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THE ORIGIN OF LIFE: ATMOSPHERIC HYPOTHESIS

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ABSTRACT

An original hypothesis of the origin of life in an atmosphere of ancient Earth is proposed. It is shown that the atmospheric conditions of ancient Earth had been beneficial not only for initial abiogenic synthesis of organic monomers, but also for their polymerization and decomposition of protobiopolymers. Protobionts are particles of water aerosol the size of 1–10 microns. The proposed hypothesis can tie together all relevant facts on the early Earth's history, antiquity and ecology features of methanogenic Achaea, the small size of prokaryotes, the discovery of fossilized prokaryotes in meteorites and others. The hypothesis provides an opportunity to consider the evolution of all principal components of the cell in a continuous relationship with each other and with the environment, from the earliest stages of the origin of life. According to the proposed hypothesis, the origin of life can be considered in conjunction with the development of formation of biogeochemical cycles as a natural process, which is an integral part of the birth of planets.

Keywords: Origin of life, non-equilibrium, chirality, ancient Earth, atmosphere, protobionts, Venus.

In the first third of the 20th century, independently of each other, Aleksander I. Oparin and John B. S. Haldane proposed the idea of the origin of living organisms from inanimate nature. In the 1920s–1930s it was possible to show that in the reactions of formaldehyde with cyanide, amino acids can be formed, which then condense to form oligo- and polypeptides.[1] Subsequently, these works were successfully continued.[2]

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[1] Серебровская К. Б., Сущность жизни. История поиска, [The essence of Life. A History of Search], Moscow 1994.

[2] J. Oró*, Stages and Mechanisms of Prebiological Organic Synthesis*, in: The Origin of Prebiological Systems and of Their Molecular Matrices, S. W. Fox (ed.), Academic Press, New York 1965, pp. 137–162; M. G. Rutten, *The Origin of Life by Natural Causes*, Elsevier, Amsterdam 1971.

In experiments, coacervates were formed (Oparin, 1966), but there are well-founded doubts that they are real cell precursors (Bernal, 1969). Although their formation occurs under non-equilibrium conditions, they themselves are equilibrium systems and in this way differ radically from living cells that are in a state of stable non-equilibrium, constant exchange of matter and energy with the environment—this became most clearly clear after Ilya Prigogine created a non-equilibrium thermodynamics and the emergence of the term "dissipative structures" (Tchaikovsky, 2006).

In addition to metabolism, cell imbalance is characterized by two major asymmetries in the distribution of substances between cells and the extracellular environment. We are talking about the distribution of alkali and alkaline earth metal ions and the so-called chiral purity of biological systems (Yakovenko et al., 2007).

In the cytoplasm of living cells, the concentration of potassium ions is 10–30 times higher than the concentration of sodium ions, and in the environment (sea water or intercellular fluid), the ratio of the concentrations of these ions is reversed. Based on this fact, many researchers reject the possibility of the origin of life in the ocean (Natochin, 2009).

The second aspect is that only L-amino acids are used in cells for ribosomal protein synthesis, while only D-sugars are included in nucleic acids (Avetisov, Gol'danskii, 1996). Although enantiomers of amino acids and sugars of a different chirality are found in cells, they are not found in proteins, DNA, and RNA (Yakovenko et al., 2007). The homochirality of proteins and nucleic acids determines the stability of their structures, which ensure the performance of specific functions: for heterochiral molecules, matrix synthesis is impossible, which is one of the main features of living systems (Tverdislov et al., 2007).

In addition to the inexplicability of the occurrence of ionic and chiral asymmetries during abiogenesis, there is another difficulty: the abiogenic synthesis of organic substances-monomers occurs at temperatures above the boiling point of water, and their polymerization occurs at much lower temperatures. In other words, it was not possible to describe abiogenesis within the framework of a single process, because for this it was necessary to explain how the components of the "primary broth" synthesized in a hot atmosphere are separated into mirror isomers and even form increased concentrations of them at much lower temperatures on the same Earth. None of the hypotheses put forward gave a satisfactory explanation—their detailed criticism was published in 1983 by the Romanian scientists C. Simionescu and F. Denes (1986).

The concept of the RNA World appeared around the same time and was an extreme expression of the reductionist approach in the study of biopoiesis (Zavarzin, 2006). RNA is the only molecule that combines some of the working functions of proteins and is capable of self-replication, on the basis of which it was placed at the basis of the process of the origin of life. However, the problem of transition from the ancient world of RNA to the modern protein-synthesizing world turned out to be very difficult even for a purely theoretical solution (Spirin, 2001). Several hypotheses of the origin of the modern mechanism of protein biosynthesis in the RNA world have been proposed in the literature, but, according to one of the leading developers of the concept of the RNA world, A. S. Spirin (2001), none of them can be considered as elaborate and perfect in terms of physicochemical capabilities. Moreover, Spirin (2007) published a paper in which several paradoxes were formulated that cast doubt on the very expediency of further development of the concept of the RNA world.

The fact that it is impossible to imagine the conditions for the origin of life on the surface of the Earth has led to a significant revision of their views by many researchers. Even more than 30 years ago, the Nobel laureate F. Crick wrote a book in which he tried to scientifically substantiate the hypothesis of panspermia—the spread of life through space (Crick, 2002). This alone perfectly characterizes the depth of disappointment in such a promising and very serious confirmation of the Oparin-Haldane hypothesis at the beginning of development. The concept of the RNA world is now experiencing the same serious crisis—one of the last articles by A. S. Spirin on the RNA world ends with a reference to the theory of panspermia (Spirin, 2010).

However, between space and the surface of the Earth there is another medium—the atmosphere. Until now, the possibility of the origin of life in the atmosphere of the ancient Earth has not been considered.

Meanwhile, in the lower layer of the atmosphere, the troposphere, both pressure and temperature decrease with height. It is the upper boundary of the troposphere that can be considered the upper boundary of the distribution of water in the Earth's atmosphere (Budyko, 1977).

The existing ideas about the atmosphere and lithosphere of the Earth in the Catarchean (more than 4.0 billion years ago) are based on very few reliable facts:

1. The age of the most ancient rocks of the continental crust is about 3.85 billion years (Myers, 2001). Only Australian zircons are older (Mojzsis et al., 2001; Cavosie et al., 2005), but most of them contain diamonds, which indicate an impact (meteorite) origin (Dobretsov, 2009).

2. The oldest reliable evidence for the presence of liquid water on the Earth's surface is of the same age (Nutman et al., 1997; Peck et al., 2001).

3. The oldest carbonate rocks with a biogenic C12/C13 carbon isotope ratio (Isua Formation) also date back to about 3.8 billion years ago (Schidlowski, 2001), while the first stromatolites are dated later (Rozanov, 2003; Zavarzin, 2004).

4. Up to 3.9 billion years ago massive meteorite bombardment continued (Valley et al., 2000).

Based on the main fact—the presence of traces of life in the oldest known rocks, most researchers, considering that hundreds of millions of years are needed for biopoiesis, agree with the opinion that the Earth was cold for most of its initial period of existence, and its condensation from a protoplanetary cloud (accretion) occurred in a relatively short time—about 100 million years (Sorokhtin, Ushakov, 2002). However, there is no other evidence for this—there are no rocks older than 4 billion years on Earth, except for a few grains of zircons (Galimov, 2006), therefore, there are other views on the early history of the Earth, which allow the presence of a dense hot atmosphere on it (Ozima, 1990; Rezanov, 2006). There is also no strong evidence that the meteorite bombardment, the end time of which is traced from the overlaps of impact craters on the Moon, is not the final stage of the Earth's accretion and, in fact, has not been continuous all the time since the beginning of the planet's formation (Valley et al., 2000). The paucity and incompleteness of data on the early stages of the Earth's history makes it possible to doubt even such a seemingly generally recognized fact as the reducing nature of the Early Archean atmosphere (Rozanov, 2003; Rozanov, 2009b).

However, if life could not have occurred on the surface of the Earth, which is the opinion supported by many authors (Mashansky, Drozdov, 1988; Crick, 2002; Spirin, 2007; Rozanov, 2009b; Zavarzin, 2010; and many others), then there is no need to imagine conditions on its surface are close to modern.

And then we have the right to assume that in the early stages of its history (up to 3.85 billion years ago):

1. The earth was melted;
2. The formation of the Earth, as a planet, from dispersed matter was completed about 3.9 billion years ago;
3. Water has always been present in the Earth's atmosphere (its dissipation from the upper layers was continuously compensated by the degassing of its interior, the gravitational differentiation of which began immediately after the beginning of the formation of the Earth).

In the troposphere of the ancient hot Earth, three layers can be conventionally distinguished (without detailing, since the Earth cooled over time, both the thickness of the layers and the position of the boundaries changed accordingly), (Fig. 1).

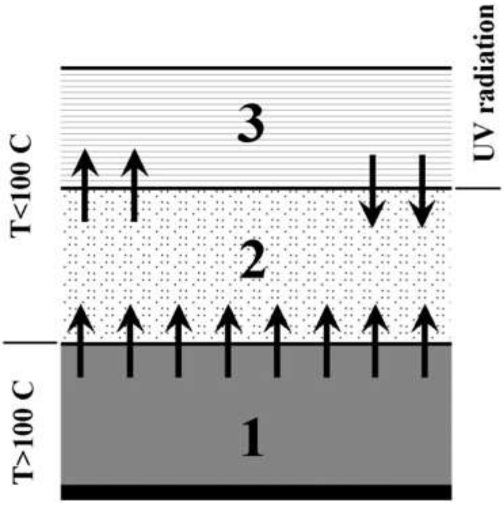

Fig. 1. The Earth's troposphere more than 4.0 billion years ago. (1—abiogenic synthesis of amino acids and other monomers; 2—formation of protobiopolymers and the possibility of the origin of life; 3—decay of biopolymers under the influence of ultraviolet radiation).

In the lowest layer there are conditions for abiogenic synthesis of amino acids and other substances necessary for biopoiesis. In the middle and upper layers there are suitable conditions for the polymerization of amino acids, i.e.—for the formation of protoproteins. However, in the uppermost layer, under the influence of ultraviolet radiation, protobiopolymers should have decomposed, with the return of decay products—amino acids and other monomers to the lower layers, covered from ultraviolet radiation by water contained in the upper layer.

Water aerosol particles 1–10 µm in size are put forward for the role of first protobiont cells. It was found that these particles are the longest-lived water components of the Earth's atmosphere and their lifetime even in the modern atmosphere can reach 3 years (Yakovenko, Tverdislov, 2003). Accordingly, in the denser atmosphere of the ancient hot Earth, their existence was much longer. Phospholipids or other amphiphilic molecules are easily sorbed on the surface of such particles, preventing the drop from drying out in dry air, thus forming a single-layer lipid membrane.[3] When studying the properties of the surface microlayer of water, it was found that under nonequilibrium conditions it is enriched in the L-enantiomer of amino acids compared to its D-enantiomer (Tverdislov et al., 2007). Consequently, conditions were created in aqueous aerosol particles for the preferential synthe-

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[3] Accordingly, the protobionts acquired the second layer of membranes during the transition from the atmospheric to the aquatic lifestyle, which is probably the reason for the huge differences in the structure of the plasma membrane between Archaebacteria and all other living cells. In the archaeal plasmalemma, the hydrophobic parts of phytanol tetraesters are bound and, therefore, the membrane is actually a monolayer (Kusakin, Drozdov, 1997).

sis of homochiral polypeptides, which is a prerequisite for mirror symmetry breaking.[4]

The proposed hypothesis satisfactorily explains all the basic information on the early history of the Earth listed above. With this approach, there is no longer any dissonance between the above data and the time of separation of prokaryotes into eubacteria and archaebacteria, calculated by the molecular clock method using the most conservative cell molecule, 16S ribosomal RNA. According to calculations, the separation of archaebacteria from the main stem occurred 4 billion years ago. (Кусакин, Дроздов 1994), when there was and could not be water on the surface of the Earth—and this dating now allows one to doubt the very methodology of the "molecular clock."

The proposed hypothesis explains, furthermore, why the most ancient organisms on Earth (according to 16S rRNA analysis) are extremely thermophilic methanogenic archaebacteria that live in the thickness of porous rocks at temperatures of 90–110^0 C and use hydrogen, which appears during the thermal decomposition of water (and a little more a young group of extreme halophiles living in hypersaline lakes) (Заварзин, Колотилова 2001). The Earth's troposphere is still slightly flattened from the poles (Будыко 1977), and when the temperature of the Earth's atmosphere began to decrease, the polar regions were the first to cool (Fig. 2). It was there that the formation of the continental crust took place 3.85 billion years ago. and it was there that the ancestors of archaebacteria had to adapt to living in extreme conditions. On the young continental crust of the cooling Earth, the first water bodies were either hot or hypersaline.

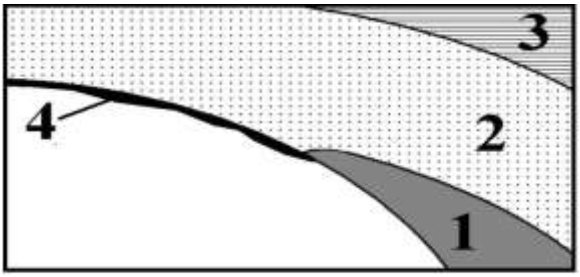

Fig. 2. The Earth's troposphere about 3.8 billion years ago. (1-3 – as in Fig. 1; 4—young continental crust).

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[4] Some organic macromolecules were synthesized on mineral matrices—the considered atmosphere at an early stage of formation of both the Earth (4.5–3.9 billion years ago) and other planets included a large amount of matter in the solid phase—meteorite fragments colliding with the Earth's surface and with each other, as well as cosmic dust, the concentration of which in the young solar system was higher than in the modern one. Considering this, it is easy to find an explanation for the discovery of mineralized remains of bacteria and lower fungi in meteorites (Rozanov, 1996; Rozanov, 2009a).

The proposed hypothesis easily fits into the explanation of the ultra-small size of prokaryotes, which is their very conservative feature that has not undergone any visible changes for more than 3 billion years (Zavarzin, Kolotilova, 2001; Rozanov, 2006). Assuming that hypercycles (Eigen, 1973) or other prebiological autocatalytic systems were initially launched in a certain reservoir, we are forced to assume that in this case the entire reservoir was a protocell[5], since due to the diffuse movement of water molecules, any chemical reaction inevitably spreads to the entire volume of water, in which it happens. But, admitting this, we are faced with the impossibility of explaining the evolutionary leap that could lead to the formation of a prokaryotic cell with a size of 0.5-4 microns from such a macroscopic protoorganism.

The main advantage of the hypothesis is the ability to abandon attempts to explain the whole through a part and consider the origin and evolution of all the main components of the cell in a continuous relationship with each other and with the environment, starting from the earliest stages of biopoiesis. We do not know life outside the cell,[6] even the most simply arranged prokaryotic cell is a complex system, the properties of which are not a simple sum of the properties of its components (Zavarzin, 2004), and an ordinary drop of water, located in non-equilibrium conditions of the Earth's primary atmosphere, is already a system, having much more in common with a cell than the most complex biological macromolecule.

On the other hand, the proposed hypothesis makes it possible to eliminate the element of chance in abiogenesis, not to reduce the beginning of evolution to the emergence of a single instance of a hypothetical “universal common ancestor,” but to consider the emergence of life in conjunction with the formation of the main geochemical cycles; as a natural process, which is an integral part of the birth of planets, which fully corresponds to the views on the origin of life as V. I. Vernadsky (Kaznacheev, 1985) and other supporters of the systemic approach (Rezanov, 2001; Zavarzin, 2007).

The proposed hypothesis can be confirmed in studies of Venus. The upper atmosphere of Venus, although in small amounts, contains SO_2 and H_2S (Moroz, 1971; Zasova et al., 2007), meanwhile, in the absence of a constant source of these gases (which should be of a biogenic nature), given that the atmosphere of Venus is very well mixed, they should have reacted and disappeared long ago. There are other signs of life in the atmosphere of Venus (Cockell, 1999). Meanwhile, there are no facts indicating that there was ever liquid water on the surface of Venus. There are no forms of river relief on its

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[5] Such an opinion, for example, was expressed by Yu. V. Tchaikovsky (2006).

[6] Viruses and viroids outside the cell do not participate in any reactions and, on this basis, should be considered intracellular parasites (Zavarzin, 2006), which have lost all structures and functions, except for reproduction, which is one of the main directions of the morphological evolution of highly specialized parasites (Schmalhausen, 1983).

surface, for example, mined-out river valleys (Basilevsky, Head, 2003), in contrast to Mars, which has such a relief (Ksanfomality, 2009); banded magnetization, which is characteristic of the oceanic crust of the Earth and is present in low-lying areas of the Martian surface, has not been detected either (Connerney et al., 1999). Consequently, life on Venus must have retained features inherent in the earliest (atmospheric) period of evolution.

Thus, the hypothesis can be confirmed if aerobionts are found in the upper atmosphere of Venus, which, unlike terrestrial bacteria found in the atmosphere, will live not in floating water drops, but in the air. And, accordingly, the plasma membrane of Venusian aerobionts will have to have a structure closer to a monolayer lipid membrane, the outer surface of which will have hydrophobic properties, than to the bilayer membrane of most living cells.

If such life forms are discovered in the atmosphere of Venus, it can be considered proven that life did not occur in the ocean, but together with the ocean, originating at the earliest stages of the formation of the planet, when its atmosphere, hydrosphere and lithosphere were still a single whole.

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