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The Life Supporting Zone I – From Classic to Exotic Life

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Abstract

When we elaborate on questions related to astrobiology, the habitability of planets or the existence of extraterrestrial life, our considerations are often restricted to water and definitions and hypotheses for life as it is known from Earth. This fact is also reflected by the concept of the habitable zone [2], which is based on water as solvent for a potential non-terrestrial biochemistry. In general, water and the chemical basic structure C=O, even though they are the only primary characteristics of life we know at present, principally may not be the only possible ingredients. As outlined in [1, 3], other liquids cannot not be ruled out to serve as solvents for an extraterrestrial biochemistry and/or metabolism and thus, the characteristics of terrestrial life have not to be the only possible ones. Generalizing the concept of habitable zones for water and consequently for classic life will result in more extended life supporting zones for different possible solvents. Miller-Urey experiments can contribute to the solution of the question which solvents and which chemical basic structures could be possible for the existence of extraterrestrial biochemistry.

1. Classic life

More than 200 different definitions of life can be found in literature (only in natural sciences). Nevertheless, up to now there is no internationally accepted definition. In general, but especially for the search for life and for the agendas of astrobiological research projects such a definition would be necessary, because only with a widely accepted definition, the outcome of search programmes in planetary habitats or of laboratory studies can be verified exactly. In [8] the whole spectrum of life definitions is classified into three different categories: (1) life is defined by terms, which are not exactly defined for themselves, (2) combinations of characteristics of terrestrial life will be designated as a life definition, (3) gradual evolution: from simple to complex chemical reactions and further on to living systems (minimal life). In [1] a widely used working definition is given as an attempt to define life. Thereby, 5 characteristics of (terrestrial) life are listed: (1) water as solvent, (2) the ability to use energy gradients (life is in a thermodynamical non-equilibrium with its environment), (3) life on Earth consists of different molecules, which can experience various transformations (a metabolism), (4) the molecules, which are used by terrestrial life for the maintenance of the metabolism, for the creation of structures, for energy balance, for transfer of information and for the control of the chemical reactions are a consequence of the chemical characteristics of C, H, N, O, P and S and (5) a system, which allows for evolution (not only reproduction), but also: de-selection of non-optimally suited organisms, adaption to changing environmental conditions and interaction with other organisms. Using these 5 characteristics as general markers for life restricts us only to life as we know it from Earth and underlies a geocentric way of thinking and doing science in questions related to astrobiology.

2. Exotic life

The underlying concept of exotic life is the assumption that (classical) life on Earth is an accommodation to the physical conditions on (early) Earth. Exotic life declines that the specific characteristics of terrestrial life are a universal concept and interprets life in a wider context. Based on the given working hypothesis, a similar construct can be set up for exotic life by generalizing some arguments of the above hypothesis. Not only water should be considered as potential solvent for an extraterrestrial biochemistry, different composites with water (e.g. water-ammonia), but also solvents as different hydrocarbons (methane, ethane, etc.) or sulphuric acid cannot be ruled out. In some cases chemical basis structures with carbon could be possible, in some other cases, basical structures not based on carbon have also to be taken into account.

3. On the origin of exotic life

For the life on Earth different scenarios and theories will exist for its origin, but besides the theory of Wächtershäuser and the transport of (at least some) ingredients for life from outside - the theory of panspermia, the Miller-Urey theory for the origin of life ([4]) is widely accepted. A lot of different experiments based on the idea of Miller have been performed in the last 50 years but the main result remains the same. In [7] a review of modern Miller-Urey experiments is given and summarizing it can be stated that independent of the energy source (electric discharges, shock waves, thermal energy, UV-light, electron irradiation, etc.) as well as of different amounts of CH_4, NH_3, H_2O, H_2, CO, CO_2, H_2S or C_2C_6, simple amino acids have been formed. But nevertheless, the common denominator of all these experiments was water as the solvent. Moreover, simulations of the origin of life in a Titan environment resulted in saturated and unsaturated nitriles as well as oxygenated compounds, which can be the basis for organic compounds as amino acids [6]. Thus, when using water as solvent it seems that amino acids (or predecessor molecules) will result in spite of different early-Earth atmospheric composition assumptions. Performing Miller-Urey experiments not only for water as solvent, but also for other polar and apolar solvents and different atmospheres and not only in context of early-Earth, but also for exoplanets and hypothetical exoplanet-scenarios these could offer new possibilities for the origin of exotic life.

4. The life supporting zone

The results obtained by Miller-Urey experiments for alternative solvents can be used to define the solvents of interest and the borders of the life supporting zone more in detail. The primary concept of the life supporting zone is a radiative convective model including cloud droplet formation and growth which allows the calculation of the surface temperature of different planets and for different spectral classes of interest. It is given in detail in [5].

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