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Closure, Function, Emergence, Semiosis, and Life: The Same Idea?

Reflections on the Concrete and the Abstract in Theoretical Biology

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ABSTRACT: In this note epistemological problems in general theories about living systems are considered; in particular, the question of hidden connections between different areas of experience, such as folk biology and scientific biology, and hidden connections between central concepts of theoretical biology, such as function, semiosis, closure, and life.

INTRODUCTION

The aim of this brief note is to consider partly hidden ideas about theoretical biology and its subject matter, living beings, organisms in their ecosystems—which means beetles, cows, worms, bacteria cells, green algae, and dinosaurs, their history and interactions, their development and evolution, their structure and function, their origin, self-organization, the extinction of individuals as well as species, and the genesis of higher modes of life. In other words, an extremely multifaceted subject. First, however, recall an observation on the fate of general systems theory, which in the 1960s and 1970s had the ambitious goal of synthesizing the general fields of cybernetics, information theory, operation analysis, and specific fields, such as evolutionary theory and thermodynamics. That goal was not achieved and various reasons may be given for the failure, but an important factor might have been a too high level of theoretical generality in accounting for the highly different types of systems included in the ambitions of systems theory.[1] With this in mind, we could ask for the possibility of facing a similar situation with respect to the current trends in systems thinking.

EXPERIENTIAL, EXPERIMENTAL, AND THEORETICAL BIOLOGY

We commence with the epistemology of evolutionary systems theory (complex adaptive systems, developmental systems, self-organizing systems, etc.). This idea

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may be called the hidden prototype fallacy. It focuses on the risk of becoming seduced by our own theoretical creations, blinded by the life of abstractions, and it asks if we all commit a fallacy of presupposing certain characteristics of the class of systems under investigation (e.g., evolutionary systems), even though these are not accounted for by the theoretical apparatus of our theory. The argumentative rhetoric found in many discussions within the field of self-organizing systems theory (and others) tends to hide basic connections between folk biology, theoretical biology (e.g., evolutionary systems theory), and experimental biology in one of its disciplinary normal-science forms. We tend to neglect the deep role played by *real biology* as a reservoir of experience and knowledge about living systems. I claim that we should more explicitly cultivate such connections between experiential, scientific, and theoretical biology; but also that we should be critical about the limits of such connections when they are hidden to explicit discourse. To explain this idea, I need to give some definitions and interpretations.

Folk Biology: Even though one should be careful about the scientism-related connotations of this term (especially if one associates it with the term *folk psychology* within philosophy of mind, where it is occasionally supposed that in some distant future of neuroscience, folk psychological terms can be reductively eliminated when neuroscientific terms take their place), *folk biology* as used here is simply a name for the phenomenological fact that before anyone may learn scientific biology, we all experience the biology of real creatures, we see animals move by themselves, we see flowers grow and unfold, and we may even experience stories the adults tell about very small or invisible living beings like bacteria, amoebae and algae; creatures that some of us eventually come to see in school, or on television. The later fact should make it clear that phenomenologic experiential *folk biology* in a modern society is deeply influenced by the products of scientific instrumentation and science-derived notions and ideas about microbial life, cells, genes, molecules, and so on. Even though the borders between folk biology and scientific biology are vague in this sense, we do indeed have both kinds of *systems of experience*, with the important historical asymmetry that everyday life and language is primary (ontogenetically and historically) to scientific biology.

Prototypes: Prototypes may not be the best notion to use in a *scientific* context, because it describes a semantic feature of everyday language that, in some concept-fields, there is an instance (the prototype) that is more central in (seemingly) having most of the content-aspects of that notion than other instances. Thus, an apple is a more prototypical instance of the general everyday concept *fruit* than, say, the nut in the fruiting body of the grass-like sedge plant—even though botanically, both are equal instances, each with its own particular properties.[2] It is a characteristic feature of most of the notions used within one of the frames of thought, or paradigms of theoretical biology (such as evolutionary systems, developmental systems theory, or biosemiotics) that they are rather abstract and vague. *Abstract* in the sense that they denote very general properties of life, and that they can be conceived of at some high or medium level of abstraction from concrete instances; and *vague* because it is seldom that the definitions of the notions in question entail clear-cut demarcation criteria to decide whether specific instances belong to the system type (or posit the property) in question. Here are some relevant examples of abstract and vague notions (some of which are closely related, almost by family-resemblance, and are thus grouped together):

(a) self-organization (or emergence, autopoiesis, autocatalysis);
(b) evolution (or development);
(c) communication (or semiosis, information processing); and
(d) living (or feeling, acting, learning).

To the extant that we, within a given paradigmatic frame, can use these terms in a coherent way, we are also able to decide (within the limits of various ambiguities) if a concrete specimen of life, or a physically concrete dynamic system, instantiates one or more of these concepts. For example, from my understanding of the original theory of autopoiesis,[3] I happen to be able to decide that a single *E. coli* cell is an autopoietic system, whereas my bicycle, a piece of cake, or my home city are not. I even know that a multicellular organism may be more a problematic case, it may be a higher order autopoietic system, but there is the possibility that "the observer is mistaken" (Ref. 3, p108). From reading selected thoughts about self-organizing systems (from e.g., Simon, Prigogine, Jantsch, Salthe, Kauffman, and Gell-Mann), I really know that a tornado, a bamboo plant, and a city are examples of such systems; whereas a watch, a dish, a rock, or a carbon atom are not. Furthermore, that there seem to be borderline cases, such as the Earth, the solar system, a three-dimensional globulin macromolecule, and a piece of crystal, all of which may be or may not be (considered as) self-organizing, depending on the specific conditions. The reason for calling attention to prototypes (which are normally considered as pertaining to pre- or nonscientific contexts) is the suspicion that, in some of the abstract theorizing, the base exemplars are not described much better than by everyday prototypes, and the pool of paradigmatic exemplars[4] indeed has a prototypical character.

Experiential Biology: Now, what do I know more about the bamboo plant (as a concrete plant so to speak) when I can claim it to be a self-organizing system? Only in the technical sense of conceptual property-inheritance (known within programming and artificial intelligence) will this add to my knowledge of bamboo biology. However, one could also say that it is not really knowledge about the bamboo, but about the abstract property of self-organizing systems, a property that all plants, including the bamboo, happen to share. The point is that in arguing about the theoretical details concerning evolutionary systems (living self-organizing evolving communicating systems)—and about how to frame a general theory of such systems—we take for granted the findings of experimental biology and a lot of (almost) tacit knowledge about what I would like to call *experiential biology.* This includes the domain mentioned above as folk biology (common, conventional, public, everyday notions of plants and animals) *plus* the subjective field of our own experience of what it means to be a growing, feeding organism, a moving feeling animal, a sensitive human being. Thus, in my use of the term, experiential biology includes folk biology (which again includes some, more or less non-Darwinian, but very popular ideological notions about *higher* and *lower* forms of life, and so forth) but first and foremost, experiential biology includes a kind of subjective and qualitative knowledge of the feeling of life, of sentience, of the moods of passive laziness or active engagement, and so on. It is that part of a human *umwelt* that hardly can be realized by a robot.[5] A passage that illustrates this qualitative aspect of knowledge of complex living systems very well—especially because of its sympathetic sensuality and the concreteness in its description of self-organization—is a beautiful quotation from Denis Diderot's *Le Rêve de d'Alambert* (1769), here quoted from *Man's*

New Dialogue with Nature by Prigogine and Stengers (Ref. 6, p.81), the passage where Diderot, in an imaginary conversation with d'Alambert, tries to demonstrate the failure of a mechanist explanation:

> What is in this egg? An insensitive mass before the germ is put into it…How does this mass evolve into a new organization, into sensitivity, into life? Through heat. What will generate heat in it? Motion. What will the successive effects of motion be? Instead of answering me, sit down and let us follow out these effects with our eyes from one moment to the next. First there is a speck which moves about, a thread moving and taking color, flesh being formed, a beak, wing-tips, eyes, feet coming into view, a yellowish substance unwinds and turns into intestines—and you have a living creature…. Now the wall is breached and the bird emerges, walks, flies, feels pain, runs away, comes back again, complains, suffers, loves, desires, enjoys, it experiences all your affections and does all the things that you do. And you will maintain, with Descartes, that it is an imitating machine pure an simple? Why, even little children will laugh at you, and philosophers will answer that if it is a machine you are one too!

Diderot's appeal to the experiential biology of a chicken *in formation* is of double interest here: It illustrates the point, that in the discursive context of very theoretical arguments about system types and how to explain them, we make use of more intuitive kinds of knowledge when we examine the merits or the failure of such theories (whether they are mechanist, as in Diderot's case, or not). The sentient living thing, like the chicken, or like you and me, becomes a prototype of a complex system that has not yet been explained by mechanistic principles. The fact, that even children can tell the difference between a watch or other artificial devices and living beings, is a fact of folk biology; and the capacity to make that distinction, to recognize a system as alive, is constitutive for the very concept of an organism. Furthermore, in other passages in Prigogine and Stengers' book, we can observe the tendency to blur that distinction, to hide the phenoontological difference between the prototypes of eddies, plants, and animals, by emphasizing that they all are *dissipative structures*. This hints at a general point.

When discussing the theoretical ideas of self-organizing selective systems, developmental constraints, biosemiosis, and autocatalytic systems, there seems to be an underlying reference to a shared pool of imaginable system-types, that are used conveniently to *ground* the abstract discussion in real biology or material instances of physical, chemical, and biological systems. It is this *ground* of prescientific experience with various types of concrete (or quasiabstract) systems (e.g., plants, animals, and humans) that I suggest plays a hidden cognitive role as reservoir of prototypes for the discussion. Thus, we can formulate

- *the hidden prototype fallacy:* To construct a discourse in a theoretical space that allows for the reification of its own abstractions and hides the (fuzzy, basic, and problematic) semantic references to the particulars of system types.

To investigate whether this fallacy is predominant, let us look at several examples (that remain to be worked out more carefully).

Example 1. The theory of autopoiesis, developed in the 1970s, was framed, in its core, with (almost) no reference to the rich biochemical and molecular biological concept of cellular metabolism; that is, framed in purely abstract organizational (and mechanistic) terms. Nevertheless, it seems to be almost inconceivable that the theory could get formulated without all the previous work in experimental biology on metabolism and physiology. It is hard to imagine how to comprehend the notions of this theory without the possibility of imagining certain prototypes of living systems as concrete instances. If one reply, from the stance of the theory itself, that it is indeed a generalization over these instances (a natural objection, though not in strict accordance with the theory itself) to focus on the universal aspects of living systems as autopoietic systems, then the logical–semantic link from concrete instances to the theory's construal of autopoiesis as a general mode of organizational stability remain unclear, partly hidden, and not reflected in the theory itself.

Example 2. Nonequilibrium thermodynamics as a theory supposed to explain or cover the origin of life. This example concerns claims that to understand the origin of life (as the emergence of biological order from disorder) it is central to deal in general with the irreversible emergence of dissipative structures that self-organize matter and energy into stable patterns—known from the eddies and vortices of streaming water, or the spiral waves of the chemical Belousov-Zhabotinsky reaction, or the spirals of the slime mould *Dictyostelium*. In this example, the water vortex, the BZ-reaction, and the *Dictyostelium* pattern (at least on the superficial level) take the form of prototypical examples of emergence of organized systems. It is like a simple syllogism. Premises: an organism is an instance of a dissipative structure; the BZ-reaction is another instance; nonequilibrium thermodynamics explains the existence of order (as in the BZ-reaction). Thus, conclusion: nonequilibrium thermodynamics possibly explains the origin of organisms.

Example 3. Dual mode theories of life (for example, the biosemiotics of Refs. 7 and 8; the linguistic–dynamic complementarity principle of Ref. 9). The biosemiotic approach to living organization can be formulated in various ways (which I cannot discuss in detail here), and some of these may give the impression that this approach constitute a separate scientific theory of life—that considers life not as organized molecular systems but as semiotic processes—and thus it might be thought of as an alternative to the traditional *paradigm* of molecular biology. Why this is a misleading formulation of an otherwise promising perspective is because, first, the real challenge is to investigate the relation between the molecular and semiotic aspects of life processes; second, because the formulation of the biosemiotic perspective (as with the theory of autopoiesis) is very much dependent upon what the discipline of molecular biology has revealed about the intricacies of cellular life during the past 50 years (for details see Ref. 10). Furthermore, the notion of code-duality as well as the notion of linguistic–dynamic complementarity must be suspected to have as a more or less hidden prototype, the classical genotype–phenotype duality in classical genetics.

Example 4. Complexity studies, for example, complex adaptive *Santa Fe* systems (see Ref. 11). Science, throughout its history, has studied the complex phenomenal world to reveal the secrets of is appearances, thus it should not surprise us that complexity itself could be a subject matter. However, from a certain *local* perspective, it might seem a bit bizarre to imagine a truly *general* scientific concept of complexity. In specific fields, such as evolutionary biology, molecular genetics, or the computational study of *life-like* automata within artificial life, one finds precise and even operational concepts of complexity for specific scientific purposes. However, again, the point of departure for these concepts is often rooted in everyday notions of complexity, and the concluding insights drawn from such studies may also interfere with prescientific everyday ideas about the subject. From a scientific point of view, doubts can be raised about the use of any *general* notion of complexity. Natural science is partitioned into a set of very specialized methods and approaches—why then, should not every particular concept of complexity have a very restricted scope, relevance, and validity? For instance, if one wants to test claims about the rising complexity in evolution, one has to design special measures of complexity that are tailored to cope with the empirical class of systems that are to be the test material (see e.g., Refs. 7 and 12).

Example 5. Artificial life (AL) research. As a general *theory* of (or conceptual frame concerning) life as an emergent self-organizing phenomenon that may appear in quite variable media, AL presupposes the prototypes of growing plants (in the algorithmic models of growth), moving animals (in robot studies), and metabolizing cells (in various computational models of life). As a research program, AL aims to liberate us from the too restricted conception of *life as we know it*, but one does not have to look very deeply into the assumptions involved in its quest for *life as it could be* to realize that the escape from folk biological notions of life is never complete, and that the issues about the so called reality of the simulated creatures recourse to our precious prototypes of the kind of life we know from biology and folk biology.[13]

Observing all these specific theories of self-organizing and developing systems, one is tempted to ask “Why is it that all these good old fashioned organisms—concrete instances of mosquitoes, influenza viruses, jackdaws, bananas, fruit flies, and Neanderthals—seemingly play such a little role in theoretical biology?” A possible answer is simply that theoreticians do not care about specific organisms—or that, apparently, in the Platonic way of doing biology, a bamboo plant cannot tell anything significant about self-organizing systems, because even though it may be an instance of one, it is simply too concrete—or, that theoreticians pursue generality to such an extent that differences between biology and physics seems to disappear at the cost of recognizing the uniqueness of organisms, which is exactly their history, contingency, biochemical peculiarity, functionality, and purposefulness—and sign functions. It may be an illusion to think that a new deeper understanding of self-organizing living systems will come from theorizing alone. The base type of systems are often defined and well described as concrete instances of living organisms of a specific species within a specific experimental and/or experiential frame.

IS OUR CONCEPT OF AN ORGANISM A CLOSED ONE?

Having considered a peculiar epistemological aspect of the abstract nature of the new complex systems theories and their relation to concrete instances of known species of life, the focus can now be directed at a related though more intrinsic theoretical question about attempts to characterize complex evolutionary systems.

Theoretical biology since Kant has invented several seemingly different but very general ideas about what constitute a living system, for example, metabolism, self-reproduction, evolution, hereditary information, code-duality, autopoietic semantic and autocatalytic closure, emergence, and functionality of parts in relation to a whole. I will now propose the apparently odd thought (1) that these notions refer to the very same feature (or property cluster), and furthermore, (2) that these general ideas are crucially dependent on the triumphant development of experimental molecular biology in the twentieth century.

As a caveat, it must be noted, that although a common idea or an everyday concept may easily be expressed in various natural languages such as Danish or English, it is not so evident that *the same* theoretical idea can be expressed in distinct theoretical settings. Several arguments exist against such a claim, for instance the notion of incommensurability between paradigms that allows only partial translation of concepts from one paradigm to a succeeding one, so the theoretical meaning of a term is not well preserved in the process of translation. Nevertheless, it is still possible to imagine, in a vague sense of sameness, that some fundamental characteristics of complex living systems, characterized by distinct conceptual tools, somehow refer to the same idea of what constitutes the most distinctive feature of a living system.

Another way to state this idea is to say that distinct theoretical perspectives abstract certain more or less crucial special features of *real living systems*, or (to state the same proposition in a less naive-realist mode) of some *prototypical idea of living systems*. We may posit a common deep structure of these prototypes (corresponding to a common unitary whole of characteristic processual properties of living systems) that we cannot see at the surface level of everyday concepts, but which nevertheless is constitutive of *life* as a generic phenomenon. Each specific theoretical paradigm then abstracts certain aspects out of this deep-level cluster of characteristics, for example, metabolism, the possession of a genetic code, autonomy, interaction with environment, interplay of self-organization and natural selection, or whatever. Furthermore, this abstraction process takes place in part by the hidden reference to certain system prototypes as explained above, for example, the BZ-reaction (or Turing patterns) as a prototype for emergence or developmental order in embryogenesis, or the metabolism of a bacterial cell as a prototype for the autonomy (or autopoiesis) of life as such.

In this note I will only consider a subset of about four general notions related to the study of living systems:

1. *Function* as an explanatory tool of experimental biology and a philosophical argument for the autonomy of biology (or an embarrassment for some philosophers of science);
2. *Emergence* as an ontological notion covering all levels of organization from the physical to the mental, and considered to be an especially important aspect of understanding the origin of life because this process created special, new, unpredictable properties such as self-reproduction and evolution by natural selection;
3. *Semantic closure* and the concept of dual modes of complex systems in the theory of H.H. Pattee; and
4. *Biosemiosis* as the defining feature of life, where biosemiosis means a sign interpretation process in living organisms.[7]

To jump to the conclusion of this comparative analysis: It is conjectured that biosemiosis presupposes functionality, that functionality is only possible under a closure of operations, and that this closure is an emergent phenomenon of a semiotic character. (If this is so, a synthesis is needed, and also an epistemologic clarification).

Thus, the null hypothesis to test, so to speak, alternative to the conclusion just mentioned, is that these four notions of life are either irreducibly incompatible, or that they express four independent characteristics of life. We go step by step:

(i) Biosemiosis presupposes functionality. The first step is to assume that we have defined life in a semiotic way in some sense.[7,14]

To explain how, let me combine Peirce's notion of a sign with Bateson's notion of information (cf., Ref. 15) to emphasize the relational character of a biosemiotic process: Life entails semiosis as the action of signs, where a sign is a first, that is, a representamen that stands (by a code or a habit) in such a relation to a second, its object, so as to determine a third, its interpretant, to take the same relation to that object (that the representamen takes) and thereby effecting that interpretant so that this effect is *significant* (potential or actual) to that interpretant's interpreter organism, in the sense that it is a difference that makes a difference to the interpreter. The interpreter must be an organism, a part of an organism, or an organism-like entity, and the effects on that organism's parts, to be significant (i.e., to make a difference), cannot be merely physical, because by definition, the difference, if any, they make, is of potential or actual purport or relevance to the organism in question, which means that they concern the organism's chances of finding food or other sources of energy, or that they ultimately concern its chances of surviving and reproducing.

Admittedly, this is a more restricted sense of sign action that connects the semiotic interpretant more closely to a material interpreter-organism (than Peirce's sense of sign action; or than found in Ref. 16; cf., Ref. 17). Nevertheless, it shows the relation between the parts of the semiotic process and the functionality of the organism as a whole in relation to that organism's biophysical parts: Were there no organisms—or no functional parts of the organism that contribute to maintain the organism as a whole (where each part, as it were [and as it evolutionary is], exists for the purpose of the whole, as Kant pointed out)—there would be no action of signs. In this sense, sign function and biofunctionality of organisms are intrinsically related. (Of course, on higher levels of organization, anthroposemiotic processes may display a semiotic functionality that only indirectly presupposes biofunctionality; for example, the Internet as a growing semiotic web functions to connect many computers in a huge virtual library, that may be described linguistically or sociologically, and only ontologically presupposes the biofunctionality of the brains of their human designers and users). The hidden prototype of a basic biosemiotic system is the simple prokaryotic cell.

(ii) Functionality is only possible under a closure of operations. In this note I cannot comment upon the body of philosophical research done on the notion of function in biology (but see Ref. 18), and I shall simply assert that basically, the notion of function in biology is the teleological (and mereological) notion of "a part existing for the good of the whole", or "having the purpose of" doing something in relation to the whole. This is the case disregarding whether the whole is intentional or not, and disregarding whether or not the notions of purpose, and "the good of" (and the related complex of function-ideas) in principle, theoretically, may be reduced to mechanistic causal explanations in a historical setting, for example, in a neo-Darwinian setting. There are serious reasons for assuming such a reduction as impossible, even in principle, but I do not go into that here.

Instead, I will claim that the reason why functionality is only possible under a closure of operations is astonishing simple (if I have fooled myself here, I hope to learn how). Only when the causal chain from one part to the next closes or feeds back in a closed loop—at once a feedback on the level of parts and an emergent function defined (as mentioned) as a part–whole relation—can we talk about a genuine function. In other words, it is because function is the function of a part that works effectively to produce (part–part efficient causation) influences on other parts within the same whole (the same form, the organism's)—where each part is constrained by the same whole (formal causation)—the total of parts interacting under these constraints in a coherent emergent pattern *is* the whole organism, whose maintenance (final causation) as form is the goal of each part. Here, final causation—that is, the dual process of *downward* constraints (formal cause) on the behavior of the parts and the *emergent* pattern of the parts forming a functioning organism (final causation), which is made of parts (material causation)—is the causation of a physical part within a biological whole being committed to a specific role in the internal organization of that whole, thus the internal ascription (*de re*) of a role to the part is the emergence of that part's function. Consider a newly transcribed polypeptide chain in a cell before it folds (by self-assembly or with the help of protein chaperones) into an enzyme. This physical thing has not yet an actual function, only a potential one as a finished part, that is, an enzyme. As a physical thing, the enzyme is just a complex molecule; as a biochemical thing, the enzyme is a functional part of the cell's metabolism which, in addition to the membrane and the DNA code, makes up the very cell! Function can only be cell-organized, so to speak, not simply physically *self-organized*. (Again we can observe: The hidden prototype is [in the twentieth century] the cell, or [in the twentieth and nineteenth century] the organism).

(iii) Closure is an emergent phenomenon. This is in part implied in the previous development: Only by analyzing a system in terms of minimally a higher and a lower level (a whole with some parts) can one identify functionality as based on the causal closure of operations; this functional causality being *emergent* (as defined in Ref. 19) upon the local part-to-part interactions of the individual parts (efficient causality) within that whole. A further comment, closure has been used as a predicate in quite different circumstances (see other contributions to this volume) and to denote quite different concepts. Here it is used and defined in the biological realm, and is not merely informational, or organizational, but also material and energetic, and thus biologic closure is never perfect (compare Ref. 20).

(iv) Closure in biosystems is of a semiotic character. As an imperfect emergent phenomenon, the closure of operations between parts in organisms is a producer of differences that makes differences to the parts as well as to the whole organism. Thus, endosemiotic sign links can be analyzed as causal links between functioning parts that regulate the entire organic machinery of the body. However, one could object, by what necessity should an organic complex device with the property of emergent functionality be of a semiotic character? This is the deepest and most difficult question and I shall only sketch two possible answers, one of metaphysical necessity, the other of a fact-like or law-like necessity: (1) The Peircean (metaphysical) answer; wherever Nature takes on so complex habits that allow for the existence of living feeling, the intensity of mind has grown high enough to generate the action of "thirdness" characteristic of genuine triadic sign action.[16,21] (Since few scientists

are familiar with Peirce's philosophy, few will accept this answer I am afraid). (2) The von Neumann-Schrödinger answer (termed so to emphasize that it is a reconstruction of their original arguments combined with contemporary molecular biology). The minimal complexity of a system that does not spontaneously degenerate but complexifies further by open-ended evolution (Ref. 22, p80) is exactly the first self-organizing system (feeding on negative entropy) with an internal semiotic structure, an internal *code-script*.[23] The endosemiotic nature of the code is the fact that it (biochemically) embodies an internally defined mapping from a nucleotide sequence space to a protein sequence space within the system. Were there no code (and memory) of this kind, there would be not enough biochemical specificity (*information*) in the closed structure of reactions, and the system would fall below the threshold and degenerate. This may be related to unknown *laws of complexity.* Due to lack of present knowledge about primitive kinds of metabolisms (covering the continuum no life–primordial life–life), this answer may be read as a not yet proven hypothesis open to scientific investigation.

To sum up: biosemiosis presupposes functionality, and functionality is only possible under a closure of operations. The prototype organism at this level of research is a single cell, its parts form the endosemiotic network, and the membrane parts make that organism receptive also to changes in the ambient reservoir of significant influences. This closure is an emergent phenomenon of a semiotic character, and as a *closure*, it is only partial, imperfect, relatively open. Therefore we can conclude: (1) synthesis is needed; (2) further epistemological clarification of these concepts is needed also; and (3) a null hypothesis—that the four notions of life, they are, biosemiosis, functionality, emergence, and closure, express four independent characteristics of life—has been refuted.

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