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THE ORIGIN OF LIFE PROBLEM THE S- SPACE SELFORGANIZATION

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The relevance of the topic, goal, and objectives of the research is substantiated, the purpose of the article is formulated, and a review of recent research and publications is made.

The main part presents the characteristics of the research apparatus (the wave model of S-space, the theory of self-organization of S-space and open complex systems), as well as the results of checking the compliance of the apparatus with the conditions of emergence and signs of life (formulated by the authors on the basis of the data given in the review). The check showed that the device corresponds to the object of study.

Next, a definition of life is given that corresponds to its systemic understanding within the framework of the theory of self-organization. Its advantage, in comparison with the known definitions, is its invariance with respect to the conditions existing on the Ancient Earth, as well as the characteristics of earthly life, which makes it possible to study the problem of the origin of life without reference to earthly conditions. In turn, by specifying specific conditions and features as calibrations, the definition can be adapted to solve specific problems.

This approach allows, based on known data, to formulate a hypothesis about the biocrystalline nature of the first terrestrial living organisms and intermediate forms, their "two-dimensionality", as well as places of origin, to explain a number of properties of living organisms, in particular, the emergence of heredity, and also to explain the complication and adaptability reactions of abiogenic synthesis at a time when natural selection did not yet exist, resulting from the theory of self-organization of S-space by the general laws of self-organization of open complex systems in a dissipative environment. The mechanism of natural selection can also be considered as one of the possible calibrations of the general scenario of self-organization realized under terrestrial conditions.

A comparison of this hypothesis with modern ideas about the "Last Universal Common Ancestor" (LUCA) shows their significant similarity.

The conclusions evaluate the theoretical and practical significance of the obtained results.

Keywords: origin of life, S *-space, theory of self-organization, biocrystals.*

Problem statement. The problem of the origin of life is one of the most important in modern science. The problem is clearly multidisciplinary and systemic in nature; it includes philosophical, natural science, practical and other aspects. Accordingly, there are a large number of theories and hypotheses, but the problem itself is far from a satisfactory solution.

Some of the most important unresolved issues include:

- determination of the essence, characteristics, conditions and place of appearance of living organisms;
- determination of the driving forces of complication of inorganic matter into living forms, while natural selection has not yet taken place;
- what the intermediate forms were and what the last common ancestor of all living things could have been;
- origin of the mechanism of inheritance.

Progress in solving these issues depends, among other things, on new research methods based on a systematic understanding of the nature of the problem of the origin of life.

The apparatus used here – the theory of self-organization of S-space – is based precisely on such ideas.

Recent research and publications analysis are divided into several groups.

The first group includes publications related to the justification, verification and application of the wave model and the theory of self-organization of S-space, as well as complex open systems.

The authors propose to use the theory of complex systems self-organization based on the axiomatic wave model of S-space. Its advantage is the ability to model open complex systems consisting of heterogeneous components, which is consistent with both human nature and the nature of the data used. This theory was used to model human consciousness and behavior in various historical eras, as well as to solve applied problems in the field of modeling, evolution, optimization open complex systems of various nature, including its life cycle [1].

The second group includes publications devoted to determining the conditions for the emergence of life. They will be used to test the applicability of the apparatus for studying the problem of the origin of life.

The chemical composition of cells, the structure of proteins, lipids and carbohydrates, sugars and amino acids, as well as other vital substances, are well known [2]. Reactions leading to their synthesis are also known, but under laboratory conditions. Therefore, it is necessary to check how these reactions

and laboratory conditions correspond to the situation on Ancient Earth.

The age of the Universe is 13.799 ± 0.021 billion years [3]. The Solar system formed about 4.57 billion years ago; the age of the Earth is 4.54 billion years [4] or, according to the International Stratigraphic Commission, 4.6 billion years. The first living beings appeared on Earth 3.7 billion years ago [5]; according to other sources, 4.1 billion years ago [6].

A vast literature is devoted to the reconstruction of the parameters characterizing the conditions on Ancient Earth. Sources use data from comparative planetology, research of objects in the Solar system by spacecraft; radioisotope dating; structure of geological rocks; paleontology, and others.

The third group includes publications that substantiate and criticize definitions of life and the origin of life theories.

The various phenomenological definitions of life based on lists of attributes [7] and the similar. The similarity is explained by the implicit "geocentricity" of ideas about living organisms – on a carbon basis, consisting of cells, etc. Interest in determining life and its signs has increased in recent decades in connection with programs for the instrumental study of the planets of the solar system. In publications, devoted to the definition of life in general or specifically the life of cells, the existing definitions of life and its signs are criticized and clarified [8].

In biochemistry, the basic idea is "carbon life", according to which carbon, oxygen, nitrogen, and hydrogen are necessary for the emergence of life. Hypotheses about the silicon basis of life, as well as about nitrogen, boron, etc. are considered less probable and they were not realized on Ancient Earth.

Cells, separated by a “complexity barrier” from inanimate nature, are interesting in that they are the simplest of known living organisms, capable of self-reproduction and largely self-sufficient. The biosynthesis of nucleic acids and proteins [9], cell energetics [10], exchange processes with the environment [11].

Publications, devoted to attempts to find an intermediate link between inanimate matter and living beings. If we take the presence of reproduction as a necessary feature of living organisms, then viruses are not alive - cells are necessary for their reproduction. On the other hand, there is a huge difference in the complexity of the organization of viruses, as well as viroids and prions, not to mention abiogenic compounds and cells. To solve this problem, the RNA world hypothesis was proposed in [12].

The RNA world, according to this hypothesis, is an intermediate stage in the emergence of life on Earth, when systems of ribonucleic acid molecules perform the function of storing genetic information and catalyzing chemical reactions. Subsequently, modern DNA-RNA-protein life arose from them, isolated from the external environment by a membrane. This problem is related to the characteristics of LUCA, the primordial ancestor of bacteria and archaea [13].

There are several hypotheses for the origin of life – the theory of the iron-

sulfur world by K. Wächtershäuser [14], the theory of the zinc world by A. Mulkidjanian [15; 16] and other.

The article's purpose is to present the results of testing the theory of self-organization of complex systems for compliance with the conditions and signs of life, to substantiate the hypothesis about the origin of life as a result of self-organization (driving forces, conditions and place of origin, the first living organisms, heredity), as well as its relationship with other modern hypotheses.

After checking the axioms, it is possible to return to the definitions of life and the problem of an intermediate link between non-living matter and living organisms. The authors give such a preliminary definition and suggest liquid crystals as such an intermediate form.

Main part.

Let us check the apparatus by comparing the available data on the conditions for the formation of life with the conditions for the formation and self-organization of S-space [1]. Based on the data from the studies listed above, let us formulate and group the conditions for the emergence of life:

1. *Homogeneity of the environment*. Life arose in that part of the Universe where there is practically no antimatter left, there is a unified physics, globally homogeneous and isotropic space. This homogeneity is also transferred to living beings – they consist of the same atoms and obey the same laws as the Universe.

2. *Differentiation of the environment*. At the same time, there is a separate substance and field, time, physical interactions, chemical compounds, and so on, interacting with each other. The diversity of such factors and their qualitative heterogeneity are the prerequisites for the complexity of life.

3. *Symmetry of the environment*. According to Noether's theorem, certain symmetries correspond to different conservation laws. Symmetry stabilizes the environment, and a certain constancy of conditions for a long time is necessary for the efficient flow of abiogenic synthesis.

4. *Asymmetry of the environment*. The property of chiral purity is very important. In the symmetrical with respect to the number of right and left connections environment, the useful functions of connections are not realized. Probably, our part of the Universe (or our entire Universe, if we accept the hypothesis of multi-worlds) would not have evolved without the separation of matter from antimatter. Further, if symmetry stabilizes the environment in whole, then asymmetry causes the transfer of various substances and the spread of fields from one area to another.

5. *The dissipativity of the environment* follows from the previous condition and is an important independent factor. Even systems of abiogenic synthesis are complex open systems, not to mention living beings. The transfer and dissipation of energy, matter, and fields create "free" resources necessary for the self-organization of complex systems, and then the existence of living organisms, which are "parasitic" on these resources.

6. *The periodicity of the states of the environment* is manifested in the change of day and night, seasons, astronomical phenomena, etc. – unfavorable

conditions for the emergence of life for some periods are replaced by favorable ones and vice versa. Both create a non-equilibrium, dynamic environment, are selection factors and initiate the creation of adaptation mechanisms.

7. *The limited values of vital parameters*. There are certain limits of temperature changes, radiation levels, concentrations of substances, and similar factors that make abiogenic synthesis based on carbon possible. The distances from the star to the planets where life is possible are limited – naturally, taking into account the characteristics of the star's radiation ("life zone"). Similarly, a limited area is allocated around underwater thermal springs, and so on. The time of existence of the "life zone" is limited - the time remaining before the explosion of a star, the fall of a large meteorite, etc. Such examples testify to the important role of boundary spaces for the manifestations of not only life but also death.

8. *The external initiating factors*. The periodic presence of favorable factors for life emergence is not enough – an external initiator is needed. Such as an electric discharge, energy, substances, and radiation of thermal sources. The role of external factors reaches its maximum in the panspermia hypothesis – whether it be the "delivery" of catalysts, genetic material, or living organisms.

9. *The possibility of self-organization as a factor of evolution*. Self-organization is a common property of complex open systems.

10. *The possibility of selection and inheritance*. Usually, these factors are already associated with living beings, however, even in abiogenic synthesis, compounds are selected according to certain “chemistry”, resistance to ultraviolet radiation, etc. The same applies to inheritance – the environment that has changed as a result of a cycle of reactions serves as the basis for the reactions of the “next generation”. The selection and inheritance of living organisms are to some extent based on the mechanisms worked out in the process of abiogenic synthesis.

The wave model abstractions implement all of this conditions [1]:

1) The homogeneity of the environment corresponds to the wave nature of S-space; when modeling within the subject or object parts of the S-space, signature homogeneity is added;

2) The differentiation of the environment corresponds to the division of the Universe and the subjective and objective parts of the S-space;

3) Symmetry of the environment. The subjective and objective parts are "skew-symmetric";

4) Asymmetry of the environment. The subject and object parts have different signatures;

5) The dissipativity of the environment also follows from the previous paragraph: different signatures create the basis for the emergence of interaction;

6) The periodicity of the states of the environment follows directly from the wave character of the S-space abstractions;

7) The limited values of vital parameters correspond to the boundary nature of the S-space. If we talk about the time of existence of waves on the

surface of the subjective and objective parts of S-space, then it is obvious that it cannot exceed the time of existence of these parts themselves;

8) The external initiating factors are expressed in the influence of external factors S and O on S-space;

9) The possibility of self-organization as a factor of evolution is expressed in the formation of differentiation of the subjective and objective parts of the S-space under the influence of the influences of S and O;

10) The possibility of selection and inheritance. The actual effects of S and O select a specific scenario of self-organization from their set; each stage of self-organization depends on the previous one, using both its potential and elements.

Now let's summarize the lists of formal signs of life.

1. *Relative homogeneity with the environment*. Homogeneity is expressed in the fact that living organisms include the same substances and fields as the environment. Separation is expressed in chirality, the existence of homeostasis and self-regulation, the instinct of self-preservation, defensive reactions, etc.

2. *Self-organization and structuring*. There is a certain internal potential for self-organization, which can be traced already at the stage of abiogenic synthesis. Its result is a complication of both the structures of the body (the formation of multicellular creatures, separate systems, organs, cells, organelles, and so on) and ecological systems. However, its actualization requires external initiation.

3. *External factors*. The biotope determines the specific composition of the biocenosis; its changes initiate the evolution of both ecosystems and individual species, whether in the form of aromorphoses, allogenesis, or degeneration. The direction of evolution depends on the number of resources and energy; with their excess, parasites, and predators appear, the number of organisms increases, etc.

4. *Symmetry and self-similarity*. Organisms have substance and field components; they are characterized by one or more symmetry groups; the anthropic principle testifies to the similarity of man and the universe, children are like parents, and so on. But symmetry is not absolute; asymmetric structures are also present in organisms. Probably, symmetry is interconnected with isolation and homeostasis, and asymmetry is related to changes and interactions with the environment. This is how the fractal basis of life is manifested, which has several mechanisms of its formation.

5. *Self-regulation and regeneration*. In living organisms, both relatively simple and complex, involving several systems, direct and feedback, methods of self-regulation are observed. Complex organic compounds and living beings are characterized by reparation and regeneration. In simple organisms, regeneration is usually more complete than in complex ones.

6. *Replication and translation, reproduction and inheritance*. The isolation of living organisms from the environment sooner or later leads to a struggle for existence and against death, for which evolution has developed

various mechanisms. The most important of them are the replication and translation of nucleic acids in cells; reproduction and inheritance of organisms, which are themselves a manifestation of self-similarity and lead to the appearance of descendants similar to parents. These mechanisms are necessary for the survival and development of individual living beings and species.

7. *Variability*. Variability is an immanent property of life, inherent in it to a much greater extent than inorganic matter (trees grow, a person grows in childhood, and he also decreases in old age, adaptation to climate and seasons occurs, biorhythms accelerate and slow down, and so on). Variability is also a natural property of a wave.

8. *Energy exchange, metabolism, endo- and exocytosis*. Compared with property 3, note the influence of external influences on the state of the internal environment of the organism. Exchanges with the environment are complex in nature, affecting different types of energy and substances, and involving different levels of the body (systems, organs, cells). They, depending on the conditions, change the state of the body. Direct and reverse links are involved.

9. *Reaction to stimuli*. A living organism reacts to external stimuli – it moves, changes internal parameters, etc. Such a reaction implies the existence, along with the bodily, also of a mental component, somehow “evaluating” the harm or benefit of the stimulus. Probably, the existence of both "symmetrical" components is due to the fundamental differentiation of the external environment at the time of the emergence of life. The set of such reactions may be simple or very complex; it is conditioned by the current state of the organism as a whole. In turn, the reactions of the organism change the ecosystem as a whole.

10. *Periodicity, nonlinearity, threshold effects, and interaction restrictions*. The frequency of interactions is associated with the rhythms of nature and biorhythms, as a result of evolutionary adaptation. Nonlinearity is determined by the nature of interactions and reactions. Threshold effects are determined by the sensitivity of receptors and limitations by the lethality of external influences. It is quite obvious that all these features are of a wave nature.

12. *Life cycle*. During childhood, everything happens as if "by itself": the size of the body increases, knowledge and skills are acquired, and mental organization becomes more complicated. In old age, the body and mind degrade. The nature of aging remains unclear, but a formal comparison of the life cycle with a wave provides a possible explanation.

13. *Death*. The finiteness of existence is the irreversible destruction of a living being as a system.

Thus, all these characteristics take place in the implementation of any of the possible self-organization scenarios. We have now all necessary to give a preliminary definition of life in terms of systems theory:

A complex system is alive if it is emergent, boundary, open, finite, and includes immanently changing components that interact nonlinearly with the

surrounding dissipative environment and with each other.

This definition is free from reference to carbon or any other basis of life, from the forms of reproduction and inheritance and from the specific conditions of the Ancient Earth; it does not contradict the lists of signs of life; it corresponds to the axioms of the wave model – and this is its advantages. The quality of emergence clearly separates a living system from additive artificial systems.

The definition is quite abstract – and this can hide both advantages (for example, when modeling viruses, prions, and ecosystems; all of them, within the framework of the definition, are alive), and disadvantages - if it is necessary to model an organism, where specific properties prevail over general ones; also, if artificial emergent systems are ever created, there will be a debate about whether they should be recognized as alive.

However, this preliminary definition can be interpreted as an "invariant" and adjusted to a specific situation, the features of which will act as "calibrations" – as was noted for the basis and variability of life processes.

But even now the definition allows us to formulate a hypothesis about the place of origin and features of intermediate forms between inanimate and living matter, and, possibly, of the first living organisms:

Intermediate forms appear on the surfaces of crystals in a liquid environment; inherit from crystals methods of self-organization and exchanges with the environment; are liquid biocrystalline systems.

Let’s present several arguments in favor of such a hypothesis.

1. The place of origin of life is debatable: we have competing hypotheses of the iron-sulfur world, zinc world, nuclear geyser system, primary pizza, primary mayonnaise, as well as panspermia. The common problem of these hypotheses is the need for the availability of substances necessary for further syntheses in the required concentrations. Crystals, that absorb substances from the environment during the formation, concentrate (“storage”) them, and give them back in the process of dissolution, are open systems and satisfy these conditions. The necessary variety of crystals can be achieved, as modern hypotheses suggest, in "black smokers" and other suitable places.

2. It is also necessary to have energy at certain points in time – the processes of crystallization and dissolution can be tied, for example, to periods of nuclear geysers, daily or seasonal changes in temperature and solution concentration; in addition, they themselves occur both with the absorption and release of energy, forming a dissipative environment.

3. Geometrically, intermediate forms are a good illustration of the S-space concept, where S-space (intermediate forms) *occupies a boundary position in a dissipative environment between S and O* (crystals and liquid).

4. *The biocrystalline nature* can be found in the biological structures of different levels of modern organisms, for example, in chloroplasts, muscle and nervous tissues, membranes, and visual receptors; it would be natural to extrapolate this characteristic to the distant past - another argument in favor of

an expanded understanding of the definition.

5. The boundary position in a dissipative medium corresponds to the *liquid-crystalline nature of the first organisms*, which combines the properties of both crystals and solutions: the influence of crystals is manifested *in self-organization and exchanges with the environment*, the influence of the solution is in the plasticity of forms and the ease of *interchanges* already between organisms that become polycrystalline. We also state the openness of living systems-organisms.

6. Phase transitions between liquid and solid crystalline states, taking into account self-organization, give rise to *the emergence* of living systems-organisms, self-similarity, and the fractality of structures of different levels. They also contribute to the preservation of structures when environmental conditions change, however, too strong changes lead to the destruction of structures (*finiteness, nonlinearity, threshold effect*).

7. Here are the origins of the origin of *the life cycle* of the first living organisms – from the appearance to the destruction of liquid crystal structures.

8. There is a known morphological similarity between crystals and some biological forms; however, this similarity is not comprehensive and can only be considered as an additional argument.

The dual nature of liquid crystals, and the presence of their periodic changes, corresponding both to periodic influences of external factors and to the immanent properties of liquid crystals, make it possible to use soliton-wave abstractions for their modeling.

Substances necessary for the existence of life are formed as a result of autocatalytic reactions of abiogenic synthesis. Thus, autocatalytic reactions are the synthesis of sugars based on the Butlerov reaction, synthesis of nitrogenous bases and ATP, synthesis of nucleosides and nucleotides [17].

The participation of catalysts for abiogenic synthesis is also necessary within the framework of the iron-sulfur world reactions and A. Mulkidjanian's zinc World. This implies the assumption that the mechanism of inheritance was originally autocatalytic: catalysts stimulated the necessary reactions, the products of which were the catalysts themselves. Gradually, *autocatalysts became more complex, acquired control functions, and "received protection" from unfavorable external factors inside organisms, gradually turning into the bases of heredity TNK, RNA and DNA that we know today*.

Why did the chemical foundations of life become more complex at a time when natural selection did not yet exist?

The reason for the complication is self-organization as a general property of both abstract S-space and specific complex systems in a dissipative external environment [1]. This is also an invariant; calibrations that implement the principle of self-organization are sets of various chemical reactions, such as those mentioned above. Note that self-organization occurring in a limited region of the Universe does not violate the second law of thermodynamics, since outside this region "chaos" continues to increase.

Finally, let us consider whether there is a correspondence between the idea of intermediate forms (or the first organisms) as “two-dimensional” membrane formations on crystal surfaces with the modern understanding of the “common ancestor” – the above-mentioned LUCA.

Based on modern reconstructions [11] performed by methods of comparative genomics, it is believed that the common ancestor had more than 1200 gene families, which corresponds to modern bacteria. This set included genes for metabolic pathways that are not now present together in the same cell. Therefore, the common ancestor could constitute an entire ecosystem with closed geochemical cycles. The LUCA genome consisted of at least a million base pairs (for comparison: in modern viruses, RNA genomes do not exceed 30 thousand base pairs, while DNA genomes reach 1.2 million).

However, this genome size is insufficient to encode all LUCA proteins. To resolve this contradiction, as well as to explain the presence of duplicate biochemical pathways in one organism, ideas have been put forward regarding the non-cellular nature of the common ancestor. E. Kunin [18] presents LUCA as a community of replicating RNA and DNA molecules that lived on the surface of minerals but had lipid membranes. It is possible that the membranes covered flat accumulations of proteins and nucleic acids on the surface of the mineral, preventing them from dissolving in water, and also limited free-floating bubbles – the first "community organisms" similar to cells. Horizontal gene transfer unified these replicators enough that they could not evolve as separate species.

Thus, the “two-dimensional” biocrystalline membrane on the surface of crystals in an aqueous environment do not contradict and corresponds to the signs of LUCA in the understanding of E. Kunin – and this circumstance allows us to extend the definition of intermediate forms to the first living organisms.

Conclusion. It is shown that the concept and theory of S-space self-organization and the theory of open complex systems self-organization, constructed on their basis, correspond to both the known conditions for the emergence of life and properties of living organisms.

Considering S-space and self-organization scenarios as invariants, and specific conditions and properties as calibrations, we get the opportunity to give a definition of life, free from restrictions by the conditions of the Ancient Earth.

The formulated and substantiated hypothesis about the biocrystalline nature of intermediate forms and the first living organisms opens up, on the one hand, the possibility of searching for life on a biochemical basis other than for terrestrial life, and, on the other hand, limits the search sites to the conditions of existence of S-spaces at the boundaries of environments on Earth, planets, in outer space.

Self-organization, as an immanent property of S-space and dissipative open systems, explains the fact of the complication of chemical compounds in the course of abiogenic synthesis in the absence of natural selection.

Consideration of autocatalysts as predecessors of currently existing

carriers of hereditary information allows us to understand the nature of heredity, excluding connection to the characteristics of the Ancient Earth.

Modern ideas about the LUCA, obtained on the basis of biochemical and molecular genetic data, do not contradict the hypothesis put forward.

Further research can be developed both experimentally and theoretically; in the latter case, their subject should be the evolutionary process as such.

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ПРОБЛЕМА ПОХОДЖЕННЯ ЖИТТЯ І САМООРГАНІЗАЦІЯ С- ПРОСТОРУ

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В роботі обґрунтовано актуальність теми, цілі і задачі дослідження, сформульовано мету, зроблено огляд попередніх публікацій.

В основній частині представлені характеристики апарату дослідження (хвильова модель С-простору, теорія самоорганізації С-простору та відкритих складних систем), а також результати перевірки відповідності апарату умовам виникнення та ознак життя (сформульовані авторами на основі наведених в огляді даних). Перевірка показала, що апарат відповідає об'єкту дослідження.

Дано визначення життя, яке відповідає його системному розумінню в рамках теорії самоорганізації. Його перевагою, порівняно з відомими визначеннями, є інваріантність стосовно умов на Стародавній Землі, а також особливостей земного життя, що дозволяє досліджувати походження життя без прив'язки до земних умов. У свою чергу, задаючи конкретні умови та особливості як калібрування, можна адаптувати

визначення для вирішення конкретних завдань.

Такий підхід дозволяє, спираючись на відомі дані, сформулювати гіпотезу про біокристалічну природу перших живих організмів і проміжних форм, їх «двовимірність», а також місця виникнення, пояснити ряд властивостей живих організмів, зокрема виникнення спадковості, а також ускладнення та адаптивність реакцій абіогенного синтезу в той час, коли не існувало природного відбор,у загальними закономірностями самоорганізації відкритих складних систем у дисипативному середовищі, що випливають з теорії самоорганізації С-простору. Механізм природного відбору також можна розглядати як одне з можливих калібрувань загального сценарію самоорганізації, що реалізується в земних умовах.

Зіставлення цієї гіпотези з сучасними уявленнями про «останнього спільного предка» (LUCA) показують їх значну схожість.

У висновках оцінено теоретична та практична значимість отриманих результатів.

Ключові слова: походження життя, С- простір, теорія самоорганізації, біокристали.

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