth.

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