



Review

Self-organization vs. self-ordering events in life-origin models

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Abstract

Self-ordering phenomena should not be confused with self-organization. Self-ordering events occur spontaneously according to natural “law” propensities and are purely physiodynamic. Crystallization and the spontaneously forming dissipative structures of Prigogine are examples of self-ordering. Self-ordering phenomena involve no decision nodes, no dynamically-inert configurable switches, no logic gates, no steering toward algorithmic success or “computational halting”. Hypercycles, genetic and evolutionary algorithms, neural nets, and cellular automata have not been shown to self-organize spontaneously into nontrivial functions. Laws and fractals are both compression algorithms containing minimal complexity and information. Organization typically contains large quantities of prescriptive information. Prescriptive information either instructs or directly produces nontrivial optimized algorithmic function at its destination. Prescription requires choice contingency rather than chance contingency or necessity. Organization requires prescription, and is abstract, conceptual, formal, and algorithmic. Organization utilizes a sign/symbol/token system to represent many configurable switch settings. Physical switch settings allow instantiation of nonphysical selections for function into physicality. Switch settings represent choices at successive decision nodes that integrate circuits and instantiate cooperative management into conceptual physical systems. Switch positions must be freely selectable to function as logic gates. Switches must be set according to rules, not laws. Inanimacy cannot “organize” itself. Inanimacy can only self-order. “Self-organization” is without empirical and prediction-fulfilling support. No falsifiable theory of self-organization exists. “Self-organization” provides no mechanism and offers no detailed verifiable explanatory power. Care should be taken not to use the term “self-organization” erroneously to refer to low-informational, natural-process, self-ordering events, especially when discussing genetic information. © 2006 Elsevier B.V. All rights reserved.

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1. Introduction

Self-ordering should not be confused with self-organization. Typically, self-ordering and self-organization are merged as a result of unrefined definitions. Ill-defined distinctions lead to category errors of fallacious inference. Systems science, biosemiotics, biocybernetics, life-origin research, neural network and cellular automata studies, and many fields of natural science research all suffer from this confusion.

In addition to failing to perceive the necessary and sufficient conditions of bona fide *organization*, confusion exists about the nature of intuitive *information*. Shannon knew the limitations of his uncertainty measurements, and stated them in his first paper [119,143]. His measurements would not be applicable to meaning or aboutness. As the von Weizsäcker have pointed out [140], Weaver also understood what the negative logarithm of an event’s probability could not provide: “Two messages, one heavily loaded with meaning, and the other pure nonsense, can be equivalent as regards information” [138]. Weaver’s only mistake was to call the quantifiable uncertainty to which he referred, “information”. Reduced uncertainty (mutual entropy) does not provide what Abel has termed, “prescriptive information” [2,3,128]. Prescriptive information either instructs or directly produces nontrivial optimized algorithmic function.

To begin to understand both organization and the prescriptive information upon which organization depends, the limitations of the self-ordering phenomena of physical nature are examined.

2. Self-ordering events

Self-ordering phenomena occur according to natural “law” propensities. Self-ordering events are physicydynamic. Crystallizations and the spontaneously forming dissipative structures of Prigogine [99–101] are examples of self-ordering. They do not algorithmically “self-organize”. Rather, they self-order out of seeming chaos and the complex interacting force relationships of inanimate nature. They are constrained by environmental starting conditions and the pre-existing orderliness described and predicted by the “laws” of nature. No other factors such as instructions are required for self-ordering phenomena to occur. Except within the formal mathematical expression of “laws” themselves, self-ordering phenomena involve no decision nodes, no dynamically-inert configurable switches, no logic gates, and no steering toward algorithmic optimization. “Dynamically inert” (dynamically incoherent) means that physicydynamics plays no role in the setting of a configurable switch [106,107]. Gravity, for example, plays no role in which

way a switch knob on a horizontal switch board is flipped. Despite the switch knob's being physical, the agent operator's choice alone determines which way the knob is pushed. The essential element of configurable switches of all types is dynamic incoherence (inertness). The setting of the switch is not coherent with physiodynamic causation.

Function is never an issue with the self-ordering phenomena of nature. Self-ordering is oblivious to whether computational halting, cellular metabolism, or function of any kind are achieved. Just as objective *being* in philosophy is oblivious to *shoulds* and *oughts*, *being* is also oblivious to formal algorithmic choices made with the intent of achieving utility. Self-ordering events do not pursue design and engineering success. Computational halting and potential protometabolism are not desires or goals of self-ordering phenomena.

Anti-informationists are well-represented in Refs. [7,13,24,29,51,55,56,69–72,78,79,113,114,139]. The school of thought known as *infodynamics* treats information as nothing more than a subset of physiodynamic interactions. Yet empirical evidence and prediction fulfillment are sorely lacking for unaided physiodynamics producing nontrivial computational or metabolic function. Schrödinger's *What Is Life?* started the negentropy concept [115]. Brillouin contributed to a physical concept of information and organization [16–18].

The Russian E. Liiv has of late helped popularize infodynamics as it relates to a defined negentropy: "The negentropy of systems as a special form of reality" [77]. Not all, however, agree that negentropy is real or even possible. Yockey points out that Boltzmann specifically excluded a negative constant from his mathematical definition of physical entropy [143]. Shannon employs a negative constant in his H equation [119]. Yockey argued that every probability distribution is unique, and that the S probability distribution phase space of Boltzmann's physical entropy (S) cannot be equated or synthesized with Shannon's "informational" uncertainty (H) probability distribution despite seemingly identical S and H equations. Section 5 below addresses such issues in "open systems far from equilibrium".

When attempts are made to reduce semantic and prescriptive information to physiodynamics, the patterns created by self-ordering become the object of much attention. An examination of the informational capabilities of self-ordering physical events follows.

2.1. Crystallization is a self-ordering phenomenon typically of the same molecular species. Crystallization proceeds spontaneously under conditions of dehydration, cooling, and supersaturation of solutions. No decision-node choices are required for crystallization to occur. Physiodynamic thresholds are reached, not purposefully chosen or controlled. No configurable switches must be set. Apart from agent manipulation and selection of initial conditions, precipitation is not controlled to achieve some purpose.

Almost no Shannon uncertainty is associated with crystallization. Aside from impurities, the probability of a particular crystalline structure forming for each molecular species under the same conditions approaches 1.0. The information retaining potential, therefore, of a crystal is extremely low. Only crystal impurities provide opportunity for information retention in such a monotonous physical matrix. But crystal impurities are rarely controllable in nature. Impurities that are controllable tend to be too regular for programming and significant information retention. The limited amount of prescriptive information that can be retained in crystal layers is one reason Cairns–Smiths model of initial "clay life" did not progress [25,26].

2.2. Self-ordered dissipative structures arise spontaneously out of seeming chaos. The nonlinear nature of complex, multi-variable phenomena make precise prediction extremely difficult. Yet the underlying law-like self-ordering tendencies of nature make spontaneously forming vortices at bathtub drains, hurricanes, and tornadoes unsurprising. Computerization has made possible large numbers of complex interacting computations in minimal time. Bennett used such computation time as a measure of complexity [9,10]. But Bennett's "logical depth" presupposes cybernetic concepts that are foreign to spontaneous self-ordering events.

The fundamental nature of Prigogine's dissipative structures within chaos theory [101] remains self-ordering rather than self-organizing. The title of Prigogine and Stengers book was correct: *Order Out of Chaos*, not *Organization Out of Chaos*. The title of Nicolis and Prigogine's earlier book [86] was incorrect in the title, "Self-Organization in Nonequilibrium Systems": and correct in the subtitle, "From Dissipative Structures to Order Through Fluctuations". Unfortunately, others since have continued to blur the distinction between order and organization [32,33,36–38,54,63–68,82,95,123,137]. The illegitimate merging of the two concepts now seems almost universal. The "category error" of logic theory leads to countless faulty inferences.

No programming is necessary for the spontaneous occurrence of a water vortex at a bathtub drain, the behavior of a sand pile, the shape of a candle flame, the formation of a tornado or hurricane. Such dissipative structures form out of

a continuous stream of instantaneously self-ordered states and phase changes that have nothing to do with cybernetic organization. No reason or empirical data exist in chaos theory to suggest that a physical environment is capable of marshalling cybernetic organizational skills. The environment cannot program or compute. Chance and necessity cannot set configurable switches to optimize genetic algorithms in genomes [2,3]. No evidence exists for attributing algorithmic organization to chaos theory.

2.3. *Spontaneously ordered nanotubules and other self-assembled structures*

Spontaneous self-assembly of various physically ordered structures has been the topic of much research. Pohl et al. [98], for example, described a spontaneous process that takes place on a single-atom-thick film of silver sprinkled with sulfur. A lacework nanopattern emerges with precision as the sulfur atoms pierce the silver with great regularity. Each hole is over 20 times further apart than the force field generated by each atom. The authors envisioned the generation of nanostructures that might exceed the best currently known patterning techniques.

Papaseit et al. observed microtubule self-assembly to be gravity-dependent [89]. The list of publications and types of spontaneous self-assemblies in physics alone seems endless. But under careful analysis, every instance of inanimate self-assembly can be traced to complex interactions of self-ordering force relationships. No algorithmic integration or organization is required to explain the spontaneously formed structure.

From a biological perspective, one must distinguish between physically self-ordered structures and those that are essentially “designed, engineered, and manufactured” by the linear digital programming instructions of codon strings. Clark et al. studied the bio-nanoscience of self-assembling supramolecular protein-nucleic nanostructures [31]. Reblova et al. [102] found that the core region of RNA “kissing complexes” form cation-binding pockets with highly negative electrostatic potentials. These pockets show nanosecond-scale breathing motions coupled with oscillations of the entire molecule. Amos used electron crystallography to study the structure of tubulin to predict structural interactions with nucleotides, drugs, motor proteins and microtubule-associated proteins [6]. Surrey et al. identified parameter combinations that determine the generation of asters, vortices, and a network of interconnected poles. They found that microtubules and their associated motor proteins in eukaryotic cells can be organized into various large-scale patterns [125]. Rothmund et al. made nanotubes from DNA double-crossover molecules (DAE-E tiles) [111]. But the structure of these nanotubes can be explained by a simple model based on the geometry and energetics of β -form DNA.

In no instances of self-ordering are functional selections required at true decision nodes. Bifurcation points may exist, but choice with intent is not needed to decide which course to take. Formal computation and control are not involved in self-ordered self-assembly. Optimization of algorithmic programming is always missing from natural-process, physicochemical, self-ordering events.

If the assembly of RecA on single-stranded DNA is examined, this process is measured and interpreted as a finite-state machine [8]. The machine is able to discriminate fine differences between sequences. Such discrimination is a formal computational operation, not a physicochemical self-ordering phenomenon. An iterative cascade of multistage kinetic proofreading amplifies minute differences, including single base changes. Such a Turing-like machine seems to be able to compute integral transforms. We do not see such processes arising independent of digitally programmed life. Prescriptive information is required to organize such a system. Decision nodes and efficacious configurable switch settings are involved. Such digital programming is unique to life. It should not be confused with the low-informational self-ordering events of inanimate nature.

2.4. *Spontaneous biopolymerization*

Leman et al. have showed that carbonyl sulfide (COS), a simple volcanic gas, can bring about the formation of peptides from amino acids under mild conditions in an aqueous solution. But this reaction, like others that have been published (e.g., Stanley Miller type experiments), produce only short stochastic-ensemble peptides rather than long functional sequences.

The leading group of experimenters with clay adsorption polymerizations is that of James Ferris [43,62,84] Ferris' group has concentrated mostly on the polymerization of oligoribonucleotides [62,84]. Minimal gene length in any life-origin model is generally thought to be 30–60 monomers (mers). 10 mers is the maximum length that forms in solution. Ferris' group has been able to produce 55 mer lengths on clay: montmorillonite for activated nucleotides;

illite and hydroxylapatite for joining activated amino acids directly [44]. The longer lengths are formed by successive 'feedings' with monomers. Polymerization is similar to solid-phase synthesis of biopolymers.

The problem with polymerization on clay is the strong tendency to produce highly ordered sequences rather than informational sequences. Montmorillonite aligned monomeric sequences offer no help in explaining the origin of genetic instructions.

Bernd M. Rode's group has also been a leader in pursuing spontaneous peptide formation, including homochiral preferences. Homochirality refers to a pure population of the same optical isomer (all right-handed gloves, or all left handed gloves). Most of Rode's group papers have been first-authored by either Plankensteiner [96,97] or Bujdak [21, 23]. Bujdak has also worked with clay adsorption [20,22]. Certain amino acids can catalyze peptide bond formation in "Salt-Induced Peptide Formation (SIPF)" reactions. Rode argues that SIPF reactions in connection with adsorption processes on clay minerals is the most likely universal mechanism for initial biopolymerizations in a Peptide World [109].

Certainly Rode and many others are correct that physycodynamic biases exist, especially with clay adsorption. However, the reasoning strikes us as being a nonsequitur in the statement, "Reaction-inherent preferences of certain peptide linkages make the argument of "statistical impossibility" of the evolutionary formation of the "right" peptides and proteins rather insignificant" [109]. In our opinion, physycodynamic bias only reduces through self-ordering tendencies the vast sequence spaces needed for prebiotic molecular evolution. Even if vast sequence spaces had been available in a theoretical primordial soup, no known mechanism exists for the prebiotic selection of *prescriptive* sequences. Prescriptive sequences require freedom of selection at each successive decision node. This freedom is anti-thetical to the self-ordering "necessity" of physycodynamic bias.

Fontana et al. studied phenotypic equivalence classes of genotypes in view of neutral genetic drift [46]. They then computed a statistical topology organizing the set of RNA shapes. Neighborhood relations among phenotypes were correlated with the statistics of neighborhood relations among equivalence classes of genotypes in genotype space.

Reza Ghadiri's group was able to replicate peptides using hydrophobic interactions between side chains of short alpha-helical peptides [112]. Some view this as a nonlinear molecular information transfer processes. But, as Mellersh points out [81], starting with RNA polymerase presupposes and incorporates considerable prior programming into Ghadiri's supposedly materialistic origin of protein self-replication. The initial information input is monumental (two 32-mer peptides). Mellersh argues that the Ghadiri group is merely joining together two large pre-activated chains. This is not really self-replication, but bioengineering. Continuity with present day biochemistry is also lacking.

How did the RNA polymerase achieve *its* functional sequencing? Even if there were some natural process explanation for this, how would all of the other needed substrates and enzymes acquire their critical monomeric sequencing at the same time and place? The self- or mutual replication of RNA polymerase would also use up most of the resources needed for other essential biopolymers to explore sequence space.

Homochirality theoretically could have been established through some mechanism similar to the self-replicative peptide model suggested by M. Reza Ghadiri's group [112] or the nonenzymatic templating of Bernd Rode's group. But no known physicochemical processes can produce anything close to a pure homochiral population of levo amino acids or dextro ribonucleotides. The question always remains, "How would *the template* acquire its homochirality in a prebiotic environment?" Ghadiri's group artificially amplifies an initially minimal enantiomeric difference in a racemic mixture of peptide fragments.

Despite having noteworthy success in producing self-replicating peptides, Ghadiri's research does not demonstrate self-organized autocatalytic networks capable of homeostatic metabolism. In addition, they stated quite accurately, "These results augur well for the rational design of functional peptides". Like the ribozyme engineers using SELEX, the Ghadiri group is very honest and up-front about the fact that the only way they accomplished this feat with polypeptides was through artificial selection, not natural selection. This rational design was formal, not physical. Of course the objects being manipulated were physical. But the rational design that alone produced the desired homochiral result was formal.

Take away rational symbol selection, and noise immediately begins to corrupt the functionality of linear digital sequences. This is true of any other kind of "meaningful" message that depends upon a particular syntax abiding by semantic and pragmatic rules. In the case of proteins, the "letters" of the sequence comprising the long "word" are monomers with specific *R* groups. The correct "letters" must be chosen at the individual covalently-bound primary-structure (sequence) level. This must be done before protein folding ever begins. Spontaneous natural-process peptide

formations have no ability to select and covalently bind “correct” amino acids. A prebiotic environment cannot anticipate future folding and binding needs for complex life.

2.5. *The role of variable free-energy binding of amino acids*

Amino acid (AA) free-energy binding creates a sequencing bias. Such a physicochemical bias creates highly ordered (patterned) sequences. Not only do the sequences have no foresight into how to generate a folding program, their highly patterned sequencing precludes programming. Spontaneous peptide formation cannot anticipate the tertiary-structure binding needs of complex integrated metabolism. Rigid covalent bonds firmly establish sequencing before hydrogen bonding, hydrophobicities, polarities, and van der Waals forces secondarily fold polyamino acid chains into needed shapes. Once in a long while the sequencing arising from free-energy preferences could just happen to correspond to the sequencing needed for functional tertiary structure and metabolic binding function (e.g., a membrane protein of archaeobacteria or prokaryote). But such an association would be extremely rare. It certainly would not establish a cause-and-effect relationship between physicochemical bias and algorithmic linear digital programming of needed tertiary function. The latter requires freely configurable, dynamically inert (dynamically incoherent) switches [106]. Physicochemical bias precludes such freedom, greatly reducing the Shannon information-retaining potential of any biopolymer.

Freely configurable switches are observed in all known current life. When proteins are formed by living organisms, their sequences are much closer to random than highly ordered or patterned by physical bias. Kok et al. [73] and Thaxton et al. [127] analyzed twenty-five ancient proteins and observed the peptide bond frequencies to have a distribution predicted by random statistics rather than physicochemical bias. The coding of proteins is unrelated to the free-energy AA bonding tendencies. This is not surprising. Given the mechanism of translation, one would expect freedom from such bias. Amino acids are located on the opposite ends of each *t*-RNA from the anticodon. If AA free-energy binding tendencies determined sequencing, the high information content needed to instruct and control life, its development, growth, and reproduction would be severely compromised. Other investigators have affirmed the conceptually ideal nature of genetic coding and control [15,48].

2.6. *Self-ordered structures can sometimes mimic true organization*

Anti-informationists often appeal to epigenetic factors, prions, self-replicating peptides, regulatory proteins and small RNAs to argue life is merely physical without need of formal genetic algorithmic control mechanisms. “The appearance of design” [38] is all that is granted to the most highly organized phenomenon known to science, that of life. A corollary of this perspective is to often view cases of merely self-ordered objects and events as being evidence of self-organization.

Garcia-Ruiz et al. were able to synthesize inorganic micron-sized filaments with curved, helical morphologies suggestive of biological forms [52]. Self-ordering abiotic and inorganic hydrocarbons readily condensed onto these filaments. The filaments were similar to supposed cyanobacterial microfossils from the Precambrian Warrawoona chert formation in Western Australia. These structures were once thought to be the oldest terrestrial microfossils. The authors showed that abiotic and morphologically complex microstructures that are identical to currently accepted biogenic materials can be synthesized inorganically. Thus self-ordering phenomena can mimic life’s algorithmic organization. Upon careful examination, such structures were found to be inanimate.

Epigenetic factors notwithstanding, empirical life has invariably been found to be fundamentally cybernetic. Linear, digital, genetic control of metabolism has been suggested as the most consistent singular criterion for differentiating life from nonlife [143,146]. No nonliving material in nature manifests this property.

3. Organization

Organization involves choice contingency rather than chance contingency or law-like necessity [2,3]. Organization requires purposeful selection from among real options. Organization is fundamentally algorithmic, goal-oriented, and formal. Organization requires dynamically-inert (dynamically incoherent) configurable switch settings [106] to instantiate formal choices into a physical matrix. Organization utilizes a sign/symbol/token system to represent those

choices. Symbols can be alphanumeric or other kinds of physical symbol vehicles. But their function is representational, not just physicydynamic. Triplet codons function in molecular biology as a Hamming “block code” of physical symbol vehicles in a sign system. They do not function physicochemically in their coding role. They *represent* a specified amino acid which is located on the opposite end of each *t*-RNA from the anticodon that binds with the codon. Representationalism using signs/symbols/tokens involves the matter-symbol problem, or philosophy’s “problem of reference”: How do symbols come to stand for physical structures? [27,57], [92, p. 11], [141].

Every example of true organization can be traced to cybernetic steering [11,34,110,136]. Algorithmic decision-node programming choices cannot be actualized by physicydynamics. Dynamics cannot generate “choice with intent” or formal computation. To instantiate free selections at decision nodes into a physical system requires the programming of dynamically-inert configurable switches [106]. These switches are not set by physicydynamic forces and laws. “Dynamically inert (dynamically incoherent)” was defined in the first paragraph of Section 2.

Instruction sets can be transmitted, received, and understood at the destination using a common coding-decoding system [119]. Coding systems, like choice with intent, is formal, not physical. Switch settings represent pragmatic choices at successive decision nodes in order to integrate circuits and instantiate cooperative management into physical systems [134–136]. Switch positions must be freely selectable to function as logic gates. Switches must be set expediently according to rules, not laws. Rules can be broken at will, often at the expense of achieving successful function [92, pp. 15–16], [93, p. 69].

Unlike digital systems, Hoffmeyer [61] considers analog systems to be dynamically coherent processes that specify a different dynamic system. But formality is still required to specify selections for function when designing an analog device. Switch settings never violate physical law. But physical law cannot set the switches so as to achieve formal computational success [2,3,128]. Chance, necessity, and extended periods of time cannot generate algorithmic programming. No empirical or rational support exists for believing that the environment can generate a sophisticated configurable system such as a computable cell. In addition, the code appears to be not only formal, but formally ideal for life [15,47].

A physicydynamically induced sequence could not be trusted to have any algorithmic function. The sequence would be “ordered” by redundant law and chance variation rather than by formal programming. The sequence would tend to be either random or highly patterned by law, such as a polyadenosine adsorbed onto a clay surface. Natural law produces only monotonous, redundant, low informational order. Natural law governance of configurable switches would set all switches the same, thereby precluding the freedom needed to program those switches. The program would contain all 0’s, or all 1’s. Nothing imaginative and complex could be computed from such an operating system or program. Yet biological computation is superior to the finest computer systems in existence [58].

We reluctantly use “self-organization” in our title for the benefit of those searching the all-too-widely-accepted term in the literature. But we question the rational validity and physical reality of the notion of self-organization. The only self that can organize its own activities is a living cognitive agent. In models of inanimate nature, including theorized primordial soup models, we maintain that “self-organization” is a nonsense term that should be critically analyzed for lack of both meaning and scientific content. The literature is replete with publications using the term self-organization erroneously to refer to self-ordering events.

Kauffman is one of many who continues his pursuit of “self-organization” out of mere self-ordering and statistical mechanics phenomena [67]. Purely physicydynamic cause-and-effect events are low-informational. They do not require engineering choices at successive decision nodes. No configurable switches have to be set in a particular way at each bifurcation point. Logic gates are irrelevant to the process. In self-ordered structures, the matrix or latticework is regular in a low-informational repeating pattern. No formal categorizations or teleonomic selective compartmentalization is required. The event just spontaneously self-orders by natural process with no selectable goal or desired function. The phenomenon is not algorithmically integrated. It is not organized by choice contingency. The process does not require programming to steer it toward formal computational halting. It is not contingent (could have occurred differently). Events occur by “necessity”. It self-orders “by law”, though our understanding of the interaction of combinations of the particular force fields involved may be poorly understood. The unimaginative matrices will never generate computations from buttons and strings, or from islands of quantum dots, because they contain no dynamically-inert, formally set, configurable switches.

Deamer [39], Luisi [126], and many others envision amphiphilic compounds spontaneously self-assembling into bimolecular layers. These in turn form closed membranous vesicles that supposedly incorporate self-organizing proto-

life. The formation of a bilipid micelle is a classic example of a self-ordering event. No design or engineering decisions are required. Like a soap bubble, the structure just spontaneously forms through natural process. It self-orders.

Sowerby et al. looked for clues in life-origin science as to how self-reproducing molecular machines might have originated. They looked to the spontaneous adsorption of purine and pyrimidine bases that become “self-organized” into monolayers and adsorbed onto the surfaces of crystalline solids [121]. The formation of these layers has nothing to do with organization. Their alignment and adsorption onto a surface is an example of natural process self-ordering.

Whitesides and Boncheva correctly use the term “self-assembly”: “Self-assembly is a process in which components, either separate or linked, spontaneously form ordered aggregates” [142]. Fletcher et al. have developed an artificial protein scaffold that allows linking of an in-vitro synthesized protein directly to the nucleic acid which encodes it through a self-assembly process [45]. They too correctly avoid use of the term “self-organization”.

Base-pairing is an example of self-assembly of a complementary strand. It proceeds by a self-ordering natural process. Only the sequencing of the *template's switch-settings*, if that template contains prescriptive information worthy of being copied, is organizational. But the replication of the template proceeds by natural process except where catalysis is required by formally instructed enzyme-sequences.

4. Laws and fractals are both compression algorithms

Laws and fractals contain minimal uncertainty, complexity, and information. They represent a unique synthesis of highly-ordered natural-process patterning with formal algorithmic compression. The formal component of a compression algorithm is always simple.

4.1. Laws are themselves compression algorithms for reams of empirical data

High order content hidden in experimental data allows compression down to an extremely low-informational formal description. Ocham's razor states the simplest explanation for any natural phenomenon should be preferred. The simplest and most pristine formulae are considered “elegant”. Ocham's razor is prized as a general principle of science precisely because law-like behavior is so highly ordered that endless data can be compressed to one simple equation (e.g., $F = ma$; $E = mc^2$). Such parsimonious equations are not complex. This does not deny that they have tremendous pragmatic value. But they nonetheless contain very little Shannon uncertainty or prescriptive information.

No newly discovered law or theory of everything will explain the vast information content found in genomic instructions. Highly informational algorithmic organization cannot arise from such simple, highly ordered, low informational formulae. Thus quests such as “the search for laws of self-organization and complexity” [64] make no sense.

4.2. Fractals create the illusion of complexity

Fractals correspond to redundant, monotonous, highly-ordered states. Fractals select members of geometric shapes for endless reuse. Parts of fractals resemble the whole in a self-similar pattern. Like laws, the instructions producing fractals are compressible to parsimonious descriptions. The only significant algorithmic aspect of fractals is found in the compression algorithm that can reduce their high order content to an extremely low informational Kolmogorov reduction [76]. They have little or no potential to organize or instruct anything sophisticated. Nearly all of the switches of fractals minimal program are set the same way. Nothing imaginative can result. Almost no instructions are provided, certainly not the cybernetic prowess required for a living cell or complex eukaryotic organism. The Cantor Dust Fractal (see Fig. 1) is a prime example: “Take a line segment, remove the center third. Repeat N times”. Such a fractal may seem “complicated” compared to the same fractal with many fewer iterations, but it certainly is not “complex”.

Maximum complexity is located at the opposite end from maximum order on a uni-dimensional vector that flows from high order to high complexity [3,143,144]. Maximum complexity is a random sequence with no compressibility. Maximum order is purely redundant pattern (e.g., a polyadenosine: pick adenosine, repeat N times). Fractals are anything but random. Fractals are highly ordered and among the least complex of all structures. Hence fractals are of minimal interest in explaining highly informational organization.



Fig. 1. The Cantor Dust Fractal representative of the high order content of all fractals. Fractals create the illusion of high complexity. Their low complexity is demonstrated by the simple Kolmogorov compression algorithm: “Take a line segment, remove the center third. Repeat N times”.

5. Open systems far from equilibrium

Nicolis and Prigogine [86] argued that for any time interval (ΔT),

$$\Delta S = \Delta S_i + \Delta S_e.$$

Where ΔS_i is the change in entropy internal to a system and ΔS_e is the change in entropy resulting from an external flow of mass or energy through that open system. Thaxton et al. [127] summarized some of the thermodynamic problems associated with life-origin scenarios. In a closed system, $\Delta S_i \geq 0$ according to the Second Law. Also in a closed system, $\Delta S_e = 0$, which is why in a closed system total ΔS is always positive.

When $\Delta S_e > 0$, the system is open to an influx of mass or energy. But the mere influx of mass/energy by itself does not necessarily mean the system will become metabolically homeostatic. The influx of raw energy is far more likely to add to the unusable, wasted energy generated internally by the system. An influx of energy usually only speeds degradation of the system being intruded.

What generates the possibility of metabolic homeostasis and growth in living organisms is the prescriptive information [2,3,128]. Prescriptive information either instructs or directly produces sophisticated algorithmic utility. It comes in the form of dynamically-inert configurable switch-settings [106] that have been programmed in a certain way so as to successfully compute. Computation has never been observed to arise independent of choice contingency. Neither chance contingency nor the necessity described by law has ever been observed to produce algorithmic optimization. Prescriptive information alone produces organization [2,3,128], not physiodynamics. The engineering mechanisms generated by this prescriptive information are alone what makes homeostatic metabolism possible in the cell possible. Such metabolism never violates the second law of thermodynamics. The mechanisms merely make energy trapping, transduction, and utilization for cellular work possible. Metabolic function is instructed by preset configurable switches.

One of the sources of so much confusion between self-ordering events and true organization is the failure to realize that the definition of “entropy” is formal, not physical. “Energy not available for work” presupposes that we know the definition of “work”. What is “work”? “Work”, like “function”, is a formal engineering concept that extends far beyond mere physical ISness. Like “shoulds” and “oughts”, work and function lie in a different category and dimension entirely from mere order and complexity [3]. Even Shannon, Kolmogorov, and Chaitin concepts are formal. Both high order and high complexity can exist in systems that have no function. Neither work nor function is reducible to physicality. They both have formal components. When entropy is thought of in purely physical terms, a serious category error of logic theory has been committed which leads to fallacious inferences.

The result of failing to realize the formal component of entropy is confusing entropy with order/disorder. Both highly ordered and disordered states can manifest variable amounts of entropy. A highly ordered crystalline structure can trap and store considerable usable energy, or a crystal can be a near thermodynamic dead end. Highly complex and disordered states can possess considerable usable energy given the right algorithmic mechanism to harness it. Entropy is not synonymous with “disorder”. Published scientific literature is replete with nonsense emanating from this source of confusion.

Another catastrophic result of failing to appreciate the formal component of entropy is trying to define work solely in terms of physical states. Work is a directed process. Work accomplishes something useful in a larger engineering context. Mere physicality is blind to concepts of “usefulness” and “usability”. Work is almost always algorithmically directed. Mere phase changes do not constitute usable work unless those phase changes have been deliberately incorporated into an algorithmic scheme. Even analog systems must be designed with choices. Agents value usefulness. Physicality values nothing. “Energy available for work” entails more than spontaneous phase transitions.

A third problem with failing to realize the formal component of entropy is the confusion of physical entropy with the Shannon's probabilistic uncertainty in communication engineering. Physical phase spaces often have no cross-over with numerical and alphabetical symbol string combinatorial probability spaces [143,145]. As mentioned earlier, the merging of thermodynamic entropy with Shannon entropy has been called into question [143, p. 84]. The two probability spaces are nonisomorphic even though the formulae are the same. Information theory *lacks the integral of motion* present in thermodynamics and statistical mechanics. In thermodynamics and statistical mechanics, there is no *code* linking the two "alphabets" of linear stochastic ensembles that we see in the information theory of biomessages. Kolmogorov–Solomonoff–Chaitin complexity does not reside in the domain of stochastic ensembles of statistical mechanics. In addition, Boltzmann's definition of entropy *specifically excluded a negative constant* from the mathematical definition of entropy [12]. All of the probabilities involved in S are of necessity nonnegative numbers from 0 to 1. This makes the notion of "negentropy" an illegitimate extension from the thermodynamic entropy equation. No physical system, life included, escapes the domain of the 2nd Law of thermodynamics.

In an open system far from equilibrium, prescriptive information in the form of pre-programmed configurable switch settings provide the formal mechanisms required to capture, store and use otherwise unusable energy. This qualifies as "work". It is accomplished through organization. Solar energy, for example, is wasted energy apart from algorithmic capabilities instantiated into the control mechanisms of such structures as chloroplasts. Spontaneous electron transfers may occur through natural process. But it is the algorithmic harnessing of such energy transfers into a utilitarian schema that defines and produces "useful work". Cybernetic steering is required to transduce, store, and call up that energy in a usable form when needed. Without such steering toward eventual function, organization is impossible. No purely physical system devoid of algorithmic control from a formal source can "self-organize".

6. "Self-ordering" and "self-organizing" cannot be used interchangeably

Self-ordering events and algorithmic organization lie in completely different categories with no cross-over and no set intercepts [3]. Only after instantiation of formal choices into a physical medium of dynamically-inert configurable switch-settings are physycodynamic factors secondarily introduced. The selection of desired switch-settings is not reducible to physycodynamics except in the instructed physical act of throwing the switch. This is the point of instantiation of cognitive intent into physicality. But the setting of the switch on a horizontal circuit board panel *in one direction rather than another* is formal, not physycodynamic.

Stegmann shows that at least one class of genetic information exists wherein molecular processes exhibit the semantic properties of aboutness, error, and information storage [122]. Aboutness [19,59] is not an attribute of chance and necessity. No self-ordering event conveys representational meaning, except what might be constructed within the mind of an interpreting agent. Adami is correct when he insists that "information is always about something" [4]. But aboutness will not be found in comparing two combinatorial syntaxes alone. As Adami argues [5], aboutness exists in an environmental context. But significance must be read into, or applied to, sequences by agents using arbitrary rule-based assignments. The inanimate environment does not make value judgments regarding meaning, significance, or the worth of potential function. Such assignments of significance are formal, not physical.

Science, mathematics, and logic demand exact definitions to avoid the invalid logical inferences known as "category errors". Linguistic equivocation results in faulty models and conclusions. Once considerable publication capitol is invested in models and theories, linguistic equivocation often grows into obfuscation by proponents to support the mirage of their pseudo explanatory mechanism. This approach is not scientific.

Not even a satisfactory hypothetical model has been provided for "self-organization". Yet the literature liberally appeals to this imaginary process as proven fact. "Self-organization" is granted causal status for "complex" phenomena we do not understand. A healthy scientific skepticism is necessary. Organization is not a physical cause. It is the product of incorporating formal choices into physicality using dynamically-inert, deliberately chosen configurable switch settings.

7. “Self-organization” has not been demonstrated to exist

7.1. *No empirical evidence*

We are aware of no publications demonstrating bona fide “self-organization” in nature. Self-ordering has been observed. But self-ordering shows no dependence upon, and plays no role in, cybernetic programming. Evidence of spontaneous generation of algorithmic optimization is simply absent from the literature. Physical objects have never been observed to spontaneously compute. They self-order. But they do not spontaneously program. Neither random number generators nor stochastic ensembles have ever been observed to produce computational halting. There is no reason to ascribe formal creativity to physical ISness. Computational halting is no more derivable from the ISness of physicality than are “shoulds” and “oughts”. Algorithmic optimization requires steering toward “success” [28,35,83]. Physicality possesses no such motives. It does not and cannot make wise formal programming choices.

Genetic programming is the most sophisticated cybernetic phenomenon known to humans. No human-made system is as complex as biological computation, organization, and regulation. Life is programmed with degrees of freedom to respond appropriately to diverse environmental eventualities. For example, in prokaryotic organisms genes are expressed under certain environmental conditions. No natural process model has come close to explaining the reality of the formal component to biological cybernetics.

7.2. *No rational plausibility*

Leslie Orgel [87] examined the plausibility of theories that postulate the development of spontaneous complex chemical organization. He concluded that “theories that involve the organization of complex, small-molecule metabolic cycles such as the reductive citric acid cycle on mineral surfaces make unreasonable assumptions about the catalytic properties of minerals and the ability of minerals to organize sequences of disparate reactions”. Orgel argues that “data in the Beilstein Handbook of Organic Chemistry that have been claimed to support the hypothesis that the reductive citric acid cycle originated as a self-organized cycle can more plausibly be interpreted in a different way” [87]. Even a theorized protometabolism involves far more than just self-replication. Life cannot be reduced to mere self-replication or micellar GARD’s. GARD’s are “graded autocatalysis replication domains”—mutually catalytic sets of simple organic molecules envisioned to be capable of self-replication and rudimentary chemical evolution [116–118]. Even a protometabolism requires true organization. Stochastic ensembles possess no organizational skills.

It is common for theorists to limit the discussion to only the first steps toward life. But why would inanimate nature make *any* steps *toward* life? Evolution has no predetermined goal or end point. The environment could care less whether anything functions, let alone whether anything comes to life. In a prebiotic molecular-evolution environment, no differential survival or differential reproduction exists yet. Natural selection does not exist yet in a prebiotic environment. Organization requires selection at the decision-node rigid covalent-bond level of sequence formation. Each switch setting must be made so as to contribute to eventual computational success. Organization is a formal process, not a physiodynamic necessity. No rational scientific basis exists for blindly believing in a relentless uphill push by mere physicality toward formal algorithmic optimization and organizational sophistication.

A minimal degree of integration is required of many cellular biochemical pathways and cycles to produce homeostatic metabolism, differential survivability, and differential reproduction. Only then does selection pressure on phenotypes come into play. It is not sufficient to keep stating “That is too complex to have been there from the beginning”. Simpler Ganti like scenarios [49–51] are too accidental and momentary to be sustained without linear digital memory and heritability programmatically organizing and maintaining that protometabolism. The wheel would have to be reinvented with each new generation. Homeostatic metabolism is statistically prohibitive enough as it is as a one-time event. No Metabolism-First model can be sustained without rapid incorporation of any minimal successes into a recorded, integrated, heritable, cybernetic scheme.

“Self-organization” is not rationally sound. Cybernetics requires not only “anticipation” of pragmatic needs, but prescription in the form of a programmable fulfillment strategy. Inanimacy and physical nature cannot anticipate the future needs of living organisms. Yet anticipation is needed to program any kind of step-wise procedure for sophisticated utility/function. Random number generators do not produce computational halting. Neither does fixed law-like behavior.

Physicality is not logically capable of generating the abstract representationalism inherent in sign system use. Chance and necessity cannot generate choice contingency required for symbol selection and arbitrary assignment of meaning to those symbols [2,3,128]. The physical symbol vehicles themselves are not capable of generating rules and engineering cooperative integration between parts. It is irrational to attribute algorithmic organization to “self” when “self” consists of inanimate objects that cannot choose. If there is any universal criterion of agency, it is the ability to choose with intent. Programming is impossible without this attribute. Organization requires programmed integration. Components must be formally controlled into a cooperative effort to produce a functional cell.

Physicality is divided from symbolization by an “epistemic cut” [60], [90, p. 36], [94]. A description of an event is separated from the objective event itself. “Semantic closure” must occur [91,92,130,132]. This is similar to the measurement problem in quantum theory. The genotype-phenotype dichotomy in biology also portrays a similar epistemic cut. Options cannot be selected stochastically if any engineering function is expected. Symbols must be selected for their representational value. The meaning of these symbols is defined by their function. Codons, like the letters of words, function as symbols, not as chemical reactants. In the absence of repeated observation, falsifiability, prediction fulfillment, and rational respectability, the notion of self-organization is wishful thinking and speculation [88].

We question Eigen’s recent definition of information “meaning” [41]. “The conclusion is reached that information content is generated via selection, which can be described as a phase transition in information space”. We agree with Eigen that “information content [what we would call “prescriptive information” content, at least] is generated via selection”. But we challenge the ability of phase transitions to reflect any of the attributes of selection pressure or of biological instructions (not all of which are genetic). A more constructive definition of “meaning” in biological information is, “The meaning of bioinformation is the biofunction that information instructs or produces at its destination” [1]. Phase transitions do not instruct anything, nor do they contribute to biological algorithms. They fail to explain selections at the bifurcation points of networks and neural net equivalents. They cannot explain efficacious settings of configurable switches. We need a better paradigm than phase changes to explain selection of functional monomeric sequencing.

Biopolymers are essentially strings of decision nodes. Monomers function as alphabetical symbols in a sign system [2]. The decision at each node is more than a mere coin flip [128]. Self-replication of “gibberish” strings offers far less to any life origin model than we suppose. Each nucleotide in an oligonucleotide represents the equivalent of a four-way fork in the road. The right road must be taken at many successive four-way forks prior to the realization of any after-the-fact phenotypic biofunction. We need a mechanism that explains the correct selection of each of these road options. After-the-fact phenotypic selection does not explain how the computed phenotype came into existence. We cannot continue pointing to clay or lipid templates without explaining where/how the template acquired its instructive sequencing.

7.3. *No prediction fulfillment*

A key tool of verification in science is the ability to predict future physycodynamic events using nonphysical, formal models. Not one realization of prediction of self-organization of a nontrivial cybernetic system has been experienced and published, to our knowledge. Given the millions of supposedly self-organized systems that exist in the empirical world, there should be no problem observing such a prediction fulfillment of spontaneous self-organization. Little reason or excuse remains for clinging to the metaphysical presupposition of self-organization.

The Stigmergic Systems website [120] defines “Self-organization” as the “unplanned organization that emerges from an open system of interacting components. The system can be thought of as lifting itself up by its boot straps”. By what scientific mechanism does this self-help system arise in nature? The website responds, “It is impossible to even begin to understand how all these different influences have an effect on the organization that emerges”. It is impossible for these authors to distinguish such self-organization dreams from “wish fulfillment”. Any biophysical explanation is absent.

When predictions of infrequent events fail, it is common to appeal to long periods of time as a caveat. But the longest possible period of time based on current estimates is 10^{17} seconds (14 billion years). This maximum time can be factored into probabilities to adjust for infrequent events. Even after multiplying probabilities by 10^{17} , self-organization of life models yield probabilities far less than every published probability bound. The most widely referenced probability bound in scientific literature is also the most conservative: 10^{-50} [14, p. 28]. The most lib-

eral and permissive is 10^{-150} [40]. The latter probability bound grants chance enormous potential. Yet most models of biological self-organization are far less probable than 10^{-150} .

7.4. No falsifiability

The notion of self-organization is not falsifiable by hypothesis-driven scientific method. Hypotheses must be testable, especially to merit respectability as a scientific theory. No experimental design has been offered that can test and potentially falsify such an open-ended postulate as hoped-for self-organization. Its source is not scientific, but metaphysical. In the conclusions of this paper we offer two testable null hypotheses that are potentially falsifiable. Demonstration of a single exception would falsify either null hypothesis.

Kurakin [75] provides an example of many investigators who are progressively abandoning mechanistic concepts of molecular motors and protein translocations in favor of stochastic models. The latter are seen as being a more fruitful conceptual framework for understanding biological organization at the molecular level. Once stochastic self-organization has been metaphysically presupposed as the central integrating theme of biology, the paradigm takes precedence over empirical, predictive, and rational inconsistencies. The lack of falsifiability of self-organization leaves the notion with widespread acceptance.

8. The problem of prescriptive sequencing

The problem of prescriptive and functional sequencing exists whether we begin our life-origin model in a Peptide/Protein World [109], or in a Pre RNA/RNA World [53]. The first question that must be resolved is the degree to which polymerization is dynamically inert. This is the degree to which sequencing is dynamically incoherent rather than coherent. Incoherence is freedom from physicochemical cause-and-effect determinism. Physicodynamic incoherence in turn subdivides into two subcategories of interest to life-origin science: how dynamically inert is:

- (1) peptide bond formation between the 20 main biological amino acids, and
- (2) 3'5'-phosphodiester bond formation between the five heterocyclic nucleotides.

In both categories of untemplated polymerization in a prebiotic environment, physicochemical self-ordering tendencies would severely preclude instantiation of prescriptive information into the sequence. The reason is that freedom would be restricted in coding selections if physicochemical “necessity” forced certain selections. Law-like determinism would tend to code every sequence the same. Physicochemical bias would reduce each linear digital programming “choice” of monomer to a noncontingent, fixed, cause-and-effect result with only mild random variation of alternatives.

Let us begin with the spontaneous formation of polyamino acids. As mentioned briefly above, Kok, Taylor and Bradley [73,127] disproved the notion that differences in chemical binding forces between amino acids would lead to nonrandom dipeptide distributions. If amino acids *A* and *B* have the strongest bonding affinities for each other in a mixture of *A*, *B*, *C*, *D*, *E*, *F*, and *G*, then we would expect many more *AB* dipeptides to form than *AG*'s or *BE*'s. Kok, Taylor and Bradley analyzed 25 different proteins, finding a nearly random distribution of peptide bond frequencies. Bonding preferences appeared to play almost no role in protein coding [73]. Sequences were dynamically incoherent with cause-and-effect physical law. They were dynamically inert.

In current life, polyamino acid sequencing is prescribed by codon sequence, not by amino acid free-energy bonding preferences. If in a Peptide World bonding forces determined sequencing, the high degree of self-ordering would have produced low-informational, monotonous, redundant sequences of the same few amino acids. The peptides would have lacked the many specific functionalities needed even for the simplest of protometabolisms. All spontaneously formed peptides would have tended to be the same. This would have restricted the sample space of three-dimensional shapes that is invariably cited as mechanism for molecular evolution [46,133]. Given the short period of time between earth's cooling (4.0 to 3.9 Ga) and the 3.8 billion-year-age of life [85,131], life could not have evolved from a peptide world out of such a highly self-ordered minimal sample space. The nearly ideal nature of genetic coding could only have arisen out of freedom of programming selection for function [47].

Aside from templating and base-pairing, ribonucleotides show little physicochemical bias in polymerization of in aqueous solution. Any differential availability of nucleotides in a primordial soup would have produced weighted

means in the formation of stochastic ensembles, however. But this would only reduce the number of bits of Shannon uncertainty and complexity. Information retention in the RNA matrix of a forming RNA World would have been severely restricted by both the limited availability of certain nucleotides, and/or by varying nucleotide binding energies. The key to instantiation of prescriptive information into nucleic acid sequences is the fact that polymerization of nucleotides corresponds to freely configurable switch settings. Physical laws do not determine sequencing in aqueous solution. Only templating and the replication of existing informational sequences by base-pairing is physicyodynamically constrained. Source code, on the other hand, is truly *controlled* by symbol selection and by encryption/decryption *rules, not laws and constraints*. The fixed laws of nature cannot explain formal instructions or coding function.

9. Discussion

Cybernetics is not achieved through physicyodynamic constraints and cause-and-effect laws. It is achieved using arbitrary rules governing a theory of logic and “language convention”. Expedient programming choices must be made at each critical decision node. Not all decision nodes in biopolymers are critical. Some sections of primary structure become buried in the tertiary structure of the protein where the *R* groups play little or no role.

The selection of physical symbol vehicles and messages are inert with respect to dynamics [106]. Semiotic function is not achieved through law-like behavior. It is achieved through formal cybernetic prescription [74]. Prescription can be achieved only through the sequencing of particular alphabetic symbol selections and/or configurable switch-settings. Switches can be freely set because no physicyodynamic preference exists for any of the four nucleotides to bind in a nontemplated single-stranded positive strand.

Only the replication of an existing template is physicyodynamic. But the programming of the template itself must be formal, not physicyodynamic, if the template is to convey nontrivial prescriptive information and functional meaning to its replicant. No physical theory can explain this dynamically-inert, digital coding function [143,146]. Self-ordering could never generate the freely programmable configurable-switch-settings required for organization. Functional choices at successive decision nodes cannot be made by chance or by fixed laws. Self-ordered phenomena cannot program the organization of algorithmic systems. Genetic control is algorithmic and cybernetic. It employs a representational sign system, dynamically-inert configurable switches, coding encryption/decryption, formal computational halting, and meaningful messages understood in terms of eventual metabolic success. Cellular and organismic processes require all of the above. These lead to differential survival and reproduction required for evolution and diversification of species. But natural selection cannot generate the genetic programs that compute the fittest already living phenotypes. Selection pressure favors only existing, already-computed, phenotypes.

“Selection for function” has escaped quantification efforts in information science. Yet it is this selection for function that is the essence of organization. It occurs at successive decision nodes. Both functional and nonfunctional selections are possible at each decision node within the constraints of the laws of physics. Physicyodynamics cannot make efficacious choices. If law made the choice, all switches would be set the same. No computational function would result. If the choice were random, no sophisticated utility would result. Neither chance nor necessity can explain molecular machines and computable cells. Protein and ribozyme conformation is prescribed by the sequencing of primary structure. Primary structure in turn determines minimum-free-energy folding constraints into a three-dimensional structure. Sequencing is formal, not physical. In biology, the sequencing of nucleotide selections into digital prescriptions and the use of a formal encryption/decryption, rule-based system is what organizes life. No such cybernetic system can self-order or self-assemble.

The emergence of agents is not possible from a connectionist state-determined system [80]. Neural networks and connectionist models are dynamically coupled to, or coherent with, their environment [30,103]. The aim of research into connectionist systems is to be able to explain emergent classifications (Eigen-behavior). This classification is considered emergent because “it is the global result of the local, state-determined, interaction of the basic components of the self-organizing system with its environment” [105]. But such a system precludes the most fundamental aspect of agency: choice contingency. Choice contingency in turn requires freedom from cause-and-effect determinism and random noise at configurable switches. Agency is able to choose with intent. Connectionist systems cannot properly be called “embodied agents” because connectionist systems are dynamically coherent with their environments. If embodied agents were connectionist systems, no mind-body problem would exist to ponder. Thoughts would be determined by cause-and-effect physicyodynamics [108, p. 7]. Thoughts would be either random or self-ordered into a fixed regularity. Logic gates would produce either noise, or be locked into one fixed position by necessity. Dynamically

coherent agent-environment couplings cannot, therefore, give rise to “embodied cognition”. The connectionist system cannot be isolated from its environmental determinism to achieve choice contingency.

Molecular biology preceded temporally and causally all forms of brain-secreted cognition. Each amino acid prescription is the “letter” of a protein “word”. Biomessages have real meaning. No direct physicochemical binding or reaction occurs between the codon symbol and the prescribed amino acid. The genetic code table is formal, not physical. No amount of physicochemical self-ordering events can explain its abstract concept and freedom from dynamic constraints. Infodynamic reductionism cannot explain the literal genetic algorithms of living organisms. Systems biology must confront the need for selection at the genetic level [124]. Although integrated algorithmic systems can be instantiated into physicality, they are fundamentally formal, not physical. Physicodynamics is incapable of self-organizing such a formal system of genetic control.

Separate manuscripts will address why neither *hypercycles* nor *evolutionary algorithms* can give rise to bona fide self-organization.

10. Conclusions

The numerous published papers referring to inanimate “self-organization” usually fall into one of three categories:

- (1) The authors are mistakenly referring to natural-process self-ordering phenomena that have nothing to do with algorithmic organization,
- (2) The process described involves hidden experimenter interference (artificial selection and investigator involvement in the experimental design). The most common form of behind-the-scenes investigator involvement consists of choosing which iterations to pursue in pseudo evolutionary algorithms (e.g., ribozyme engineering experiments using SELEX [42,104,129]).
- (3) The term is used to refer to an imagined ingenuity of physicality for which no scientifically verifiable reality exists.

We propose the following fully falsifiable null hypotheses to test the ingenuity of spontaneous physicodynamics:

- (A) Self-ordering phenomena cannot generate cybernetic organization.
- (B) Randomness cannot generate cybernetic organization.

We invite falsification of either or both of these null hypotheses. Demonstration of a single exception would falsify either null hypothesis.

Our contention is that all organizational systems are fundamentally formal. Dissipative structures (e.g., hurricanes, tornadoes, candle flames) are not true organizational systems. They are a string of moment-by-moment self-ordered states incapable of organizing physicality into nontrivial computational utility. If anything, dissipative structures destroy physically instantiated, algorithmically programmed material sign systems (MSS) [106] and the functionality they engineer.

We maintain that “self-organization” is a nonsense term when applied to inanimate nature and pre-biotic molecular evolution. The notion is without empirical and prediction-fulfillment support. “Self-organization” is not falsifiable, provides no mechanism, and offers no plausible explanatory power. The concept fails every test of scientific respectability, and should be skeptically viewed until further research provides more verifiable substance to the notion.

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