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WEAKNESS OF THE SCIENTIFIC HYPOTHESES ABOUT THE ORIGIN OF LIFE**

Abstract

This paper makes a case for the weakness of the scientific hypotheses about the origin of first life (hereafter OoL). There is no consensus on when, where, and — most importantly — how and why life emerged on Earth. There are significant impediments to the scientific explanation of OoL, at least in relation to the accepted (meta)heuristic postulates of scientific study of OoL and (meta)theoretical postulates that hypotheses must satisfy to be recognized as true explanations and not just-so stories. Following these rules and methodologies did not help to bridge the gap between the most complex inorganic components and the simplest living entities. The main arguments for the weakness of the scientific hypotheses about OoL are: (i) there is no scientific hypothesis that successfully explains OoL, and (ii) there is an evident experimental failure of the attempts to (re)create life from inorganic components. The long-term resistance of the problem and the weakness of the hypotheses about OoL stem from the commitment to the ontology of repeated occurrences and/or from inappropriate epistemological-methodological tools used to explain the transition from inorganic to simple life forms (exclusively by means of the “language” and methodology of physical-chemical sciences). Accordingly, either the scientific study of OoL rests on a mistake or science must reduce the scope of phenomena that can be scientifically explained.

Keywords: origin of first life, unique event, scope of theories, self-organization principle, micror-versibility, philosophy of biology

This paper argues for the weakness of the scientific hypotheses about the origin of first life (OoL), on the grounds that OoL is neither scientifically ex-

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plained nor experimentally recreated. Despite the growing scientific support for the claim that life is a natural property of certain types of organized matter, there is persistent disagreement on how or why the OoL process happened. A number of scientists doubt whether OoL can be “explained by scientific methodology” (Griesemer 2008: 264). Many scientists claim that, in principle, the origin of life is solvable (Penny 2005: 634) and that “significant advances” have been reached in our understanding of the steps that could lead towards the explanation of OoL (Service 2015, Sarkar 2005: 135, Eigen 2013: 521). However, despite these claims and a “tremendous growth of the literature on »origins« in the last 20 years” (Spitzer, Pielak, Poolman 2015: 2), the optimism of scientists has not been supported by results. Even if we consider different postulates of scientific pluralism, there is a well-established scientific methodology and commitment in the investigation of OoL. And yet the gap between the most complex macromolecules and the simplest form of life has not decreased. To explain the reasons for the weakness of the scientific hypotheses about OoL, I will present: (i) the fundamental epistemological and metaphysical postulates put forward in the field, (ii) the (meta)heuristic postulates endorsed by the OoL research, (iii) the difficulties with scientific explanation of OoL, including explication of two main arguments that point to the weakness of the OoL hypotheses (there is no “winning” theory and no successful recreation of life). Finally, (iv) I contend that either scientific research of OoL rests on a mistake or science should reduce the scope of phenomena explainable by its methodology.

1. THE SELF-ORGANIZATION OF MATTER

The fundamental principle of contemporary research on OoL is a physical-chemical evolution and the concept of self-organization of matter. According to this approach, first life arose by a process of millions of intermediate steps (Penny 2005, Griesemer 2008). On this account, life is not only “too complex to arrive all at once” (Penny 2005: 636), but it is unlikely to imagine even a temporary formation of a single protein, one of the essential macromolecules of life, consisting of only 100 amino acids. The “actualist” approach rejects the possibility of explaining OoL as a random or highly improbable event.

The “statistical” or “probabilistic” approach, which assumes the appearance of first life all at once or by chance, is not accepted by the scientists in the OoL research (Penny 2005: 636), although there are researchers who defend

it, including some notable names (mentioned below; cf. White 2007). The main objection to the “chance origin” is that the parts of living systems are functionally and structurally complex, mutually dependent, and interlocked. Life is highly improbable, so there is a need for some type of “magic” “to fit together a metabolism, a membrane, and a genetic system” (Griesemer 2008: 272). Still, some influential scientists assume “that life emerged following a highly improbable, fortuitous »first event«” (Fry 2000: 193). Nobel laureate Francis Crick claims that OoL was “almost a miracle”, “a happy accident” (Crick 1981: 88, 14). Another Nobel Prize winner, Jacques Monod, described the emergence of life as “a unique accident” (Fry 2000: 195), having estimated the probability of the random formation of such a system as almost zero.

There are other advocates of the happy-accident approach, including Fred Hoyle, Leonard Troland, and Ernst Mayr. For most scientists, the statistical or probabilistic explanation of OoL is suspiciously similar to a version of creationism, but also to the last sentence of Darwin’s *Origin of Species* according to which life “originally breathed into a few forms” (Darwin 1979: 459). Nevertheless, also some versions of a purely naturalistic approach that explain OoL as a consequence of a specific chemical arrangement raise the question whether it is sufficient to order chemical elements or whether, in addition, a special (external) kick-start is needed (Penny 2005: 634), thus sliding towards scientific, epistemological, and metaphysical vitalism.

It appears that, on the probabilistic approach, some type of “magic” is needed as a supplement to naturalistic explanation. Otherwise, it would be possible experimentally to recreate life from prebiotic macromolecules; but this has not yet been achieved, nor is there any elaborate idea of how to repeat a process of millions of steps towards the origin of first life. Furthermore, it is unclear what such a recreation would mean for the scientific explanation of OoL, because: (i) this would not have to be a real reconstruction of the origin of first life, but (ii) could be “just” one possible (new?) way to reshape inorganic compounds into life.

It is necessary to note that, although the binary division into the naturalistic or actualist and statistical or probabilistic approaches is simplified (more related to theoretical “elegance” than reality), there are still questions whether OoL is a determined process, which is either inevitable or improbable. Likewise, there is a dilemma of models of the origin of first life: replicator-first theories, protein-first theories, metabolism-first theories, dual-origin theories, iron-sulphur world, surface metabolism, etc.¹ The short time frame of

¹ A comprehensive listing of theories can be found in Griesemer (2008) and Penny (2005).

life on Earth, which emerged quickly upon creating the conditions for it, is usually interpreted in favor of the “deterministic (causal-mechanistic) origin” (Griesemer 2008: 271-272), although it requires millions of intermediate steps that would need a different time period; or it could be assumed that life easily and repeatedly occurs from prebiotic elements — which is not noticed.

Attempts to answer the abovementioned doubts and almost all contemporary hypotheses about the origin of first life (on Earth)² are derived from the self-organization principle of the 90-year-old Oparin–Haldane hypothesis (coacervate droplet idea; warm dilute soup idea).³ Attempts at experimental proofs of this hypothesis rely on the Miller–Urey experiment from 1953, based on the idea of creating primordial conditions and synthesizing compounds that constitute a living entity from prebiotic components. These theoretical and laboratory approaches were a significant signpost for all further investigation. However, the discovery — presented as a success — of simple compounds that could cause a network of simple reactions that produce the three major classes of biomolecules (nucleic acids, amino acids, and lipids) needed for the earliest form of life to get its start (Service 2015), did not result in the expected experimental transition from inorganic molecules to life. The Miller–Urey experiment produced some relatively simple organic molecules and advanced our understanding of the environmental conditions in the early period of Earth; nevertheless, the gap between simple organic elements and first life did not decrease. In addition, the experiment involved inaccurate assumptions about the composition of Earth’s earliest atmosphere (Hazen 2005).

The problem is that the scientifically noncontroversial constitutive reductionism “asserts that the material composition of organisms is exactly the same as found in the inorganic world” (Rosenberg 1985: 23). This reductionism also uses the principle according to which OoL cannot include any unnatural forces or intentions (White 2007). The Miller–Urey experiment sets out the metaphysical foundations for further research on OoL within the scientific community: “a materialistic view of nature ... a continuity between matter and life, combined with the realization that new properties emerge that are unique to different levels of organization” (Fry 2000: 78). These metaphysical postulates are later transformed into (meta)heuristic postulates of the scientific research on OoL.

² Except the hypothesis of panspermia and exobiology.

³ Oparin’s (1924) and Haldane’s (1929) hypotheses are both built on the idea that early Earth had no oxygen (Griesemer 2008).

2. HEURISTIC PRINCIPLES OF THE SCIENTIFIC INVESTIGATION OF OoL

The study of OoL is committed to scientific methodology; physical, chemical, and biological postulates of research and postulates of philosophy of science. Two indispensable principles that should be followed in scientific study of OoL are (a) the principle of current utility and (b) the principle of continuity or microreversibility (Penny 2005, Griesemer 2008). From the perspective of philosophy of science, the hypotheses aspiring to be more than a just-so story need to satisfy the requirements of (a) a theoretical entrenchment, (b) precise predictions, and (c) the failure of rival explanations (Sesardić 2003). This does not exhaust the list of principles of the study of OoL; nevertheless, the listed principles are crucial.

2.1. SCIENTIFIC METHODOLOGY

The first principle, the principle of current utility or immediacy, allows no planning or acting “because it will be useful in the future” (Penny 2005: 640). The denial of purposeful activity is the basic premise of all versions of Darwinian interpretation of evolutionary mechanisms, although evolutionary mechanisms are only partially relevant to the research on OoL. This clearly denies the possibility of a teleological “plan” and eliminates the possibility of intentionality as a trigger for the appearance of first life. This principle theoretically cannot accept the explanation of the appearance of first life by chance but sees OoL as “quite likely, or at least not very surprising” (White 2007: 453). Also, this postulate confirms the new science mechanistic approach to nature as the only valid model of explanation and denies the purpose in occurrences. Thus, OoL as a product of purposeful agency is unacceptable, and teleology as an explanatory strategy “does not play any explicit role in theorizing” (White 2007: 454) about OoL. Despite the attempts to introduce the principle of teleological or functional explanation of phenomena according to the goal-direction, despite the harmonization of the teleological model with the naturalistic mechanism, and even in spite of claims that the teleological principle is not only “naturalistically acceptable” but “indeed indispensable” (Walsh 2008: 132), the teleological model of explanation remains epistemologically non-legitimate in modern science. Some can recognize this as teleophobia, while others claim that the mechanism “has to be functional now” (Penny 2005: 640). The principle of current utility remains one of the principles and guidelines in the OoL research.

The second principle is the principle of continuity or microreversibility, no miracle principle, or actualism. This principle of scientific research on OoL requires explanation by means of causes now in operation (Griesemer 2008). This is a normative epistemological principle that, in the description of the phylogenetic tree, forbids the radical transition from early forms to significantly different new forms “because they are much less open to investigation” (Morowitz 1992: 14). Accordingly, actualism reduces the OoL research “to those hypotheses that are subject to analysis using the experimental, theoretical, and epistemological tools of normative science” (Griesemer 2008: 274). The possibility of rapid changes is excluded together with any “miracle” that could occur in accordance with some speculative and untestable hypothesis about OoL. The principle of continuity is equivalent to the principle of microreversibility, which “requires that a process can be broken down to large numbers of microscopic steps, each of which is reversible” (Penny 2005: 637). This means that each of many intermediate small steps towards life have to be reversible and that there is no miracle in the process (Griesemer 2008).

Some complaints about these principles focus on the large difference between the form of the first cell, which arose by physical-chemical processes, and the enormous complexity of the progenitor of life as we know it (cf. Morowitz 1992: 88-89). Despite some doubts and concerns about the compatibility of this principle with the principle of contingent irreversibility in the “macro” domain of cells and higher parts of organisms, the principle of continuity or microreversibility remains, in its original form, a standard principle of scientific methodology of the OoL research. In addition, the standard scientific approach assumes other principles: Eigen limit or Information retention/loss, The Darwin-Eigen cycle, Universality through time and No reverse by RNA — which are listed and described by Penny (2005) and repeated by Griesemer (2008).

2.2. THEORETICAL COMMITMENTS

In philosophy of science, there are numerous competing definitions of (scientific) explanation, theory, and hypothesis. In general, a scientific hypothesis could be seen as an idea that proposes a tentative explanation of a natural phenomenon and satisfies a crucial condition: it must, in principle, be testable (verifiable and/or falsifiable). Scientific legitimacy of a theory or a hypothesis assumes its testability/verifiability/falsifiability by observation or experiment. “The degree of acceptance of a hypothesis is related to the severity of the tests that it has passed” (Ayala 2009: 375). Otherwise, theories

or hypotheses are pure narratives, so-called “just-so stories”. The term “just-so story” is primarily associated with socio-biology and evolutionary psychology, but it is also used in the discussion on OoL (Waddington 2009, Yockey 2005). In the research on OoL, it is possible to specify the criteria that a hypothesis must meet to avoid the label of “just-so story”: (a) a theoretical entrenchment (of a more fundamental theory); (b) precise predictions (testable and to a certain extent confirmed); and (c) the failure of rival explanations (Sesardić 2003).

The first requirement is that a scientific hypothesis must be a consequence of a more fundamental theory that is successfully empirically tested (across a wide range of phenomena). Numerous hypotheses that attempt to explain the origin of first life rely on fundamental and empirically proven theories of physics and chemistry.⁴ All hypotheses about OoL are successfully derived from more fundamental theories at the prebiotic stage, which involves the synthesis of organic elements outside a living being, and at early stages of life’s origin, such as *in vitro* evolution of RNA catalysis. The naturalistic assumption of a process of millions of intermediate stages or steps of transition from inorganic matter to life — with “each incremental step following known scientific principles” (Penny 2005: 637) and fundamental theories — respects the methodological commitments of science, both theoretical and experimental. Still, despite numerous theories and hypotheses, the chronology of the progressive steps towards the origin of first life that could be successfully empirically tested is not yet specified. Hence, pieces of the puzzle are present and organized in scientifically acceptable ways, but they are only parts of the complete OoL image.

The second requirement concerns predictive power: scientific hypotheses must offer precise predictions that are, in principle, testable and — at least in some cases — confirmed. The Hempel–Oppenheim DN (Deductive-Nomological) Model of scientific explanation, generally presupposed in the OoL research, includes an *explanandum*, a sentence “describing the phenomenon to be explained” and an *explanans*, “the class of those sentences which are adduced to account for the phenomenon” (Hempel 1965: 247). The *explanation* should be a (sound deductive) argument in which the *explanandum* follows as a conclusion from the premises in the *explanans* (Woodward 2014). In addition, the *explanans* must contain at least one general law or lawlike sentence that holds up the explanation. According to these assumptions:

⁴ “Physical and chemical principles, including kinetics, catalysis, thermodynamics and quantum mechanics ... are granted” (Penny 2005: 639); “Morowitz urges that the first living cell arose by physical-chemical principles” (Griesemer 2008: 277).

...given the particular circumstances and the laws in question, the occurrence of the phenomenon could be expected ... at least with reasonable probability (Hempel 1965: 337, 367-368).

Hypotheses on the origin of first life are partially verifiable, because they assume or explain only a part of the processes of millions of intermediate steps or components in its origin, without explaining the complete procedure or the crucial steps in that process. We can be certain that forces necessary for assembling prebiotic components into life are “covalent bonds, hydrogen bonds, electrostatic interactions, and the hydrophobic effect”, but the big question is “how they could be assembled into a system of molecules that has properties of life” (Deamer 2011: 116). Identification and explanation of the function of the components, at least from the perspective of the paradigm of the OoL research, is a necessary condition of arriving at a solution, but it is not sufficient. For now, it appears there is no hypothesis about OoL that holistically explains phenomena by deriving them from known general laws or lawlike sentences (not even with acceptable probability).

The third requirement states that successful fundamental predictions cannot be derived from alternative hypotheses. This means that the existence of a superior hypothesis must entail the downfall of rival explanations. Alternatively, “some of its crucial and successful predictions cannot be plausibly explained by these alternative hypotheses” (Sesardić 2003: 430). The hypotheses about OoL are subtle and nuanced, but still very diverse and, at any rate, not convergent.⁵ This indicates immaturity of the field, whereby radical changes of theories and approaches with every new discovery are hardly surprising. Thus, the third requirement would be harder to fulfill due to the current “conceptual instability” (Griesemer 2008: 265) in the OoL research. Furthermore, the field is full of eclectic methods and approaches as well as diverse theories and principles.

The plurality of approaches and hypotheses indicates that the field is in the pre-paradigmatic stage of science (in Kuhn’s terms). On the other hand, some believe that the debate within the field is highly articulated and commensurable (Griesemer 2008: 269). However, it is plausible to regard the different hypotheses as methodologically and semantically incommensurable, since the proponents of the competing paradigms are unable to agree which process or entity should be lionized: metabolism, replication, definition of life, etc. Even those who deny the incommensurability of the OoL research acknowledge “significant disagreement on many fronts in origin of life stud-

⁵ The extensive list of approaches, theories, and principles of the OoL research, can be found in (Griesemer 2008: 265).

ies” (Griesemer 2008: 269). It is difficult, if not impossible, to decide whether the requirement of the failure of rival explanations is easier to fulfill by conceding the pre-paradigmatic status of the OoL hypotheses. In any case, most scientists believe it is possible to explain the origin of life on Earth scientifically, and so it should be possible to recreate life, even if “it certainly will not be easy” (Penny 2005: 634). So far, however, the attempts have been unsuccessful.

3. THE MAIN ARGUMENTS FOR THE WEAKNESS OF THE HYPOTHESES ABOUT OoL

In accordance with the assumptions of the OoL research, it would be necessary to determine a sequence of the “process of millions of intermediate steps” (Penny 2005: 637) and “to establish a progressive hierarchy of emergent steps leading from prebiotic Earth ... to self-replicating molecular systems that copy themselves ... to cellular life” (Hazen 2005: 29). Despite the inconsistencies between the various accounts of the occurrence of first life, the scientific community agrees that life begins “with some significant molecular actors” that “put the chemical system on the road to life” for the first time (Griesemer 2008: 265). However, the hypotheses that explain the process of complexification, on both the bottom-up and top-down approaches, differ in their selection of the part of the chemical system that was the first factor in the origin of life. Therefore, it is usually assumed that the key for understanding these essential or “progressive stages between nonlife and life lies in experimental studies of relevant chemical systems under plausible geochemical environments” (Hazen 2005: 31).

One could say that scientists understand the core components, forces, and processes by which life works, as well as the general core systems of life. The Miller–Urey experiment and numerous later experiments confirmed the hypothetical predictions about the possibility of laboratory synthesis of fundamental biological macromolecules: carbohydrates, lipids, nucleic acids, and proteins.⁶ However, experimental attempts to reach the subsequent hypothetical stages, such as the “conditions under which ... polymers would or-

⁶ Prior to Miller and Urey, the Nobel Prize winner Melvin Calvin synthesized organic compounds under prebiotic conditions. Miller and Urey paved the way for a series of similar experiments, carried out by Fox and Harada in 1958, Oró in 1961, Ponnannparuma in 1972, Usher and McHalle in 1976, Orgel in 1983, Huber and Wächtershäuser in 1997, McCollom et al. in 1999, Matsuno in 1999, Ferris et al. in 2002, Cody, Hazen et al. in 2002, etc.

ganize into protocells capable of sustaining a primitive metabolism” (Fry 2000: 89), have failed. It is only confirmed that most of the simple organic compounds of life can be synthesized in laboratory conditions outside a living entity. Experimental production of chemical systems provides key steps in transition from non-life towards life and is a theoretical success of the hypotheses on OoL, but only within the limited and insufficient scope of components necessary for the emergence of life.

The inconvenient fact is that all the hypotheses and experiments performed in accordance with them “still lack some components required for a full living ... system” (Penny 2005: 638). For this reason, I believe that, despite the advances in our understanding of life, the hypotheses about OoL are weak with regard to the assumed methodological demands. The key methodological assumptions are not fulfilled: there are no successfully tested hypotheses that explain the natural phenomenon, because the available ones, despite principal possibilities, are not confirmed by successful tests, or the results of testing are not relevant for the holistic explanation of OoL. Empirical confirmation of the hypotheses indicates “only tiny steps on the long road to life” (Hazen 2005: 93). However, this does not explain the OoL phenomenon. It seems that OoL, in the long term, resists the explanation based on scientific methodology, so there are only “dozens of hypotheses” (Deamer 2011: 222). Such an anomaly can become significant and lead to a possible loss of trust in the power of the existing paradigm: it did not contribute to building a “winning” hypothesis nor has it enabled successful experimental repetition of the event — recreation of life from prebiotic molecules. Therefore, arguments for the weakness of scientific OoL hypotheses rely (i) on the long-term theoretical failure in building a hypothesis or theory that would be better aligned with evidence than its competitors and (ii) on the failure of experimental repetition of the origin of life.

4. IMPLICATIONS

Currently, there is no acceptable scientific hypothesis that can convincingly explain OoL, or there is no hypothesis on OoL confirmed by a successful experimental test. Perhaps this is not possible, not even in principle, because each acceptable scientific theory requires a variety of recurring events for repeated testing (Glymour 1980). Nevertheless, even a multiple successful reincarnation of life would not be relevant for rejecting the argument for the weakness of the scientific hypotheses of OoL, for two reasons:

- i. there is the non-trivial semantic objection that it is impossible to produce first life because it already appeared a long time ago,
- ii. a possible experimental success is an artificial procedure and need not be a recreation of a natural process of OoL as it happened somewhere in the deep past: experimental recreation could be a way of producing or creating life *de novo*, as a new and original human invention.

Furthermore, one could claim that it is impossible to recreate life under default methodological requirements because OoL could be a unique event, similarly to the Big Bang in the theory of the origin of the universe.⁷ Perhaps first life originated by chance, but the probability of its origin is effectively zero.⁸ Crick believes it is possible to mark such an event as a “happy accident”. Troland thinks that such an unbelievable occurrence is possible over a long time period (Fry 2000). However, it was not the case on Earth, where life arose quickly after the formation of favorable conditions: the estimates are from “100 million years for RNA and DNA-based living system to appear on earth” (Penny 2005: 660) to “a mere crack: 10 or even 5 million years” (Griesemer 2008: 271). It could be that OoL was a unique event, a singularity (Oró 2002), which cannot be explained by acceptable scientific theories (or hypotheses) because it occurs once and only once. Unique events, per se, cannot reoccur because “their significant properties are either not shared by any other event ... or it is impossible to know that” (Tucker 1998: 66). Such a phenomenon is still natural, but underdetermines all potential scientific explanations.

The cases that clarify the above claims are instances of the arch-and-scaffolding model of OoL’s explanation. All theories of this kind use as their model a simplified metaphor of an arch built of stones: an arch could be built gradually, stone by stone, with the help of a supporting scaffolding. The scaffolding is then removed, and the arch remains in place. There are several examples. The first is Cairns-Smith’s advanced version of his mineral-genes theory based on the idea of an organism as a system (of biochemical machin-

⁷ Of course, if the Big Bang is a physical event. The question whether the Big Bang could be considered a physical event arises because this type of event has to be placed within a space-time context. “But the Big Bang has no space-time context; there is neither time prior to the Big Bang nor a space in which the Big Bang occurs. Hence, the Big Bang cannot be considered as a physical event occurring at a moment of time” (Reichenbach 2016).

⁸ The probability of producing an original set of enzymes by the “random stuffing of amino acid is one part in 10^{40000} ” (Hoyle, Wickramasinghe 1981: 129).

ery) where everything depends on everything. Another arch-and-scaffolding model is Kauffman's autocatalytic network of catalysts, as a representative metabolic approach that assumes that a living system could arise through the dynamics of integrated metabolic cycles. The third arch-and-scaffolding model is Wächtershäuser's pyrite-pulled chemo-autotrophic model of metabolic cycles.

The arch-and-scaffolding model of explanation seems rational and persuasive, but it is at odds with the principle of current utility and does not operate with forces and principles existing now. Also, the model contains an unknown factor (the scaffolding), whereby it remains an important theoretical model for philosophical reflection, but is unsuitable for empirical test or verification. Theoretically, this model can serve as an explanation given that science has not yet explained OoL within the accepted scientific methodology.

Scientific research on OoL has reached a high level of understanding of the elements, processes, functions, and complex systems of living. Still, the key task, putting forward a hypothesis or theory that would allow successful experimental repetition of the process of origin of life from inorganic compounds, has not been accomplished. The insistence on methodological requirements of reductionism and on (meta)heuristic rules did not decrease the gap between the inorganic and organic worlds. The failure of scientific explanation could be associated with placing OoL within the ontology of repeatable events and the epistemology that requires drawing conclusions from known general laws (the DN model) and presupposes the availability of numerous different repeatable events for testing. Accordingly, it is necessary to consider a modification of methodology, which would abandon the ontology of repeatable events or loosen some heuristic principles that are irrelevant for the field of life science. Alternatively, science needs to be prepared for a reduction of the scope of scientifically explainable phenomena.

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