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THE PROTOBIOLOGICAL THEORY OF CEILINGS AND FLOORS, OR CHEMICAL EVOLUTION AS A PLANETARY PROCESS

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ABSTRACT

The article presents a modern protobiological theory based on the classical archetype. It connects the issues of origins of life with the theory of the hierarchy of matter and recognizes that error correction occurs within hierarchical and dynamic living systems. The paper briefly reproduces Morowitz-Smith prebiotic scenario. It highlights the importance of rTCA for theory, and the observation that the transition from a planet "without life" to a planet "with life" is a thermodynamic problem. Reflections on the philosophical foundations and worldview consequences of the theory are presented. The book and articles by the authors are crafted in a holistic approach and are critical towards the premature (and excessive) extrapolation of Darwinian selection as a means of explaining the process of abiogenesis.

Keywords: Origins of Life, chemical evolution, phase transitions.

Since the times of Aleksandr Oparin and J. B. S. Haldane, recognized as pioneers of protobiology, many other theoretical approaches to the Origins of Life issue have been developed. The theory of David Eric Smith[1] and Harold Joseph Morowitz,[2] presented primarily in *The Origin and Nature of Life on Earth: the Emergence of the Fourth Geosphere (ONLE)* stands out from the others.

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[1] David Eric Smith is an associate professor at the Santa Fe Institute, a professor at George Mason University (at the time he co-wrote the book discussed in this article), and principal investigator at the Earth-Life Science Institute (ELSI), Tokyo Institute of Technology. He is a physicist specializing in the origin of life, non-equilibrium systems, economics, and the evolution of human languages. Smith as a statistical mathematician and physicist rejects the engineering (imprecise, oversimplified) approach to the problem of the emergence of life.

[2] Harold Joseph Morowitz was a biophysicist and professor of biology and natural philosophy at George Mason University. From 1993, Morowitz headed the Krasnow Institute for Advanced Study. Morowitz has been closely associated with the Santa Fe Institute since 1987. The origin of life has been his main research area for over fifty years. He died in 2016.

The book is a unique example of cooperation between people representing different generations of scientists. Although originally addressed to naturalists, it has philosophical layer which turned out to be transparent and rich in meaning. *ONLE* is a testimony to the ability of different minds to compromise in providing building blocks both for the purposes of a dynamically developing research field and of Weltanschauung as well. Being theoretically meticulous in Origins of Life studies seems to be walking the difficult path (especially in psychological dimension). For a scientist to avoid being ridiculous in fastidiousness, one must know what exactly he expects from a theory of Origins of Life.

The authors of *ONLE* believed that the main part of their work is a collection of "empirical generalizations and functional knowledge about the properties of life and its planetary context" (Smith, Morowitz, 2016, p. 12), which resembles the style of Vernadsky's writings. Smith and Morowitz worked together for many years, sharing a belief (different from that of Jacques Monod[3]) that the emergence of life is not the result of an isolated event of a random nature. The works of scholars such as Wolfgang Pauli, Linus Pauling and Carl Woese, but also Steven Weinberg,[4] set the worldview of *ONLE-2016*. The authors were also inspired by Kalervo Rankama's and Thure G. Sahama's *Geochemistry* (1950).[5] Smith and Morowitz developed their theory to be consistent with the hierarchical theory of matter. The theory of matter is necessary to understand how and why phase transitions[6] could lead to the emergence of life from inanimate matter (Smith, Morowitz, 2016, pp. 474–479). Although their position is described as "metabolism-first," at the same time they perceive the problem of emergence from a systemic perspective.

Their theory cannot be qualified as reductionism in the standard ontological sense—in its framework, complex structures are not just a simple union of parts. Processualism lies at the heart of their view on Origins. The authors themselves, however, suggest that their theory contains a reductionist description and makes objective reductionism possible through emergence. But what is this description? The mathematical apparatus of quantum field theory has proven successful, allowing experimental testing of predictions and observing the effects of symmetry breaking. This means that it allows to think about the study of the development of matter beyond its single historical emergence. Consequently, laws should be expected and formulated at

[3] On Monod read the paragraph: "The position of the authors in the dispute: necessity versus chance."

[4] It should be noted that this refers precisely to the article "Phenomenological Lagrangians" by Steven Weinberg (1979).

[5] These authors divided the Earth into four geospheres: atmosphere, hydrosphere, lithosphere and biosphere (Smith, Morowitz, 2016, p. XIII); earlier, the term biosphere in its specific meaning was used by Vladimir Vernadsky (1863–1945).

[6] Phase transition is a mathematical concept used in the field of processes, information systems, as well as in the field of classical theories of self-organization of matter, e.g. by Manfred Eigen.

other levels of the complexity of matter and not only in the name of the deeply human belief that the finiteness of life does not pose a challenge to existence *in se* (eternity). Smith and Morowitz"s approach is firmly rooted in the prevailing hierarchical theory of matter, which gives a solid theoretical basis. At the same time, they apply a holistic approach that they themselves have expressed.

The ontological layer, with intra-system relations (in the ecosystem, biosphere on a planetary scale), is placed in the foreground here, giving the theory its holistic character, which is reflected in the emphasis given to the concepts of biosphere, ecosystem and metabolic core. The authors refer to the ecosystem and metabolism as universals. Their position can be tentatively qualified as materialistic monism, but marked by the acceptance of conceptual realism. When the authors of *ONLE* ask the question: metabolism—a fossil or a Platonic form? (Smith, Morowitz 2016, p. 59) they suspend the judgement. It should be recognized that they are right not to clarify this issue. Certain metaphors that have source in philosophy are too easily subject to ideological abuse. It is very difficult to reconcile elements of different traditional philosophical concepts so that their consequences do not create an internal contradiction in the "image of the world." To confirm the merely metaphorical meaning of such a "Platonic" term, one can quote a statement by a naturalist who even doubted the necessity of life, a representative of alternative view on Origins.

Even Monod believed that "Platonic" elements were inevitable in science. Monod (1972, p. 101) wrote about the ambition to search for invariants in the biosphere. In a similar vein to Smith and Morowitz, he used words like unique form or "Platonic" ambition. French geneticist pointed out chemical invariants—amino acids and nucleotides. He called them the logical equivalents of the alphabet. He also defined DNA as the fundamental invariant of life. There is a need to more carefully develop ontologies that make sense of universal relations in ecosystems, but free from earlier mentioned ancient obligations. The challenge for the philosopher is to provide an ontology freed from Platonic and Aristotelian commitments. Unfortunately, the third way (of Democritus) did not develop as intensively and in parallel with the above-mentioned ones. In order not to draw naive philosophical conclusions, let us trace the foundations of Smith's and Morowitz's theory (but of course in a simplification). Their book is, after all, a compendium of specialized knowledge harnessed to the problem of the beginnings of life.

HIERARCHICAL THEORY OF MATTER

The concept of the hierarchy of matter is based on the Standard Model,[7] and, in particular, it is based on the recognition that each successive frozen state of order is a composite made of elements (not frozen at higher energies) and becomes a component of larger composites[8] when frozen to lower energies. The forces that make each successive phase transition[9] possible are mediated by the ordered states created in the previous transitions. Each frozen ordered state is built from elements that were free at a higher energy value (measured in eV) and becomes a component of larger composites when frozen to lower energies. The concepts of phase transitions and freezing are essential basics in the theory presented in *ONLE*.

In the early universe, a decrease in temperature caused a subset of dimensions to freeze[10] into an ordered state, but unfrozen quantum field variables remained internally symmetric,[11] and they are described in terms of a lower-dimensional symmetry group.

After a series of such phase transitions, freezing phase changes begin to involve spatial ordering and not just internal fields (Smith, Morowitz, 2016, p. 474). With each transition, if the frozen state is degenerate, new low-energy degrees of freedom—which are elementary particles—become present. These particles interact with each other. As a result of interactions, successive phase changes occur at subsequent lower levels of the hierarchy.

Here are some of the significant levels of the hierarchy of matter that the — authors have distinguished:

— the first phase transition—freezing, which produced a symmetry group of strong and electroweak interactions as a product of three special unitary groups, which are responsible for the properties of matter;
— the second phase transition in the electroweak force led to the separation of the heavy particles of the weak force from the electromagnetic force,

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[7] The Standard Model is the theory of elementary particles, which are the basic components of matter. It describes three of the four (i.e. omitting gravitation) fundamental forces: electromagnetic, weak, and strong.

[8] The term is customarily or even conventionally used, for example, in reference to subatomic particles which the authors use in *ONLE* when presenting the theoretical foundations of the Standard Model (Smith, Morowitz, 2016, pp. 476–478).

[9] Phase transition is a mathematical concept with origins in the laws of large numbers (the law of large numbers is related to a series of mathematical theorems (one of the so-called limit theorems) describing the relationship between the number of experiments performed and the actual probability of the event to which these experiments refer). In the theory of transitions the central properties are referred to as the order parameters of the ordered phases: they are the statistical and causal aspects of the new order created in the phase transition.

[10] Freezing is a generalized term for a phase change caused by a decrease in temperature.

[11] Internal symmetries are symmetries that are independent of space-time coordinates.

— third—two pha se transitions resulting in the formation of protons and neutrons;
— fourth—condensation phase transition—leading to the formation of atomic nuclei. The authors list more degrees of the hierarchy of matter.

They compare the hierarchy to ceilings and floors; it is a problem of the scale in which the phenomenon occurs, it is also about taking the problem of fluctuation effects into account. Phase transitions with respect to life are not associated with a decrease in temperature. However, there is an increase in the chemical potential difference (e.g. electron pairs) between two or more nodes in the so-called reaction graphs. The matter on the energetically excited young planet has transformed into conduits for the flow of energy. The function of these channels, which consist of ordered states and events of living matter in a planetary context, is, according to Morowitz and Smith, to mitigate the accumulation of potential chemical stresses. They are energy flow channels through the chemistry of covalent bonds (Smith, Morowitz, 2016, pp. 24, 26).

As Smith and Morowitz write, cascade of "freezing" transitions is a path to complex order. The cascade leading to emergence of life is due to constraints related to the need to support energy flows through chemical pathways. Stress as a boundary condition makes transport currents a limiting factor leading to biological order (Smith, Morowitz, 2016, p. 25). What are ceilings and floors when it comes to Origins of Life? In such a “cascade of transitions,” each of the ordered phases has two boundaries—the one above, that gave rise to the phase’s properties through the freezing transition, and the one below, leading to the creation of an even more ordered phase. These boundaries form the ceiling and floor—important to Smith and Morowitz. Most of the details of the structure above the ceiling need not be understood to describe the dynamics in phase under the “ceiling,” because they are unavailable.

The construction analogy has been extended and explored by the authors in such a way as to reinforce the conviction that emergence can validate reductionism. One does not need to anticipate everything about the assembly of bricks in a house in order to understand the possibilities and limitations that bricks impose on the possible houses (that can be built with them).

The cascading changes of matter must have continued. Modern scholars (probably) do not wonder whether the possibility of its further transformations was exhausted in earthlike life of biosphere. Stubborn philosopher, overly skeptical, may not want to accept place where a naturalist wants to cut off regression to infinity, even if it enables the reductionist approach to be applied in practice. What’s obvious: philosophizing scientist thinks in a different way than philosopher of science, or one that analyzes the rela-

tionship between formal logic and natural language or even relations between word meanings. He/she often struggles convincing others to adopt a carefully considered practice of research, because it is so easy to simply test new technologies in relation to the fascinating, pressing problem of the Origin of Life. The attitude that it is possible to study the development of matter in the context of ceilings and floors is strongly justified by the experimental results of particle physics. Or is it only set of abstract tools? As an alternative one can encounter a philosopher who tries to break between one of the ceilings and floors and then "sow there the seed" of the first mover, demon or demiurge and also cut something off: the perspective of the eternity of universes. The modern follower of Democritus' thought will not leave this procedure unattended. That's why these words are said here. The heirs of the father of atomism, following the actions of naturalists, are therefore vigilant to see the perspective of the eternity of universes instead of an infinite regress.

Finally, about the issue of control, which is so crucial for supporters of "RNA words" scenarios. Smith and Morowitz did not neglect to discuss it, but in specific context. They recognize obvious fact: many inter-level connections in a living system must have a control function—one level controls the others. Control mechanisms contribute to error correction. Modularity is the answer to the need for error buffering (protection against damage). The flow of energy through a system can put it in order. The beginning of the order may be a phase transition. Creating order lowers the impedance (the idea of a "bottleneck") of energy flow through the phase transition. States of disequilibrium—the authors say—can be stable when they are energy channels. The emergence of life must be understood as a cascade of reorganization of systems that were in some essential respects resilient, or at least locally necessary (Smith, Morowitz, 2016, p. 425).

In 2022,[12] Eric Smith made the recognition: both the "metabolism first" and "control first" camps agree that matter is encoded by selection. Even though central dogma is perceived as an inseparable ring of interdependent processes, he said, folding occurs as a result of physical and chemical processes and not by any agency. He finds it important to see matter divided into categories of folded matter and coded matter. Folding is obviously not understood by him as a mechanism of selection and as a product of Darwinian evolution. Since Darwinian selection resembles Bayesian filtering,[13] it is important to indicate initial limits for this bounded category; some of them descend from geochemical metabolism. Understanding that folding is part

[12] Based on a speech at the fourth edition of the Information Universe conference in Groningen (June 23, 2022)

[13] There is an analogy between Bayesian updating (filtering) and the "replicator equation" of evolutionary dynamics (formalization of the Darwinian idea of natural selection). For details see: (Shalizi, 2009, p. 1042).

of a hierarchical entropy funnel, occurred before encoding (and also prevented dissolution) makes it a strong candidate for analyzing the laws governing it. Smith also distinguished three informational gateways to life: metabolism, folding, and then encoding. Maybe the ribosome was the carrier of heredity in early life. It's too early to say this, since folding needs to be dealt with first.

WITHIN HIERARCHICAL AND DYNAMIC (LIVING) SYSTEMS, ERROR CORRECTION TAKES PLACE

The authors believe that the biggest challenge for the theory of the origins of the biosphere is the problem of sustaining it, so that it can survive in the face of threats at the micro and macro levels. The authors perceive life as a "confederation" of various sources of order (Smith, Morowitz, 2016, p. 14).

The phase transition paradigm for emergence is a general theorem that error buffering through cooperative effects is needed to enable the creation of hierarchical complex systems, especially those that apply control relationships between levels of the hierarchy. The beginning of life should not be understood as a single phase transition that created one form of order. The requirements for buffering through ordered phases are found by the authors many times at successive levels of life. Heterogeneity and multi-level regularity of life are its features, and the task of theory is to explain them.

Despite the extraordinary complexity of the order of life, the essential function of the biosphere, according to the authors, is that it opens a conduit for energy flow through the domain of organic chemistry that would otherwise be inaccessible to planetary processes. The emergence of the fourth geosphere i.e. the biosphere, introduces new channels for a stable flow of high-density energy through the chemistry of covalent bonds. These channels may run in parallel or may involve mutual chemical transformations in other geospheres. Currently, the main network of these pathways on Earth is metabolism, the authors state. Thermal relaxation (returning to equilibrium, response to disturbances) can also be related to error correction (Smith, Morowitz, 2016, p. 489). Although the description of error correction and thermal relaxation applies to other processes, they are characterized by deviations of a similar structure (Smith, Morowitz, 2016, p. 489). What protobiologists found worthy of emphasis is that the theory of asymptotically reliable error correction exists, and the source of reliability is fluctuation damping equivalent to that occurring during thermodynamic phase change. However, the application of these ideas to non-equilibrium systems is a more complex problem, so the authors present a minimal model, expressing the hope that the relationship they indicate will be treated as something more than a mere analogy.

THE MOROWITZ-SMITH ABIOGENESIS SCENARIO

Smith's audiovisual presentations have been helpful in developing this outline.[14] The description of the abiogenesis of the biosphere begins with the planetary scale.

The boundary between the lithosphere and the hydrosphere is especially important for life. Mantle convection leading to tectonic shifts breaks the physical barrier of the earth's crust, creating a local state of disequilibrium. The surface circulation of water through heated, crushed rocks leads to the formation of mixing zones, where states of imbalance accumulated over millions of years occur on a molecular scale (Smith, Morowitz 2016, p. 9). The young star's solar radiation is shaping the atmosphere in such a way that the parameters of the state are far from equilibrium. The atmosphere on Earth is constantly being brought into a state of disequilibrium with the upper part of the lithosphere. If electrons are continuously supplied to the surface and oxygen receives them, you get a "redox battery" (Smith's term) on a planetary scale. The escape of hydrogen turns the Earth into a large, rock-atmospheric battery. We lose water due to the escape of hydrogen. The system, however, is not exhausted due to the constant flow of new material to the surface of the earth's crust. This causes another imbalance in the thermodynamic sense. Convection causes the rock surface to be renewed. Oxidized rock material is pushed back into the Earth's mantle. At the same time, solar radiation constantly causes hydrogen to escape. The new crust is not evenly distributed over the entire surface, but only in the spreading centers. Convection is the cause of tectonic movements. Plate displacements cause a subduction zone, volcanoes[15] erupt etc. In places where tectonic disturbances affect the brittle crust, the uplift, cracking and detachment of the basalt crust can cause serpentinization, i.e. a series of interrelated reactions of hydrothermal transformations.[16] In a hydrothermal field environment, complexity is not built by fighting energy release: complexity is built as the path of least resistance to energy release. The core of the citric acid cycle may have formed in a hydrothermal environment where the addition of electrons and the use of free energy fuel each other. The earth is the "battery" that metabolism uses, the interconnectedness of which indicates the continuity of geochemistry and life. Water flows through porous new rock

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[14] The description of scenario was based not only on *ONLE,* but also on the basis of Eric Smith's 2015 speech as part of The McCloskey Speaker Series, entitled *Biogenesis: The Emergence of the Fourth Geosphere*.

[15] Volcanic outgassing, thought to be the main source of the present atmosphere, released both methane and carbon dioxide from carbon trapped in the Earth's mantle as the Earth cooled. Another example indicated by the authors is continental weathering at the junction of the lithosphere and the atmosphere with the participation of water.

[16] In locations where tectonic disturbance acts on friable crust, uplift, fracture, and stripping of crustal basalts can expose depleted mantle peridotites to a variety of related hydrothermal alteration reactions—serpentinization." (Smith, Morowitz, 2016, p. 131).

structures (hydrothermal vents, hydrothermal fields)—this is where the interaction takes place. This is where electron transfer takes place. Stress builds up, even if it accumulates in diffusion.

THE REVERSE KREBS CYCLE IS FUNDAMENTAL FOR LIFE ON EARTH

The citric acid cycle organizes all metabolism. The Krebs cycle (TCA) is the precursor to all five classes of biomolecules (the "five pillars of anabolism" (Smith, Morowitz, 2016, pp. 184–185). The TCA reduction cycle (rTCA) is the carbon fixation pathway that serves as the beginning of anabolism. Biosynthesis can be perceived as "energy storage" in a reducing world—extracting energy and building biomass at the same time.[17] Abiosynthesis must "catch" carbon on its way from carbon dioxide to methane.

Progressing through the stages of increasing control over metabolism and autonomy from geochemistry, oligomer systems formed, cellular integration, and then Darwinian evolution as yet another distinct order-making mechanism. The scaffolding for the emergence of life is the "arc of planetary disequilibrium" (a term used by Smith) that today "serves" chemolithotrophic life. In the early stages, the core of the biochemistry took the shape of the rTCA, but it was not separated from the geochemical substrate. An ordered, synthetic network was the basis from which cofactors (ATP, NAD, CoA), replication and cellularization were initiated in many stages. New accumulated levels of components "coupled back" freeing the lower levels and their geological supports from dependence (although each of these new levels was limited by the materials on which it grew) (Smith, Morowitz, 2016, p. 341).

COACERVATION AND COMPARTMENTS —FORMS OF INDIVIDUALITY EMERGE

In the Morowitz-Smith scenario, cellularization occurred late. The translation apparatus (ribosomal) and the replication of RNA and DNA, improved and became more precise only in the era of vertical gene transfer. Near-equilibrium phase transitions in lipid-water systems—as recognized by protobiologists—are the processes most widely described using the terminology of error buffering, which simplifies the problem of the formation of living matter. The water-lipid barrier makes it difficult for molecules to escape from order. This is an already recognized mechanism that does not

[17] Reductive metabolism, in the words of Everett Shock (his words enjoy continued popularity among naturalists) "is a free lunch that you are paid to eat." Anabolism is an electron-consuming (reducing) process, therefore probably older than catabolism.

require additional chemical regulation. Structures generated by the thermodynamics of the near-equilibrium can mediate feedback, and these cause dynamic phase transitions, increasing the supply of lipids on which the equilibrium phases depend (Smith, Morowitz, 2016, p. 481).

Transition from a planet "without life" to a planet "with life" as a thermodynamic problem

Biogenesis is the transition from a less to a more stable planetary state, namely a planet with a biosphere. In entropic terms, this transition is defined by Smith and Morowitz as a collapse from less probable to more probable. The stable phase in this case would be a dynamically ordered state of life. Trying to avoid being accused of over-interpretation, Morowitz and Smith mentioned that even for equilibrium states, the idea of "collapse to order" is not new or radical for open systems undergoing phase changes. In support, they give examples of the so-called nucleation.[18] In non-equilibrium systems, a phase change means a collapse towards order, intuitively reminding the authors of the emergence of life. Phase change is seen when a crack suddenly forms and spreads in a stressed, flexible solid, or when lightning strikes in a gap in the atmosphere between a charged cloud and the ground (Smith, Morowitz, 2016, p. XVIII). Thermal phases are perceived by the authors as carriers[19] for physical laws. Physical laws are therefore an invariant whose carriers are thermal phases.

The authors draw an analogy between an electrical discharge and a rupture of a covalent bond. In the case of cracks, the breaking of the crystal bond occurs in the area corresponding to the diameter of the atom. The distortion at the tip of the kink accumulates the stresses of the displaced atoms, leading to the breaking of the bond. However, protobiologists warn against too far-reaching interpretations. The analogy of lightning and emergence has fundamental limitations. Lightning as a model of organization represents a limited set of chemical transformations, it is a phenomenon of boundary layers.

The position of the authors in the dispute: necessity versus chance

The authors of *ONLE* are opponents of the Monod's school of thinking and of the concepts such as "frozen accidents" and happy coincidences in the emergence of life. They call the Monod School a group of protobiologists

[18] Nucleation is the initial stage of a phase transition, during which tiny "germs" of a new phase are formed in a substance.

[19] In quantum mechanics, interactions are carried by particles called interaction carriers or interaction quanta. There are two categories of such particles - real particles (carrying elementary interactions) and pseudoparticles. Particles serve as quanta of a particular type of physical field. The Standard Model postulates the existence of particles, each of which is an excitation of a specific field.

who were inspired by a 1970 book by a philosophizing naturalist. According to Monod, the search for a necessity rooted in the beginning of the existence of all things is a human tendency (the effect of anthropocentric thinking). Monod opposed the idea of destiny preempting existence. The inborn human need for full explanation—when unsatisfied—causes pain (Monod, 1972, p. 169). The forms of organization present on Earth can be placed on a scale from necessary to historically contingent. The biological order coincides with a whole range of possibilities, not all of them contingent. Geophysical processes and their associated chemistry are universal, predictable, stable as the planet matures. In opinion of the authors, universal small metabolites fall almost in the same category as geochemical phenomena. Cell forms are more variable than metabolites, and species identities are the most variable, depending on the circumstances. The continuity of metabolism in all living organisms over some four billion years is Smith and Morowitz's argument against the randomness of the birth of life. In their concept, chance is a legitimate factor only at the stage of biological evolution, and it is related to the concept of contingency. Proponents of "frozen" or "lucky accident" have overlooked the fact that there may in fact sometimes be one viable solution to a particular biological problem, as Smith and Morowitz point out. "Frozen accident" is a term that naturalists know from Crick's 1968 publication. The reactions of the metabolic network core are more conservative than the enzymes that catalyze them. Based on the above observations, the authors conclude that the distinction between chance and necessity does not apply to life as a whole (Smith, Morowitz, 2016, pp. 69–70). Smith and Morowitz take the position that the emergence of life is necessary. They leave no room for "miracles" and "happy accidents. It is high time to focus on the philosophical aspects of the theory.

Morowitz-Smith Theory: Holistic or Reductionist?

Elements of the theory that can be considered holistic:

— treating the rTCA cycle as a universal metabolic core,
— accepting the superiority of the concept of the biosphere in the hierarchy; within the hierarchical theory of matter, the reduction of the number of internal symmetries, the freezing of symmetries is tantamount to the emergence of the physical structure of matter,
— the biosphere is the fundamental unit of life, and relations are beings in the ontic sense; the biosphere as a whole defines the level of organization of life,

The theory is rooted in specific concept of terms of ceilings and floors, derived from the approach used in the Standard Model (freezing, symmetry breaking, etc.). Smith and Morowitz are little inconsistent here. But it seems

to be inevitable. When intellectual tools, empirical generalizations are nested in different traditions of thought, it is expected that we are forced to be able to change the philosophical perspective and point of view. In addition, there may be a need to develop a more lingustically adapted and developed ontology, that captures a specific way of understanding the status of the relations, and even what will be derived from the "folded matter."

After all, the very idea of abiogenesis comes from a "bundle" of different philosophies.

Notion of ecosystem

According to Smith and Morowitz, the carrier of the chemical regularity that sustains various forms of individuality is the ecosystem. Ecosystems are not just a collection of individuals' communities; they are metabolically integrated and partly independent. In their view, individuality is a complex form of organization that emerges from a chemical context structured by kinetic and energetic selection (Smith, Morowitz, 2016, p. 541).

The ecosystem seems for researchers to be a bridge between the initial order in geochemistry and the earliest biochemistry. Contrary to the creators of the Gaia hypothesis (James Lovelock and Lynn Margulis), ONLE authors believe that ecosystems should not be viewed as superorganisms. They are not organisms because they do not survive by replication or by any other more general process that might be characterized as "reproduction." Their permanence is sustained by the reproduction of individuals, partly by the niches created, and partly by relationships dynamically maintained within and through generations of belonging organisms.

The changing ecological configurations that can be explored as the associated species changes properties or relationships, the authors argue, are not subject to Darwinian selection during the competition of quasi-autonomous ecosystems. The state of the ecosystem is rather a subject to fluctuations. The analogy between an ecosystem and an organism in a stronger than metaphorical sense is therefore unjustified from their perspective (Smith, Morowitz, 2016, p. 41).

Biological entities, patterns and their carriers

"We share a common language, acquired through a long apprenticeship and jealously safeguarded by the social strictures of peer review. It is rare indeed that a formative concept falls on such hard times that a new language must be developed to take place of verbal conventions whose time has passed" (Buss, 1987, p. 174).

A pattern in biology is—according to D. E. Smith—a legitimate candidate for the role of a biological entity, even if it consists of dynamically stable

relations, and no object itself is their carrier. He sees the need to change the language of protobiology theories to one that would give self-perpetuating patterns the status accorded to Aristotle's form. The authors have undertaken this task in *ONLE*. They propose distinction between two types of "single solutions" of a biological problem: the first are the invariants mentioned earlier, the single solutions to the problem, because they are the only ones that have worked and proved irreplaceable. Examples are the citric acid cycle and amino acids. The universal core of metabolism is a pattern—an example of the regularity that distinguishes life, which a protobiological theory should take into account. The authors postulate the priority of metabolism as a precondition for (a)biogenesis. Its consequence is the trophic integration of participants in ecosystems. The second category is the "evolutionary solutions" visible in the history of life on Earth resulting from having a common ancestor—and it is to this category that all the so-called frozen or happy cases belong.

The ecosystem deserves the status of being the carrier of patterns necessary for the state of "aliveness." Hydrothermal vent ecosystems—dependent on geochemical reducers not dependent on molecular oxygen—are the most conservative environments akin to Hadean conditions, and at the same time available on Earth today.

A departure from the Aristotelian understanding of the species and organism is necessary to perceive life and its evolution in the context of biochemical processes and ecosystems, as opposed to the traditional natural language that objectifies the beings around us and treats being alive as a predicate of a material object. Metabolism and ecosystem are the two most fundamental universals of the theory presented in ONLE, with which individuals can enter into various relationships.

To sum up, it remains to note that there is a need for a more precise development of an ontology that will make sense of invariants—relations in ecosystems, but free from ancient commitments. Especially since we know more precisely what are the expectations from the categories of relations in the theory. Perhaps such an ontology would be strongly descriptive, rather than based on few general concepts—the struggle with overcoming the limitations in understanding of internally complex phenomena goes on.

Criticism of premature (and excessive) extrapolation of Darwinian paradigm in explanations of abiogenesis

The issue of the emergence of individuality is an important and relevant problem in protobiology. Attempting to circumvent this issue and adopting the laws of Darwinian evolution is an escape from theoretical difficulties. One cannot narrow "life" to its Darwinian aspects. Many scientists try to retrodict these laws to the principles of abiogenesis. Natural selection, when

taken as an error-correcting mechanism, does not have the power and scope to explain all aspects of the increase in order in pre-biological matter. Individuality is a complex form of organization that emerges from a chemical context structured by kinetic and energetic selection (Smith, Morowitz, 2016, p. 541).

The question about the limit of collective and cooperative effects leading to the creation of the biosphere is to boil down to another question—is it justified to believe that symmetry and its breaking are the most important concepts that can be the basis for contemporary theories of (self)organization? This is the function they perform in the theory of the hierarchy of matter. Smith and Morowitz, citing spin glass[20] analyses, argue that inner symmetry groups (relevant to the theory of the hierarchy of matter) may not be useful for describing phase-transition driven chemistry. A new class of symmetry or something else may replace them (Smith, Morowitz, 2016, p. 525).

The condition for Darwinian evolution to occur is the emergence of individuality,[21] claim Smith and Morowitz following Leo Buss (the author of *The Evolution of Individuality* from 1987), who also is an advocate of hierarchical thinking applied to life, treating evolution of biological life as evolution of a hierarchical organization. The Darwin threshold[22] happened when there was a sufficient barrier to the free exchange of genes because the ribosomes cannot tolerate it (gene exchange). Smith shares Carl Woese's position: the rise of vertical gene transfer marks the first crossing of the Darwinian threshold. ONLE's authors want to promote thinking about the only partially innovative nature of Darwinian selection, which, moreover, operated much later—after a series of chemical self-organization processes— and about the fact that the methods of control are changeable.

Comparison instead of critique

The theory given in *ONLE* is one of the most carefully thought out and developed in detail. Rather, it is alleged that few experiments were carried out under its dictation. In 2020, Kamila B. Muchowska and co-authors presented a comprehensive review of experiments indicating possibly important non-enzymatic metabolic pathways for OoL. Therefore, it is worth making some comparisons, and not criticizing *per se*. The issue of inspiration by Vernadsky's thought is interesting for the philosopher. It seemed

[20] Spin glass is "a collection of spins (i.e. magnetic moments) whose low-temperature state is disordered, differing from the uniform or periodic pattern we used to find in conventional magnets" (Fischer, Hertz, 1993, p.2).

[21] It is a complex issue, interestingly practical from perspective of scientists dealing with problems imposed by synthetic theory of evolution for ontogeny.

[22] The Darwin threshold is a term introduced by Carl Woese to describe the moment in the evolution of life when gene transfer changed from horizontal to vertical.

worth examining to what extent the authors were inspired by Vernadsky work.

It is fair to say, that Vernadsky when comparing living matter and inert (passive) matter, did so in a context unrelated to the problem of the origin of life. He believed in the principle of strict biogenesis—he willingly quoted the Redi Principle in this regard (Francesco Redi lived in the 17th century, conducted experiments that contradicted Aristotle's theory of spontaneous generation) *omne vivum ex vivo* meaning as much as—"All life comes from life." Vernadsky also accepted the eternity of life (Guillaume, 2014, p. 143) and in this respect ONLE differs from the scientific and philosophical heritage of the famous mineralogist and biogeochemist.

Vernadsky pinned his hopes on the distinction between the concepts of living matter and life. He believed that life on Earth was always present. He rejected not so much the idea of an abiotic genesis of life as the possibility of emergence in geologically known time. The main reason was the problem of reducing atmosphere (Vernadsky, 1998, p. 41). Ultimately, he reluctantly accepted abiogenesis and actually defended the idea of polyphyletic origins of life (Vernadsky, 1998, p. 41).

Alexandr L. Yanshin, a Soviet geologist and interpreter of Vernadsky's achievements, describes him as a philosophical skeptic who placed empirical generalizations,[23] such as the Mendeleev table, above hypotheses and theories (Vernadsky, 2007, p. XXXVII). Smith and Morowitz call most of the premises constituting their theory empirical generalizations. The periodic table and its understanding are taken by Smith as the basis for reductionist practice in chemistry. For Vernadsky, generalizations constituted the highest category of scientific cognition. The term "biosphere" made famous by Vernadsky, and fundamental to the concept of Smith and Morowitz, means living systems and the connections between them taken as a whole.

They understand the biosphere as a set of patterns sustained by processes and patterns of processes, not a collection of organisms. Living matter consists of processes maintained in a state of coordination and patterns (Smith, Morowitz, 2016, pp. 10–11). Adopting the view that both relationships and the ordered state of processes are fundamental to the nature of life makes perceiving it as a collection of organisms inadequate (Smith, Morowitz, 2016, p. 11). To sum up: inspiration from Vernadsky's writings is visible in *ONLE* both in terms of language and philosophy. However, it is superficial. The core of the Morowitz-Smith theory shows affinities with the classical model of chemical evolution. My guess is that the authors wanted to avoid associating their theo-

[23] Now it is worth returning to the issue of generational differences between collaborating authors: contemporary naturalists such as Smith use the word theory with considerable, perhaps even extreme, caution. Maybe this prevents some confusion and allows for more free use of fragments of acquired knowledge, but research problems are always placed in a broader context (even if it happens only in the author's mind).

ry with the Gaia hypothesis and they referred to the more traditional, holistic concept of life on Earth associated with Vernadsky.

Finally, the position of *ONLE* authors will be compared with contemporary representations of the systems approach. Similarly as Smith and Morowitz, Lee Cronin and John Sutherland recognize the importance of the dynamism of environmental change, although they do not focus on the whole structure of processual mechanisms of the emergence of life. In this respect, *ONLE* and other works by Smith are worthy of appreciation.

The aforementioned prominent researchers Sutherland and Cronin, view the meaning and the initiating moment of Darwinian selection in the origins of life differently. Sutherland's position is closer to Smith's in this regard. Sutherland takes the action of evolution in a much narrower range than Cronin. Cronin explicates the operation of the laws of evolution in an extreme way, ascribing to it an almost magical agency.

All the mentioned naturalists recognize the problems of "messy" prebiotic chemistry and the combinatorial explosion. Cronin proposes to solve it with chemical recursive cycles, and Sutherland with the slope of the terrain and flow chemistry and the emergence of the living system as a whole. Smith with Morowitz, on the other hand, wrote about this problem in the context of errors within the metabolic modules: "Networks in which the non-equilibrium is not very asymmetric are often referred to informally as suffering a 'combinatorial explosion' of chemical complexity under the recursive action of the generating reactions" (Smith, Morowitz, 2016, p. 561). The theory of modular architecture by Smith and Morowitz excludes molecular complex "tars" as a source of organic compounds for formal reasons. The formal reasons are: "The simplification that stable and low-dimensional macrostates afford,[24] in the problem of assembling hierarchical complex systems" (Smith, Morowitz, 2016, p. 566). Smith and Morowitz propose dynamic incrementally accreting steady states (advancing plateaus) rather than a growth of networks complexity through combinatorial explosion (and idea of combinatorial innovation)—to put it simple—theory of Smith and Morowitz avoids "messy" chemistry.

Sutherland and Cronin share the style of experiment-driven concepts. Flow chemistry is an important way for both of them to solve prebiotic problems (for example in Sasselov et al., 2020). The 2020 scenario, co-created by Sutherland, assumes extremely deterministic beginnings:

> "We simply envisage chemistry morphing smoothly into biology [...] prebiotic chemistry and early biology most likely followed a deterministic trajectory,

[24] In *ONLE,* the authors conceptualized this issue starting from the observations of Herbert Simon. The Parables of fkkSimon (The Empire of Alexandria, the Two Watchmakers) illustrate that for the complexity of matter to increase, modularity is a necessary condition. In Smith's previously mentioned 2022 talk, Leslie Valiant's book titled *Probably Approximately Correct* is identified as a means to more carefully formalized control theory.

> and if similar sequences of conditions prevailed upon other planets, we might expect the same chemistry and early biology to play out" (Sasselov et al., 2020, p. 1).

The moment from which the process of the emergence of life requires recognition of the action of selection is late in this scenario. In a similar sense, the theory of Smith and Morowitz is deterministic.

It should be recalled that Melvin Calvin explained the deterministic nature of synthetic chemistry; the limitations resulting from planetary evolution (e.g. the availability of chemical elements) are closely related to assumptions about the foundations of synthetic chemistry. Cronin's research work, on the other hand, is less about finding explanations for the historical origins of life on Earth, because he shows ambitions befitting a citizen of the universe (see: Caramelli et al., 2021). The experimenter assumes that inorganic forms evolve, and it is a never-ending story. By (metaphorically) anthropomorphizing matter, Cronin manifests the belief that a unit of natural selection may turn out to be unnecessary. Therefore, the Scottish chemist is not strictly interested in the contingent features of earthly life. As the analysis of the Smith-Morowitz theory shows, the determinism-contingency problem was extremely important to its authors. They sought to explain the geochemical mechanisms leading to the formation of the biosphere.

Morowitz and Smith believed that protobiology is a maturing research field. Although they noticed an increase in knowledge about the beginnings of life, they recognized the problem of its fragmentation. They also showed a bit of an exaggerated attachment to Thomas S. Kuhn's model of change in science, but the effort made by these (philosophizing) naturalists testifies to the best of intentions and intellectual honesty. Although Morowitz is no longer alive, the one who remains continues the research tirelessly.

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