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Hypothesis

The Origin of Life as the Origin of Biological Persistence: Molecular Darwinitis, the Category Jump, and the Soft Problem of Life

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Abstract

Origin-of-life research has largely focused on how the components of life arose and became integrated. Biological persistence, the continued existence of a living system actively maintained by the system itself, is assumed to follow once chemistry is sufficiently complex. We argue that persistence is a distinct explanandum and identify two conceptual obstacles that have kept it out of view. Molecular Darwinitis applies biological categories such as survival, fitness and selection to chemical systems before biological organization exists. The Category Jump treats extreme improbability as a substitute for mechanism, and Darwinian vocabulary, we argue, keeps this jump hidden. What remains is the Soft Problem of Life: how matter acquired conatus, the capacity to maintain and restore the conditions of its own existence. We propose that conatus emerged gradually from a measurable persistence bias, name its still-unidentified source aliqon, and argue that primitive restoration plausibly preceded replication. The framework yields testable predictions and suggests a shift in emphasis: from asking only how life's components arose to asking how chemistry became persistent.

Keywords: origin of life; biological persistence; Molecular Darwinitis; conatus; aliqon; self-maintenance

1. Introduction

Origin-of-life research has made substantial experimental progress since the mid-twentieth century. Plausible prebiotic routes have been demonstrated for many of life's building blocks, and contemporary models increasingly seek an integrated account of how these parts combine into a functioning whole[1,2]. Yet no generally accepted pathway from chemistry to life has emerged. The field remains divided not only over what came first, but over where the transition occurred and how it should be investigated[3,4].

We argue that part of this difficulty lies in a question that has rarely been posed explicitly. Most origin-of-life scenarios treat biological persistence, the continued existence of a living system as an organized whole, actively maintained by the system itself, as something that will follow once sufficiently complex chemistry has been assembled. We argue instead that persistence is a distinct explanandum. No amount of assembled complexity explains, by itself, why a chemical organization comes to maintain and restore the conditions of its own existence. Explaining that transition, the origin of what we will call conatus, is a prior problem the field has not yet posed clearly. It is also experimentally approachable: if persistence arose gradually, its earliest form should be measurable as a bias toward restoring organization after perturbation, exceeding what passive or purely dynamic stability alone would produce.

That persistence came to be taken for granted is partly a matter of history. Through much of the nineteenth century, it remained an open question whether living matter required some principle beyond the physics and chemistry then known. Vitalist answers declined as more and more phenomena once regarded as uniquely vital became experimentally accessible[5]. Darwin kept the

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origin of life separate from the origin of species.[1] In 1863 he wrote that there was no experimental basis for claiming that known physical forces could produce a living organism from inorganic matter. Privately, in his 1871 letter to Hooker, he imagined a "warm little pond" in which increasingly complex organic compounds might form[7,8]. Having supplied a powerful explanation for the evolution of living organisms, he did not simply extend natural selection backward across the boundary between chemistry and life.

The Oparin-Haldane framework of the 1920s replaced that boundary with gradual chemical evolution, and Miller's 1953 experiment gave the program experimental force[9–11]. This transition was enormously productive: the origin of life became a problem that could be attacked in the laboratory. But two propositions gradually became easy to conflate: that life has a material origin, and that increasingly complex chemistry is sufficient to explain the transition to life. The first is the foundation of modern origin-of-life research. The second is an explanatory claim that must itself be demonstrated. The rejection of vitalism established where the bridge between chemistry and biology must be sought: in the material world. It did not establish what that bridge is.

In what follows, we first examine how contemporary integrative approaches increasingly import evolutionary reasoning into prebiotic chemistry (Section 2). We then characterize biological persistence as the phenomenon requiring explanation (Section 3). Next we identify two conceptual obstacles that have kept this phenomenon out of view, Molecular Darwinitis (Section 4) and the Category Jump (Section 5), and formulate the resulting Soft Problem of Life (Section 6). Finally, we introduce aliqon as a name for the source of the earliest persistence bias, outline why restoration may have preceded replication, and propose how persistence bias could be measured (Section 7).

2. The Integrative Turn and Its Evolutionary Vocabulary

For several decades, origin-of-life research was organized around competing "first" scenarios: replication or RNA first, metabolism first, compartments first. Each captured something essential, and none proved sufficient alone. Replication does not supply metabolism or a boundary; metabolism does not readily provide heredity; compartmentalization by itself supplies neither. Contemporary models therefore increasingly seek the coordinated emergence of several properties, treating replication, metabolism and compartmentalization as interdependent features of a system maintained away from equilibrium and eventually capable of evolution[1]. The shift is understandable. Experiments have become increasingly successful at producing biologically relevant building blocks, yet making those components interact as a coherent system remains much more difficult[3].

This integrative turn has precedents. Oparin's coacervates already emphasized organized, localized multimolecular systems, and Gánti's chemoton explicitly coupled metabolism, informational replication and boundary formation[12,13]. In broad terms, the field has come full circle. Early whole-system models gave way to decades devoted to individual building blocks and subsystems, and these experimentally dissected components are now being reassembled in integrated protocell models. The experimental sophistication is radically different, but the underlying problem remains: how do multiple chemical functions become one biological organization?

As the number of interacting functions grows, the number of possible arrangements, and of routes by which they could have been built, grows explosively. Assembly Theory is one recent attempt to formalize this difficulty. It characterizes an object by the minimum number of recursive steps required to construct it, its assembly index, and uses assembly index together with copy number to infer that selection has operated[14]. The framework explicitly seeks to extend selection and historical contingency from biology into chemistry. It remains strongly debated, and critics dispute both the

[1] Darwin did not regard the question as unimportant, only as premature. Writing to Hooker in 1863, he remarked: "It is mere rubbish thinking, at present, of origin of life; one might as well think of origin of matter"[6]. By setting the origin of life beside the origin of matter, he treated it as a foundational question, one the science of his day was not yet equipped to answer.

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novelty and the explanatory power of its measures[15]. We need not resolve that debate here. What matters is the problem to which it responds: complex chemical organization that is produced repeatedly becomes increasingly difficult to explain by random assembly alone.

At this point a recurring move becomes visible across otherwise different frameworks: evolutionary reasoning is introduced progressively earlier in the transition from chemistry to biology. Replicators are allowed to differ in reproductive success; molecular associations are retained because they confer advantages; protocells compete; and selection is invoked to explain the progressive integration of metabolism and compartmentalization[16,17]. Seelig and Chen make this logic particularly explicit. Once chemistry establishes how the components of a complex biochemical system could arise, they argue, one must ask why those components would have been retained by natural selection. Their molecular-bricolage model uses differential fitness and selection to explain how initially unrelated functions could become incorporated into larger systems[18].

Our concern is not that such models are wrong. Many are carefully constructed, and some authors explicitly analyze the conditions under which selection concepts can legitimately be applied to chemical systems[19,20]. The concern is narrower. Concepts originally developed to describe living systems, such as heredity, competition, fitness, reproduction and selection, are increasingly asked to explain why particular chemical structures persist, spread and become integrated, before a biological system has been established. This raises a prior question: what kind of persistence must a chemical system possess before these concepts become biologically meaningful? We turn to that question next.

3. Biological Persistence: The Phenomenon to Be Explained

Defining life has proved notoriously difficult. No universally accepted definition exists, and formulations emphasizing metabolism, reproduction, autonomy, compartmentalization or Darwinian evolution all encounter difficult boundary cases[21,22]. Perhaps the safest definition is almost tautological: life is that which is alive. Scientifically, this says little. Conceptually, it points to a feature that deserves more attention. To be alive is to continue to exist as a living system. Whatever else living systems do (grow, reproduce, evolve, sense or metabolize), they must maintain or recover the conditions that allow them to remain alive. Continued existence therefore marks a useful conceptual line between the living state and its loss. It is not an exceptionless diagnostic test: dormancy, spores, viruses and sterile organisms all complicate any concise definition of life. Such cases do not, however, remove the usefulness of identifying what is characteristic of living organization.

The relevant kind of continued existence is not persistence in the ordinary physical sense. Rocks, crystals and stable molecules may last a long time simply because they are durable. Living systems persist differently. Their components turn over, macromolecules are damaged, gradients dissipate, membranes leak and environmental conditions fluctuate. Yet the system maintains or restores the conditions required for its continued existence. We call this phenomenon biological persistence: the continued existence of a living system as an organized whole, actively maintained by the system itself.[2]

For the capacity that produces biological persistence, we borrow the term conatus from Spinoza, who used it for the striving of each thing to persevere in its being[23]. Our use is scientific and narrower.

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[2] Flames, vortices and convection cells also persist as patterns of flow that recover from small disturbances. They recover their form while externally supplied boundary conditions persist, but contain no organization whose activity acts to maintain or restore those boundary conditions. A flame consumes its fuel and oxygen but cannot influence whether more arrives, and its recovery is carried out by physical processes it does not itself produce. Such dynamic persistence is not on the path described here, and the definition of conatus excludes it. Some such structures, including convection cells, can also drift toward conditions that sustain them (Appendix A); this changes where they are, not the boundary conditions themselves, and their recovery remains the work of processes they do not produce.

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By conatus we mean the capacity of a system to maintain and restore the conditions required for its own continued existence, such that maintenance and restoration are recurrent consequences of processes organized and sustained by the system itself. The components that carry out this work are themselves produced by the system. The term implies neither consciousness nor intention, and it invokes no non-material cause. It names a property of biological organization.

Biological persistence is therefore active. A cell maintains ion gradients, replaces damaged proteins, repairs DNA, restores membrane integrity, regulates metabolism, removes harmful products and alters its activity when conditions change. These mechanisms differ enormously, but they share a common consequence: perturbations that threaten viability initiate processes that preserve or restore the system. Continued existence is not merely something that happens to a living system; it is repeatedly produced by the system's own organization.

What persists, moreover, is not a fixed collection of matter. A cell remains the same biological system while continuously replacing its proteins, lipids and metabolites. A spinning gyroscope offers a partial analogy. Its characteristic stability belongs to no single component but to the organized system in motion; stop the rotation and the stabilized state disappears, although every part remains. In the same way, biological persistence cannot be assigned to metabolism, replication, compartmentalization, repair or any other isolated process. Membranes sustain the gradients that metabolism requires; metabolism supplies resources for maintenance and replacement; genetic systems supply the information for building components; regulatory networks coordinate their activity. Persistence belongs to the organized dynamics of the whole. A living system, however, goes further than the gyroscope: when its organization is perturbed, its own activity contributes to restoring the conditions under which that organization persists.

Persistence must also be distinguished from molecular replication. Replication can preserve or amplify a molecular pattern without giving the replicating entity any capacity to maintain itself. A molecule that produces a copy before degrading has contributed to the continuation of a lineage, but it has not thereby acquired conatus. Replication preserves succession; biological persistence preserves the organized system. The two eventually become tightly coupled, but they are not the same phenomenon, and their order matters. Darwinian evolution requires something whose continued existence is at stake. Replicating molecules can evolve without conatus of their own. RNA evolving in a test tube is the classic example, but it evolves only because the conditions of its replication, from the replicase enzyme to the supply of nucleotides and the transfers between tubes, are maintained by living systems or by the experimenter[24]. Evolution without conatus occurs only where conatus is borrowed.[3] We therefore treat conatus as a precondition of open-ended evolution rather than its product.

This distinction matters directly at the origin-of-life boundary. A prebiotic system may possess chemical stability, autocatalysis, compartments, replication, variation or even selection-like dynamics while still lacking the integrated capacity to maintain and restore itself as an organized whole. Increasing the number or sophistication of such functions does not, by itself, explain the emergence of conatus. The central question is how chemical processes became coupled so that the continued existence of the system became a recurrent consequence of their interaction.

The idea that living systems are distinguished by self-maintaining organization is not new. Maturana and Varela's autopoiesis, and the autonomy tradition developed by Ruiz-Mirazo, Moreno, Mossio and colleagues, characterize living organization as self-producing and self-maintaining. Montévil and Mossio formalize this as a closure of constraints, in which each constraint both depends

[3] The same point applies to the RNA world, the most influential current scenario for the origin of life. Two RNA enzymes that assemble each other from smaller RNA pieces can replicate indefinitely and even evolve in the laboratory, but only while the experimenter supplies the pieces and transfers the mixture to fresh supplies[25]. Suppose such a pair arose by chance in a prebiotic pool. What would maintain the conditions of its replication there? Where does the RNA world get its persistence?

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on others and contributes to maintaining them[26–29]. What we call conatus corresponds closely to this self-maintaining organization. We adopt the term to emphasize persistence as the phenomenon an origin-of-life account must explain, rather than as a definition of life. Unlike Ruiz-Mirazo and colleagues[27], we do not build open-ended evolution into the living state, for the reasons just given. Pross has made persistence central to the transition from chemistry to biology, arguing that replicating systems achieve a dynamic kinetic stability distinct from thermodynamic stability[30,31]. His account explains why populations of replicators persist; it does not explain why an individual chemical organization comes to maintain itself, which is the question we pose. Closest to our view, Deacon's autogen model places self-repair before template replication[32,33]. We share that ordering, but differ on how replication arises (Section 7) and in seeking a general, measurable criterion for the earliest persistence rather than a specific model system.

If this view is correct, the order of explanation matters. Survival, fitness, competition and reproduction acquire their biological meaning only once there is an organized entity whose continued existence is at stake. How such an entity, and its conatus, first arose is therefore a central question for any account of the transition from chemistry to life.

Box 1. Key terms

Biological persistence: the observed phenomenon of a system continuing to exist as an organized whole despite turnover of its components and perturbation.

Persistence bias: a tendency, however weak, for an organization to be retained or re-formed after perturbation more often than passive or purely dynamic stability would predict.

Primitive restoration: the earliest form of persistence bias, in which disruption raises the probability that the previous organization, or a functional equivalent, is re-established.

Conatus: the system-level capacity to maintain and restore the conditions of its own continued existence through its own activity; the developed form of persistence bias.

Aliqon: the still-unidentified basis responsible for the first persistence bias, defined by its measurable effect; its nature is left open (Section 7).

Molecular Darwinitis: the application of biological categories such as survival, reproduction, fitness and selection to chemical systems before the biological organization that gives those terms their meaning has emerged.

Category Jump: treating extreme improbability as though it could substitute for a mechanism connecting chemistry to life.

Soft Problem of Life: how chemical organization acquired conatus.

aliqon → persistence bias (primitive restoration) → conatus → replication and heredity → evolution

4. Molecular Darwinitis

The tendency described in Section 2 has not gone unnoticed. A recent review of evolutionary thinking at the origin of life concluded that evolutionary terminology is used inconsistently in the field, often without adequate justification. The authors distinguish four levels at which such usage might be justified: ontological, epistemological, heuristic and metaphorical[20]. Their analysis asks whether evolutionary concepts can legitimately be applied to prebiotic chemistry. We ask a different, prior question: what do those concepts presuppose?

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Raymond Tallis introduced the term Darwinitis for the tendency to extend Darwinian explanation beyond the domain in which it is warranted[3,4].[4] We use Molecular Darwinitis for a related tendency at the chemistry-to-life boundary: the application of biological categories such as survival, reproduction, competition, fitness, heredity and selection to chemical systems before the biological organization that gives those terms their meaning has emerged. In the terms of Schoenmakers et al., Molecular Darwinitis occurs when a term justified only heuristically or metaphorically is allowed to do ontological work.

The underlying chemical phenomena are not in question. Molecules differ in stability, catalyze their own or one another's formation, consume common substrates, generate copies and increase differentially in abundance. The difficulty begins when these observations are translated directly into biological language. Chemical persistence becomes survival; copying becomes reproduction; molecular variants become descendants; differential amplification becomes fitness; and competition for substrates becomes biological competition. Each translation sounds natural because biology ultimately operates through chemistry. Yet the terms are not equivalent.

Consider survival. If one molecule remains intact longer than another, it may conveniently be said to "survive" longer. In chemical terms, this may mean nothing more than slower degradation. Biological survival is the continued existence of an organized system that maintains and restores the conditions of that existence. A molecule can remain chemically intact without doing anything to preserve itself; a living cell persists through conatus. The same word describes two different modes of persistence.

Table 1. Chemical phenomena and the biological categories applied to them.

Chemical phenomenon	Biological category	What the category presupposes
Slower degradation	Survival	A system maintaining the conditions of its own existence
Template copying	Reproduction	A persisting individual giving rise to another of its kind
Shared substrate	Competition	Resources affecting the persistence of organized entities
Differential amplification	Fitness, selection	Individuals whose continued existence is at stake

The same holds for reproduction. A template molecule may direct the formation of a complementary sequence, or an autocatalytic system may increase the number of molecules resembling itself. Such copying may be central to origin-of-life chemistry. But propagating a molecular pattern is not the same as reproducing a biological individual. Biological reproduction presupposes an organized entity that persists long enough for another organized entity of the same kind to arise from it. Replication preserves a pattern; reproduction continues a lineage of persistent systems.

[4] This essay owes its starting point to Raymond Tallis's diagnosis of Darwinitis: the use of a respected scientific theory, Darwinian evolution, in domains where its reach is limited or where it does not belong. Tallis developed the idea with great clarity in relation to the human mind and culture, and I find it both persuasive and illuminating. Reading his work, I began to suspect that the same habit operates at the other end of life's history, at the boundary between chemistry and biology. Molecular Darwinitis extends his diagnosis to that domain, where it can be judged on its own terms.

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Likewise, two reactions that consume the same limited substrate reduce one another's yield. Calling this competition is convenient shorthand. Biological competition carries additional meaning: access to resources affects the persistence and reproduction of organized entities. The chemistry of limited resources may contribute to that later relationship, but it does not by itself establish it.

The same caution applies to fitness and selection. If molecular species A is copied more efficiently than B, A becomes more abundant. This differential amplification is real, can be described mathematically and may produce selection-like dynamics. But greater abundance alone does not show that A maintains itself or constitutes a biological individual. A may simply be a more stable molecule or a better substrate for a particular reaction.

An obvious objection is that selection is defined abstractly. On Lewontin's formulation, any population of entities that vary, differ in reproductive success and pass on their variations will evolve by natural selection, whatever those entities are made of[35]. On this view, applying selection to molecules is no category error. We accept the formal point. Selection-like dynamics can occur in purely chemical systems, and describing them as such is legitimate as a useful way of thinking. But the abstract conditions say nothing about what the entities are or how they came to exist. Godfrey-Smith makes a related point by showing that Darwinian populations come in degrees[36]. In paradigm cases, such as populations of animals, individuals are clearly bounded, offspring closely resemble their parents, and differences in success depend on the individuals' own characteristics; here, selection explains a great deal. In marginal cases these features are weak or absent: the boundaries between individuals are blurred, copying is unreliable, and success depends largely on chance or circumstance. There, selection explains little, even when the formal conditions are met. Prebiotic chemistry is, at most, a marginal case. To describe it in the language of paradigm cases is precisely Molecular Darwinitis: the word "selection" is retained, while the conditions that give it explanatory force are missing. The same applies to proposals that treat differential persistence itself as a form of selection[37]. In chemistry, longer-lasting structures accumulate, but calling this selection presupposes the persisting individuals whose origin is in question. The error we describe is not the use of selection concepts in chemistry. It is the inference that, because the formal conditions of selection can be met, the emergence of the entities that make biological selection possible has been explained.

The problem, therefore, is not merely semantic. Once molecules are described as surviving, competing, reproducing, possessing fitness and leaving descendants, they begin to appear already partly alive. The biological categories then perform explanatory work that the underlying chemistry has not yet supplied. This matters especially in origin-of-life research, where the phenomenon requiring explanation is precisely the transition between these domains. If chemical persistence is renamed survival, copying is renamed reproduction and differential abundance is renamed fitness, the distance between chemistry and life shrinks in the language before it has necessarily shrunk in the system (Figure 1, left panel). Appendix A applies a simple translation test to six examples from the literature.

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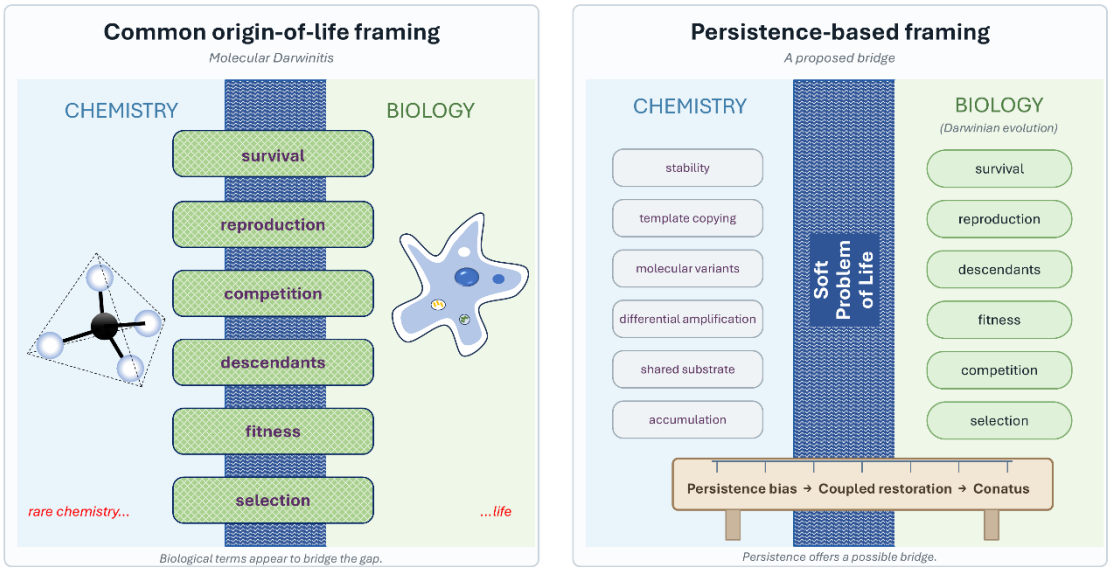


Figure 1. Two ways of framing the transition from chemistry to life. Left: in the common framing, biological terms (survival, reproduction, descendants, competition, fitness, selection) are applied to chemical systems and appear to span the gap between rare chemistry and life. This is Molecular Darwinitis: the vocabulary bridges the gap, but the explanation does not. Right: in the persistence-based framing, each chemical phenomenon is described in its own terms (stability, template copying, molecular variants, shared substrate, differential amplification, accumulation), and the biological terms are reserved for systems that maintain themselves. The gap between the two is the Soft Problem of Life: how chemical organization acquired conatus. The proposed bridge runs through persistence, from a persistence bias, whose still-unidentified source we call aliqon, to conatus (Figure 3).

A clearer distinction is therefore needed (Table 1). Chemical stability can contribute to biological survival; molecular copying can become part of biological reproduction; differential amplification can contribute to evolutionary selection. But the chemical phenomena should not automatically inherit the full explanatory meaning of the biological categories. The transition from one to the other is not a change of vocabulary. It marks the emergence of an organized system possessing conatus (Figure 1, right panel).

Recognizing Molecular Darwinitis does not tell us how that transition occurred, but it prevents biological terminology from making the transition appear already explained. A second obstacle concerns not vocabulary but probability: even if every required chemical event is physically possible, does possibility, or extreme rarity, explain the appearance of a new mode of organization?

5. The Category Jump

Molecular Darwinitis obscures the chemistry-to-life boundary by describing chemical phenomena in biological terms. A second, related problem appears when the emergence of life is treated as a question of improbability. Origin-of-life scenarios often assume that, given enough molecules, environments, reaction cycles and geological time, even extraordinarily rare events will eventually occur. That reasoning is appropriate for rare chemical events. It is not sufficient to explain the emergence of a new mode of organization.

Consider an accident I once witnessed in a restaurant. A waiter carrying a tray with several glasses of red wine collided with a table. The glasses scattered; most tipped over or shattered, and wine spilled across the floor. Yet one glass fell all the way to the floor and landed upright, still full, apparently without spilling a drop. The event was astonishing, but nothing about it was conceptually puzzling. It was extremely unlikely, yet it belongs to the same class of events as the others: glasses

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fall, roll, break or, very rarely, land upright. Given enough such accidents, an outcome of this kind should eventually occur.

Now imagine that the glass standing on the floor had contained white wine, although it held red wine before it fell. Calling this event extraordinarily improbable does not explain it, and neither would multiplying the number of restaurant accidents by a million or a billion. We would immediately ask what transformed the wine. The point is not that such a transformation is impossible, but that it requires a mechanism; in the case of life, a material one, still to be found.

Rarity cannot substitute for mechanism.

The same distinction applies to the origin of life. An unusually stable molecule may be rare; a catalytic RNA rarer; a self-copying molecular system, an autocatalytic network or a selectively permeable vesicle rarer still. These are questions of chemical possibility and probability, and given suitable conditions and sufficient opportunities, rare chemical configurations may indeed arise. But a system possessing conatus is not merely another rare configuration. Its appearance cannot be explained by assigning it a sufficiently small probability. Saying that an event occurred once in 10^{20} trials does not make its mechanism any clearer than saying that it occurred once in ten (Figure 2).

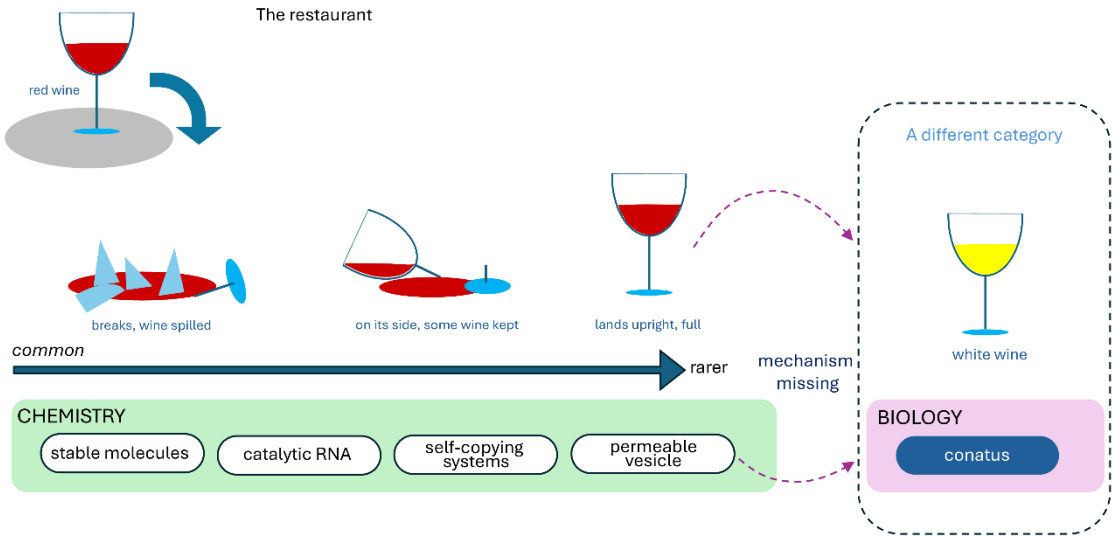


Figure 2. The Category Jump. Glasses of red wine knocked from a waiter's tray land in outcomes of decreasing probability: broken and spilled (common), on their side with some wine kept, and, very rarely, upright and full. However rare, these outcomes belong to the same class of events, and enough accidents make even the rarest one expected. The chemical counterpart, shown below, is a series of progressively rarer configurations, from stable molecules to permeable vesicles, all of which remain chemistry. A glass standing upright and full of white wine belongs to a different category: no number of accidents explains it, because a mechanism is missing. Likewise, a system possessing conatus is not a still rarer chemical configuration but a biological one. Treating extreme improbability as a substitute for the missing mechanism is the Category Jump (dashed arrows).

We call the move from the first kind of event to the second the Category Jump. The reasoning runs from "a sufficiently complex chemical system could arise, however rarely" to "therefore a living system could arise," without identifying the mechanism by which chemical complexity becomes biological persistence. Its classic statement is Wald's: given enough time, "the 'impossible' becomes possible, the possible probable, and the probable virtually certain"; "time is in fact the hero of the plot"[38]. A modern and more explicit version is Koonin's proposal that the first replication and translation systems emerged by chance, made plausible by the vast number of trials available in an eternally inflating universe, with biological evolution beginning only afterwards[39]. Koonin's account has the virtue of making the chance step explicit.

More often, the jump is left implicit, and here the two obstacles meet. Most current scenarios do not appeal to luck. They divide the transition into many small, individually plausible steps and

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invoke selection to accumulate them. But as Section 4 argued, before there are entities whose continued existence is at stake, "selection" refers to differential chemistry: some structures form faster, last longer or are copied more efficiently. Remove the Darwinian vocabulary, and what remains is a sequence of rare chemical events followed by life, with the step from one to the other still unexplained. Darwinian language lends that step the familiarity of evolution, which no one doubts, and the missing mechanism goes unnoticed. Molecular Darwinitis is how the Category Jump stays hidden. Recognizing the first is what exposes the second.

None of this implies that the transition was abrupt. The jump lies in the explanation, not necessarily in nature. Persistence may well have emerged through many small increments, but each increment in the capacity to maintain and restore organization requires a mechanism of its own. Gradualism distributes the explanatory burden; it does not remove it.

Nor does the argument require anything non-material. Life is material, and the transition to life must therefore have a material basis. But that fact does not supply the missing explanation. Materialism tells us where the bridge must be built; it does not build the bridge. Once the Category Jump is recognized, the chemistry-to-life transition can no longer be treated as complexity plus improbability, or as complexity plus selection. The question becomes how chemical organization acquired conatus. That is the problem to which we now turn.

6. The Soft Problem of Life

Once Molecular Darwinitis and the Category Jump are set aside, what remains is an unexplained transition: from chemistry that merely lasts to chemistry that maintains and restores itself. Origin-of-life research has largely asked how increasingly complex prebiotic systems could arise: how building blocks formed, how polymers were produced, how catalytic networks developed, how compartments assembled and how replication might have begun. These questions are essential. But even a complete answer to all of them would leave a further question open:

How did chemical organization acquire conatus?

We call this the Soft Problem of Life. The name is a deliberate echo of Chalmers's distinction in the study of consciousness[40]. There, explaining cognitive functions such as perception, memory and report leaves untouched the "hard problem": why any of these functions should be accompanied by experience. The origin of life has a similar structure. The component problems (how RNA, membranes, metabolism or replicators arose) are difficult in practice but well defined.

The parallel ends there, and the difference explains the name. The problem is soft in two senses. First, the boundary it concerns is probably not sharp: biological persistence may have emerged gradually, through intermediate systems with increasing capacities for maintenance and restoration, rather than at a single identifiable moment. Second, and unlike the hard problem of consciousness, it is open to experiment. Whether a chemical system tends to restore its own organization after perturbation is, in principle, a measurable property. "Soft" does not mean easy or secondary. A bridge does not cease to be necessary merely because it is crossed in small steps.

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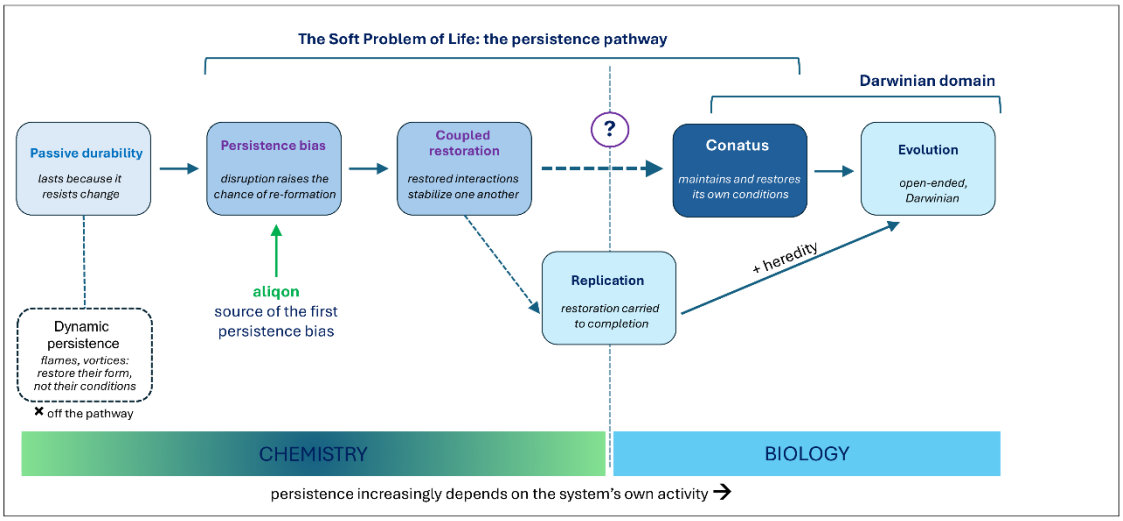


Figure 3. The persistence pathway. Passive durability (left) describes structures that last only because they resist change. On the proposed pathway, a persistence bias, whose still-unidentified source we call aliqon, first appears as primitive restoration: disruption raises the probability that the previous organization is re-established. As restoring interactions become coupled and stabilize one another, persistence shifts from individual structures to the organized whole, and conatus emerges: the system-level capacity to maintain and restore the conditions of its own continued existence. Conatus marks the transition from chemistry to biology. It is the endpoint of the Soft Problem of Life and the precondition of the Darwinian domain, and therefore lies under both brackets. Replication is proposed to have grown out of restoration, as restoration carried to completion; it provides heredity, and together with conatus makes open-ended Darwinian evolution possible. Dashed arrows mark proposed but unexplained steps: the emergence of conatus from coupled restoration (the Soft Problem) and the origin of replication from restoration. Dynamic persistence, as in flames or vortices, restores form but not the conditions on which it depends, and lies off the pathway.

The Soft Problem can also be put as a why-question: why did any chemical system begin to maintain and restore the conditions of its own continued existence? Here "why" is meant entirely in the scientific sense. It implies no purpose, intention or final cause. We are not asking what life is for. We are asking what physical principle, organization or causal architecture made persistence a property of matter organized in a particular way: what accounts for the appearance of this directional feature of chemistry.

Any answer to the Soft Problem must be material: it must identify a mechanism. Beyond this requirement, we adopt a working hypothesis: that conatus did not appear at once but emerged gradually. If so, its earliest form should have been a simple bias, a tendency for some chemical organizations to be retained or re-formed after perturbation more often than passive or purely dynamic stability would predict. In the final section, we propose how the source of such a bias might be conceived, why it would have preceded replication, and how it could be detected.

7. Aliqon: A Proposal

Molecular Darwinitis and the Category Jump are the core of our argument. Together they show why the origin of persistence has rarely been posed as a problem in its own right. What follows is not a solution to the Soft Problem, but our view of where a solution might be sought and how it could be tested.

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We use the term aliqon for whatever accounts for the earliest persistence bias described at the end of Section 6.[5] Aliqon does not specify a mechanism. It names what a mechanism must explain.

Introducing a name for something not yet identified requires justification, and biology offers a familiar precedent. Mendel inferred hereditary "elements" from the measurable ratios of his crosses, with no knowledge of their physical nature. When Johannsen later coined the word "gene," he deliberately left open what genes were made of[41]. Genes were nonetheless treated as real, and their effects were measured: how often traits were inherited together allowed geneticists to map the relative distances between genes, in centimorgans, decades before the molecular structure of DNA was known[42]. Their chromosomal and then molecular basis came later, and proved quite unlike anything Mendel could have imagined. A placeholder of this kind is legitimate when it is inferred from a measurable effect, when it supports predictions that could fail, and when it leaves its underlying nature open. Aliqon is proposed in the same spirit as the gene. Its effect, a persistence bias, should be measurable; the predictions below could fail; and its nature is deliberately left open. We do not exclude the possibility that it reflects a more fundamental, as yet unobserved, property of matter. Nor does the proposal require one: aliqon may ultimately prove reducible to known chemical or organizational principles. Whatever it proves to be, it is provisional.

Aliqon should be distinguished from conatus. Aliqon is the basis of the earliest persistence bias; conatus is the developed, system-level capacity to maintain and restore the conditions of continued existence. Between them lies a pathway of increasing persistence (Figure 3). Its first step, we suggest, was primitive restoration: disruption of a molecular organization raising the probability that the previous organization, or a functional equivalent, would be re-established. Even a weak tendency of this kind would be a significant departure from passive persistence. The system would not merely endure favorable conditions; its own organization would contribute to its recovery. As restoring interactions became coupled, with one interaction stabilizing another or one reaction replacing a lost component, persistence would shift from individual structures to the network of relations among them. At that point, conatus would begin to emerge as a property of the organized whole.

This view implies that restoration preceded replication, an ordering Deacon has also proposed[32,33]. Our argument for it can be stated in four steps. First, structures that last longer accumulate: in a steady state, abundance reflects both rate of formation and lifetime, so durable structures become enriched without anything copying them. This is accumulation through differential persistence, not selection. Second, where interactions among components hold a damaged structure together long enough, re-formation becomes more likely than disintegration. This is the persistence bias attributed to aliqon. Third, in nucleic-acid-like molecules, a damaged strand can be rebuilt on its intact partner by base complementarity. This is restoration, not yet copying, and recent work shows that RNA alone can catalyze the repair of broken RNA[43]. Fourth, rebuilding an entire partner strand applies the same template-directed principle as repairing a gap, carried to completion. On this view, replication need not have arisen independently. It may have grown out of restoration, as its runaway extension.[6] Once established, replication could greatly amplify

[5] Aliqon is a coined term inspired by the Latin aliquid, "something." It denotes the presently unidentified something that makes persistence-biased organization possible, without presupposing whether its eventual explanation will be chemical, physical, organizational or emergent.

[6] Nucleic acids can repair some lesions without enzymes: thymine dimers in duplex DNA can be repaired by charge transfer from neighbouring bases[44], and the prebiotically plausible base 2,6-diaminopurine promotes such self-repair[45]. We take this one step further and suggest that a comparable non-enzymatic process could replace nucleotides along a strand with correctly paired ones. Because nucleic-acid strands can displace one another without enzymes, by invading a duplex from a short single-stranded overhang (toehold-mediated strand displacement)[46], such progressive replacement could in principle separate the old partner strand and leave the template free for a new cycle of restoration. This remains a hypothesis; we raise it only to indicate that

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persistence and eventually make heredity and Darwinian evolution possible. The more primitive transition was the appearance of a bias to remain.

One question this account leaves open is how improvements in persistence could accumulate before heredity existed. Longer-lived structures might grow by accretion, fragment into pieces that retain their organization, or form repeatedly under recurring conditions. We do not resolve this question here, but any account of the pathway to conatus will have to answer it.

The proposal becomes testable through its central claim: persistence bias should be measurable, in principle, against controls that exclude both passive durability and purely dynamic re-formation. Box 2 illustrates how this might be done.

Box 2. Illustrating the falsifiability of the persistence-bias hypothesis

The approaches below are illustrations, intended to show that the proposal can be tested, not definitive research directions.

Operational definition. A system shows persistence bias if, after a standardized perturbation, it recovers its prior organization more often or more rapidly than a matched control containing the same components with the coupling between them disrupted. Two baselines must be excluded: passive stability (durable structures) and purely dynamic stability (patterns re-formed by external flows, as in a flame or vortex).

Candidate systems. Chemically fueled dissipative self-assemblies; nonenzymatic template-directed ligation and repair of nucleic acids; peptide-nucleic acid assemblies; fatty-acid vesicles with internal chemistry[47–50].

An example. Short nucleic-acid polymers associated with amino acids or short peptides could be damaged in a controlled way, and the probability of their restoration compared with that of polymers alone. Enhanced restoration would be evidence of persistence bias. Comparing L-, D- and racemic peptides would test whether such a bias favors assemblies of matched chirality, which would bear on the origin of biological homochirality[51,52].

Predictions. Some chemical systems should recover their prior organization after perturbation more often than passive or dynamic baselines predict. This recovery should depend on interactions within the system: disrupting the coupling between components should reduce or abolish it, and strengthening the coupling should enhance it.

What would count against the proposal. A consistent null result: in systems with intact internal coupling, no recovery beyond what passive or dynamic stability would predict.

If such a bias can be found and measured, the Soft Problem of Life becomes an experimental question.

8. Conclusion

For all its success in explaining how the components of life could arise and become integrated, origin-of-life research has, we have argued, left a more basic problem largely unrecognized: how chemical organization acquired biological persistence. Two conceptual obstacles have kept that

neither non-enzymatic damage correction nor strand separation need be an obstacle to the ordering proposed here.

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problem out of view. Molecular Darwinitis applies biological categories such as survival, reproduction, competition, fitness and selection to chemical systems before the organization that gives those terms their meaning exists. The Category Jump treats extreme improbability as though it could substitute for a mechanism. The two are connected: Darwinian vocabulary lends the step from rare chemistry to life the familiarity of evolution, and the missing mechanism goes unnoticed.

Once both are set aside, what remains is the Soft Problem of Life: how matter acquired conatus, the capacity to maintain and restore the conditions of its own continued existence. Like the hard problem of consciousness, it survives the solution of every component problem; unlike it, it is open to experiment.

We have offered one view of where an answer might lie. If conatus emerged gradually, its earliest form should have been a simple persistence bias: matter's first tendency toward remaining rather than simply disappearing. We have named its still-unidentified source aliqon, a provisional placeholder in the spirit of the early gene. On this view, restoration preceded replication, and replication may have arisen as restoration carried to completion. These proposals can be tested and could fail. The arguments of Sections 4 and 5 do not depend on them: even if aliqon proves unnecessary, the questions those sections raise remain. This is where science and philosophy meet: whether the words used to describe a transition have quietly explained it in advance is a conceptual question before it is an experimental one[53].

The implication is a shift in emphasis. Alongside asking how life's components arose and became integrated, origin-of-life research should ask how, and why in the strictly scientific sense, chemistry became persistent. The origin of life may ultimately be understood not simply as the origin of replication, metabolism or compartments, but as the origin of matter capable of continuing itself. In that sense, the origin of life is the origin of biological persistence.

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Appendix A. A Chemical Translation Test

The examples below illustrate a simple question: **how much explanatory work is being performed by biological vocabulary in descriptions of prebiotic chemistry?** We do not suggest that terms such as *competition*, *fitness*, *adaptation*, *survival*, or *selection* are always illegitimate in origin-of-life research. They can be useful shorthand. Our concern is narrower: when such language is removed, how much of the apparent explanation of the chemistry-to-life transition remains? For each example, a biologized description is placed beside a chemically austere translation of the same underlying process.

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Table A1. Biologized descriptions and their chemical translations, ordered from restrained shorthand to increasingly explanatory use.[7].

Biologized description	Chemical translation
1. Lincoln & Joyce (2009)[25] *RNA enzymes "compete for a common pool of substrates," and some variants come to "dominate the population."*	Several RNA-catalyzed reaction systems use the same limited chemical substrates. Some reaction pathways generate products more rapidly than others, causing those products to increase in relative concentration.
Here the Darwinian language remains relatively restrained. *Competition* provides an intuitive shorthand for simultaneous consumption of limiting substrates, while *domination* describes the resulting difference in abundance. But neither term is required to describe the chemistry. What remains after translation is differential reaction kinetics and accumulation.	
2. Adamala & Szostak (2013)[54] *A dipeptide made inside vesicles can "confer a growth advantage"; vesicles containing the catalyst show "enhanced fitness, as measured by competitive growth," and grow "at the expense of" vesicles lacking the dipeptide.*	A catalyst enclosed within certain fatty-acid vesicles produces a dipeptide that modifies membrane dynamics. Those vesicles consequently acquire additional fatty acids more efficiently under the experimental conditions.
The experimental result remains interesting without invoking *advantage* or *fitness*. The chemical description specifies a causal chain: catalysis changes molecular composition, which changes membrane dynamics and therefore alters vesicle growth. The biological vocabulary adds something further: the suggestion that the resulting state is somehow better *for* the protocell.	
3. Joyce & Szostak (2018)[55] *RNAs facilitating "their own reproduction" enjoy a "selective advantage"; catalysts may generate compounds "for the benefit" of replicating entities; natural selection acts through differences in "fitness."*	Some RNA molecules catalyze reactions that contribute to further RNA synthesis. Certain molecular products remain localized within vesicles and alter subsequent chemical reactions. Some RNA-vesicle combinations therefore increase in relative abundance more rapidly than others.
The contrast becomes clearer here. *Reproduction, advantage, benefit,* and *fitness* make the system sound increasingly organism-like. Yet the chemically translated version still describes the relevant processes: catalysis, localization, altered chemical reactions, and differential accumulation. What disappears is the implication that these outcomes already possess biological significance for an entity whose continued existence matters.	

[7] Words in quotation marks in the left-hand column are quoted directly from the cited source; the surrounding wording paraphrases it.

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Biologized description	Chemical translation
4. Egbert et al. (2023)[56] *Abiological "ante-organisms" may already have been "actively regulating their environment to maintain the conditions necessary for their own persistence": "self-preserving" systems that "adaptively regulate their environment in response to their health, and in so doing, increase the likelihood of their survival."*	Some non-biological structures, such as reaction-diffusion patterns and reacting oil droplets, drift toward conditions in which the reactions producing them run faster, or alter their surroundings in ways that speed those reactions up. Such a structure therefore continues to be produced, and so lasts longer, than it otherwise would. The authors also use the example of an icecap, which cools its surroundings by reflecting sunlight and so allows more ice to persist.
Here the biological vocabulary is no longer shorthand, as in rows 1–3; it carries the explanation. Translated, "health" is a reaction rate, "self-preserving" is drift toward faster reaction, and "survival" is continued production. Because the same vocabulary can characterize an icecap, these terms cannot by themselves identify a specifically biological transition. If they imply more than stabilizing feedback, the chemistry described here does not supply that additional content.	
5. Gatenby et al. (2025)[57] *Night/day cycles create "opportunities and hazards"; strand separation, hydrolysis and UV damage act as "Darwinian selection forces"; self-replicating RNA "can adapt to hydrolysis"; early prebiotic systems could develop a "noncognizant intelligence."*	During the day, higher temperatures speed up reactions but also separate RNA strands, and single strands are hydrolyzed; UV light damages molecules. RNA sequences that fold back on themselves into hairpins are hydrolyzed more slowly, so more of them remain after each day. Because days and nights alternate regularly, the same molecules remain and accumulate at the same times, cycle after cycle.
At this end of the spectrum, Darwinian terminology organizes the explanatory narrative itself. Translated, "selection forces" are heat, hydrolysis and UV light; "adapting" is slower hydrolysis; and the apparent anticipation depends on the recurring day-night environment. The philosophical question is whether molecular dynamics that exploit such periodicity warrant the added category of "intelligence," or whether that term imports explanatory content not contained in the reaction dynamics themselves.	

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Biologized description	Chemical translation
6. Wikipedia: normalization in public discourse[58] *Lipid structures produce "offspring" and "daughter vesicles," establish "lineages," and become subject to "natural selection"; RNA systems possess "fitness" and can "adapt."*	Lipid compartments grow by taking up additional lipid and can split into two smaller compartments of similar organization and composition, which carry with them molecules associated with the original compartment. Compartments of some compositions grow and split more often than others and so become more common. Proposed RNA molecules with different sequences are copied or degraded at different rates.
Wikipedia is not introduced here as a scientific authority. Its relevance is that it shows how thoroughly this vocabulary has entered the general account of the origin of life. Translated, "offspring" and "daughter vesicles" are two compartments produced by a split, a "lineage" is a series of such splits, "natural selection" is some compositions becoming more common, and "fitness" is a rate of copying. In the encyclopedia's language, a dividing vesicle already sounds like an organism with descendants; in chemical language, it is a lipid compartment splitting in two. The public account has crossed a gap that the research has not.	

What the translation reveals

One feature of these comparisons is immediately visible: **the chemical translation is usually longer than the biologized description.** This is not accidental. Biological terms are powerful compression devices. A single word such as *competition*, *fitness*, *adaptation*, or *survival* can summarize a chain of chemical events that requires several sentences to describe mechanistically.

That linguistic economy is useful. But it also carries a philosophical risk. Compression does not merely shorten a description; it can change what kind of thing the system appears to be. Differential reaction rates become *competition*, prolonged persistence becomes *survival*, and differences in accumulation become *fitness*. In this way, the compressed vocabulary may quietly import biological properties before the emergence of those properties has itself been explained. This is the shift Schoenmakers et al. describe: terms whose use is justified heuristically or metaphorically come to be read ontologically[20].[8]

The purpose of the translation test is therefore modest: **expand the shorthand and see what remains.** If the apparent transition toward life becomes less obvious once the biological vocabulary is removed, then the vocabulary may have been doing some of the explanatory work. That is precisely where philosophical scrutiny is needed.

References

1. P. Adamski, M. Eleveld, A. Sood, Á. Kun, A. Szilágyi, T. Czárán, E. Szathmáry, and S. Otto, "From Self-Replication to Replicator Systems En Route to De Novo Life," *Nature Reviews Chemistry* 4 (2020): 386–403, https://doi.org/10.1038/s41570-020-0196-x.

[8] Wittgenstein's remark that philosophical difficulties arise when "language goes on holiday" (*Philosophical Investigations*, §38) is relevant here. The concern is not that metaphorical language is forbidden, but that familiar biological grammar may carry conceptual commitments that exceed what the underlying chemical description establishes.

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Preprints.org | NOT PEER-REVIEWED | Posted: 29 October 2026 https://doi.org/10.20944/preprints202610.2955.v1

2. M. Preiner, S. Asche, S. Becker, et al., "The Future of Origin of Life Research: Bridging Decades-Old Divisions," *Life* 10 (2020): 20, https://doi.org/10.3390/life10030020.
3. S. Scoles, "How Did Life Begin?," *Scientific American* 335 (2026): 32–41, https://doi.org/10.1038/scientificamerican102026-5QKM2yYJIIFB6kEpbGxMBK.
4. O. Trapp, "Origins of Life Research: A Roadmap for the Transition From Chemistry to Biology," *BioEssays* 44 (2022): e2200157, https://doi.org/10.1002/bies.202200157.
5. G. E. Allen, "Mechanism, Vitalism and Organicism in Late Nineteenth and Twentieth-Century Biology: The Importance of Historical Context," *Studies in History and Philosophy of Biological and Biomedical Sciences* 36 (2005): 261–283, https://doi.org/10.1016/j.shpsc.2005.03.003.
6. C. Darwin, "Letter to J. D. Hooker, 29 March 1863," Darwin Correspondence Project, Letter no. 4065 (University of Cambridge), https://www.darwinproject.ac.uk/letter/DCP-LETT-4065.xml.
7. C. Darwin, "Letter to the *Athenæum*, 18 April 1863," Darwin Correspondence Project, Letter no. 4108 (University of Cambridge), https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-4108.xml.
8. C. Darwin, "Letter to J. D. Hooker, 1 February 1871," Darwin Correspondence Project, Letter no. 7471 (University of Cambridge), https://www.darwinproject.ac.uk/letter/DCP-LETT-7471.xml.
9. A. I. Oparin, *Proiskhozhdenie Zhizni* [*The Origin of Life*] (Moskovskii Rabochii, 1924).
10. J. B. S. Haldane, "The Origin of Life," *The Rationalist Annual* 148 (1929): 3–10.
11. S. L. Miller, "A Production of Amino Acids Under Possible Primitive Earth Conditions," *Science* 117 (1953): 528–529, https://doi.org/10.1126/science.117.3046.528.
12. A. I. Oparin, *The Origin of Life*, trans. S. Morgulis (Macmillan, 1938).
13. T. Gánti, *The Principles of Life* (Oxford University Press, 2003).
14. A. Sharma, D. Czégel, M. Lachmann, C. P. Kempes, S. I. Walker, and L. Cronin, "Assembly Theory Explains and Quantifies Selection and Evolution," *Nature* 622 (2023): 321–328, https://doi.org/10.1038/s41586-023-06600-9.
15. J. Jaeger, "Assembly Theory: What It Does and What It Does Not Do," *Journal of Molecular Evolution* 92 (2024): 87–92, https://doi.org/10.1007/s00239-024-10163-2.
16. I. A. Chen, R. W. Roberts, and J. W. Szostak, "The Emergence of Competition Between Model Protocells," *Science* 305 (2004): 1474–1476, https://doi.org/10.1126/science.1100757.
17. S. A. Harrison, H. Rammu, F. Liu, A. Halpern, R. Nunes Palmeira, and N. Lane, "Life as a Guide to Its Own Origins," *Annual Review of Ecology, Evolution, and Systematics* 54 (2023): 327–350, https://doi.org/10.1146/annurev-ecolsys-110421-101509.
18. B. Seelig and I. A. Chen, "Intellectual Frameworks to Understand Complex Biochemical Systems at the Origin of Life," *Nature Chemistry* 17 (2025): 11–19, https://doi.org/10.1038/s41557-024-01698-4.
19. G. Danger, L. L. S. d'Hendecourt, and R. Pascal, "On the Conditions for Mimicking Natural Selection in Chemical Systems," *Nature Reviews Chemistry* 4 (2020): 102–109, https://doi.org/10.1038/s41570-019-0155-6.
20. L. L. J. Schoenmakers, T. A. C. Reydon, and A. Kirschning, "Evolution at the Origins of Life?," *Life* 14 (2024): 175, https://doi.org/10.3390/life14020175.
21. C. E. Cleland, *The Quest for a Universal Theory of Life: Searching for Life as We Don't Know It* (Cambridge University Press, 2019).
22. E. Machery, "Why I Stopped Worrying About the Definition of Life… and Why You Should as Well," *Synthese* 185 (2012): 145–164, https://doi.org/10.1007/s11229-011-9880-1.
23. B. Spinoza, *Ethics*, trans. E. Curley (Penguin Books, 1996; originally published 1677).
24. D. R. Mills, R. L. Peterson, and S. Spiegelman, "An Extracellular Darwinian Experiment With a Self-Duplicating Nucleic Acid Molecule," *Proceedings of the National Academy of Sciences* 58 (1967): 217–224, https://doi.org/10.1073/pnas.58.1.217.
25. T. A. Lincoln and G. F. Joyce, "Self-Sustained Replication of an RNA Enzyme," *Science* 323 (2009): 1229–1232, https://doi.org/10.1126/science.1167856.
26. H. R. Maturana and F. J. Varela, *Autopoiesis and Cognition: The Realization of the Living* (Reidel, 1980).
27. K. Ruiz-Mirazo, J. Peretó, and A. Moreno, "A Universal Definition of Life: Autonomy and Open-Ended Evolution," *Origins of Life and Evolution of the Biosphere* 34 (2004): 323–346, https://doi.org/10.1023/b:orig.0000016440.53346.dc.

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Preprints.org | NOT PEER-REVIEWED | Posted: 29 October 2026 https://doi.org/10.20944/preprints202610.2955.v1

28. A. Moreno and M. Mossio, *Biological Autonomy: A Philosophical and Theoretical Enquiry* (Springer, 2015).
29. M. Montévil and M. Mossio, "Biological Organisation as Closure of Constraints," *Journal of Theoretical Biology* 372 (2015): 179–191, https://doi.org/10.1016/j.jtbi.2015.02.029.
30. A. Pross, *What Is Life? How Chemistry Becomes Biology* (Oxford University Press, 2012).
31. R. Pascal, A. Pross, and J. D. Sutherland, "Towards an Evolutionary Theory of the Origin of Life Based on Kinetics and Thermodynamics," *Open Biology* 3 (2013): 130156, https://doi.org/10.1098/rsob.130156.
32. T. W. Deacon, *Incomplete Nature: How Mind Emerged From Matter* (W. W. Norton, 2011).
33. T. W. Deacon, A. Srivastava, and J. A. Bacigalupi, "The Transition From Constraint to Regulation at the Origin of Life," *Frontiers in Bioscience (Landmark Edition)* 19 (2014): 945–957, https://doi.org/10.2741/4259.
34. R. Tallis, *Aping Mankind: Neuromania, Darwinitis and the Misrepresentation of Humanity* (Acumen, 2011).
35. R. C. Lewontin, "The Units of Selection," *Annual Review of Ecology and Systematics* 1 (1970): 1–18.
36. P. Godfrey-Smith, *Darwinian Populations and Natural Selection* (Oxford University Press, 2009).
37. W. F. Doolittle and S. A. Inkpen, "Processes and Patterns of Interaction as Units of Selection: An Introduction to ITSNTS Thinking," *Proceedings of the National Academy of Sciences* 115 (2018): 4006–4014, https://doi.org/10.1073/pnas.1722232115.
38. G. Wald, "The Origin of Life," *Scientific American* 191 (1954): 44–53.
39. E. V. Koonin, "The Cosmological Model of Eternal Inflation and the Transition From Chance to Biological Evolution in the History of Life," *Biology Direct* 2 (2007): 15, https://doi.org/10.1186/1745-6150-2-15.
40. D. J. Chalmers, "Facing Up to the Problem of Consciousness," *Journal of Consciousness Studies* 2 (1995): 200–219.
41. W. Johannsen, *Elemente der exakten Erblichkeitslehre* [*Elements of the Exact Theory of Heredity*] (Gustav Fischer, 1909).
42. A. H. Sturtevant, "The Linear Arrangement of Six Sex-Linked Factors in *Drosophila*, as Shown by Their Mode of Association," *Journal of Experimental Zoology* 14 (1913): 43–59.
43. A. Biswas, Z. Weiss, J. W. Szostak, and S. DasGupta, "A Ribozyme Ligase That Requires a 3′ Terminal Phosphate on Its RNA Substrate," *Nature Communications* 17 (2026): 5634, https://doi.org/10.1038/s41467-026-74622-8.
44. M. R. Holman, T. Ito, and S. E. Rokita, "Self-Repair of Thymine Dimer in Duplex DNA," *Journal of the American Chemical Society* 129 (2007): 6–7, https://doi.org/10.1021/ja0668365.
45. R. Szabla, M. Zdrowowicz, P. Spisz, N. J. Green, P. Stadlbauer, H. Kruse, J. Šponer, and J. Rak, "2,6-Diaminopurine Promotes Repair of DNA Lesions Under Prebiotic Conditions," *Nature Communications* 12 (2021): 3018, https://doi.org/10.1038/s41467-021-23300-y.
46. D. Y. Zhang and E. Winfree, "Control of DNA Strand Displacement Kinetics Using Toehold Exchange," *Journal of the American Chemical Society* 131 (2009): 17303–17314, https://doi.org/10.1021/ja906987s.
47. J. Boekhoven, W. E. Hendriksen, G. J. Koper, R. Eelkema, and J. H. van Esch, "Transient Assembly of Active Materials Fueled by a Chemical Reaction," *Science* 349 (2015): 1075–1079, https://doi.org/10.1126/science.aac6103.
48. L. Zhou, D. K. O'Flaherty, and J. W. Szostak, "Template-Directed Copying of RNA by Non-Enzymatic Ligation," *Angewandte Chemie International Edition* 59 (2020): 15682–15687, https://doi.org/10.1002/anie.202004934.
49. F. Müller, L. Escobar, F. Xu, E. Węgrzyn, M. Nainytė, T. Amatov, C. Y. Chan, A. Pichler, and T. Carell, "A Prebiotically Plausible Scenario of an RNA-Peptide World," *Nature* 605 (2022): 279–284, https://doi.org/10.1038/s41586-022-04676-3.
50. K. Adamala and J. W. Szostak, "Nonenzymatic Template-Directed RNA Synthesis Inside Model Protocells," *Science* 342 (2013): 1098–1100, https://doi.org/10.1126/science.1241888.
51. K. Tamura and P. Schimmel, "Chiral-Selective Aminoacylation of an RNA Minihelix," *Science* 305 (2004): 1253, https://doi.org/10.1126/science.1099141.
52. J. Kenchel, A. Vázquez-Salazar, R. Wells, et al., "Prebiotic Chiral Transfer From Self-Aminoacylating Ribozymes May Favor Either Handedness," *Nature Communications* 15 (2024): 7980, https://doi.org/10.1038/s41467-024-52362-x.

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53. L. Laplane, P. Mantovani, R. Adolphs, H. Chang, A. Mantovani, M. McFall-Ngai, C. Rovelli, E. Sober, and T. Pradeu, "Why Science Needs Philosophy," *Proceedings of the National Academy of Sciences* 116 (2019): 3948–3952, https://doi.org/10.1073/pnas.1900357116.
54. K. Adamala and J. W. Szostak, "Competition Between Model Protocells Driven by an Encapsulated Catalyst," *Nature Chemistry* 5 (2013): 495–501, https://doi.org/10.1038/nchem.1650.
55. G. F. Joyce and J. W. Szostak, "Protocells and RNA Self-Replication," *Cold Spring Harbor Perspectives in Biology* 10 (2018): a034801, https://doi.org/10.1101/cshperspect.a034801.
56. M. Egbert, M. M. Hanczyc, I. Harvey, N. Virgo, E. C. Parke, T. Froese, H. Sayama, A. S. Penn, and S. Bartlett, "Behaviour and the Origin of Organisms," *Origins of Life and Evolution of Biospheres* 53 (2023): 87–112, https://doi.org/10.1007/s11084-023-09635-0.
57. R. A. Gatenby, J. Gallaher, H. Subramanian, E. U. Hammarlund, and C. J. Whelan, "On the Origin of Information Dynamics in Early Life," *Life* 15 (2025): 234, https://doi.org/10.3390/life15020234.
58. Wikipedia contributors, "Abiogenesis," *Wikipedia, The Free Encyclopedia* (revision 1380994702, accessed 23 October 2026), https://en.wikipedia.org/w/index.php?title=Abiogenesis&oldid=1380994702.

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