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4. What Utility Does Order, Pattern or Complexity Prescribe?*

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Abstract: "Order," "pattern," "complexity," "self-organization," and "emergence" are all terms used extensively in life-origin literature. Sorely lacking are precise and quantitative definitions of these terms. Vivid imagination of spontaneous creativity ensues from mystical phrases like "the adjacent other" and "emergence at the edge of chaos." More wish-fulfillment than healthy scientific skepticism prevails when we become enamored with such phrases. Nowhere in peer-reviewed literature is a plausible hypothetical mechanism provided, let alone any repeated empirical observations or prediction fulfillments, of bona fide spontaneous "natural process self-organization." Supposed examples show only one of two things: 1) spontaneous physicodynamic self-ordering rather than formal organization, or 2) behind-the-scenes investigator involvement in steering experimental results toward the goal of desired results. The very experiments that were supposed to prove spontaneous self-organization only provide more evidence of the need for artificial selection. Patterns are a form of order. Neither order nor combinatorial uncertainty (complexity) demonstrate an ability to compute or produce formal utility. Physical laws describe low-informational physicodynamic self-ordering, not high-informational cybernetic and computational utility.

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Introduction: Order vs. Complexity

A great deal of confusion exists about the roles of order and complexity in explaining sophisticated function. We presume, incorrectly, that anything organized must be highly ordered and complex. Worse yet, we equate the two. It is true that the more organized something becomes, the more complex it tends to become. It is also true that we usually find some compressible order within Functional Sequence Complexity (FSC) [8] and Prescriptive Information (PI) [6].

But, a serious problem arises when trying to conflate order with complexity. Order and complexity are antithetical. The more ordered the conglomerate, the less complex it is; the more complex the conglomerate, the less ordered it is. This is easier to understand in one dimension (See Figure 1). When we progress from linear complexity into two- and three- dimensional complexity, quantifying the degree of complexity can quickly become intractable [10]. Thus, let us begin by precisely defining linear sequence complexity. Later we will expand this understanding into additional dimensions.

1. What is complexity?

As extensively as "Complexity" is used in life origin literature, the term is almost never defined. "Complexity" tends to be highly elastic term we use to explain everything we don't understand and cannot reduce.

An unequivocal, pristine, mathematical definition of linear "complexity" already exists in scientific literature [8, 11-13]: maximum complexity in a linear string, oddly enough, is randomness if one were to attempt to algorithmically decipher patterns or function. A sequence is maximally complex when it cannot be algorithmically compressed. Random sequences are maximally complex because they lack pattern and order [14, 15]. Thus complexity can be quantified by measuring algorithmic compressibility. The more ordered a linear digital sequence, the less complex it becomes, and the fewer bits of potential information that string can retain.

Randomness is antithetical to order. Randomness represents maximum uncertainty. Uncertainty can be measured in Shannon bits. Bits of uncertainty increase as we move from high order on the left of Figure 1 towards randomness on the right. As we move towards the left, away from complexity towards increasing order and pattern, bits of uncertainty decrease. A random string (Random Sequence Complexity, RSC) [8] is the most complex because its sequence cannot be enumerated using any algorithmically compressive string shorter than itself.

Notice that this precise definition of linear complexity has nothing to do with meaning or function. Complexity in linear digital strings is fully measurable by the degree to which each string can be algorithmically compressed. This is true whether the string *does* anything useful or not. Figure 2 helps to show the relationship between compressibility and the bidirectional vector of order vs. complexity.

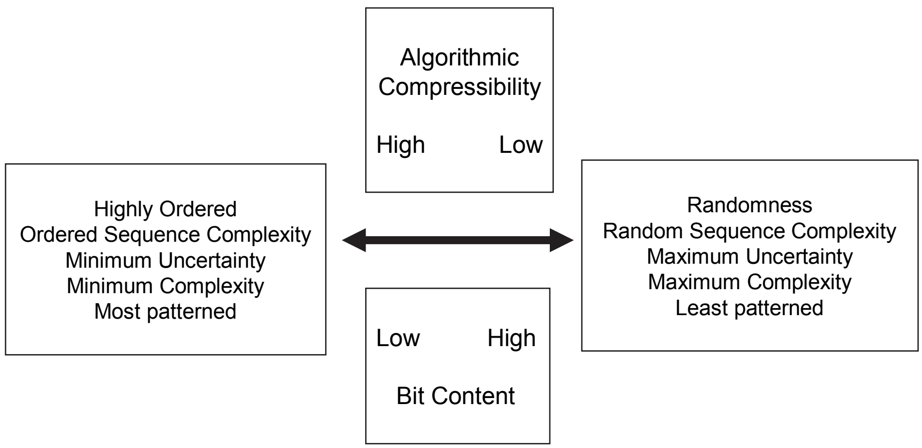

Figure 1. An antithetical relationship exists between linear sequence order and complexity. Randomness affords the greatest measure of complexity. The more ordered and patterned a sequence, the less uncertain are its components, and the less complex the sequence. Neither order nor complexity generates formal meaning or utility, both of which lie in a completely different dimension from order/complexity measures.

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Cellulose is a highly ordered molecule consisting of a string of d-glucose (dextrose) molecules. It can be algorithmically compressed by saying, “Give me a dextrose molecule, repeat X times.” A theoretical stochastic ensemble of multiple types of polymerized simple sugars, however, might have no compression algorithm shorter than enumerating the random sequence of sugars itself [14-16]. It possesses no order or pattern, and therefore no compressibility. Thus a reliable definition of complexity is provided by its degree of algorithmic compressibility. The less ordered and the more random is a sequence, the more complex it is.

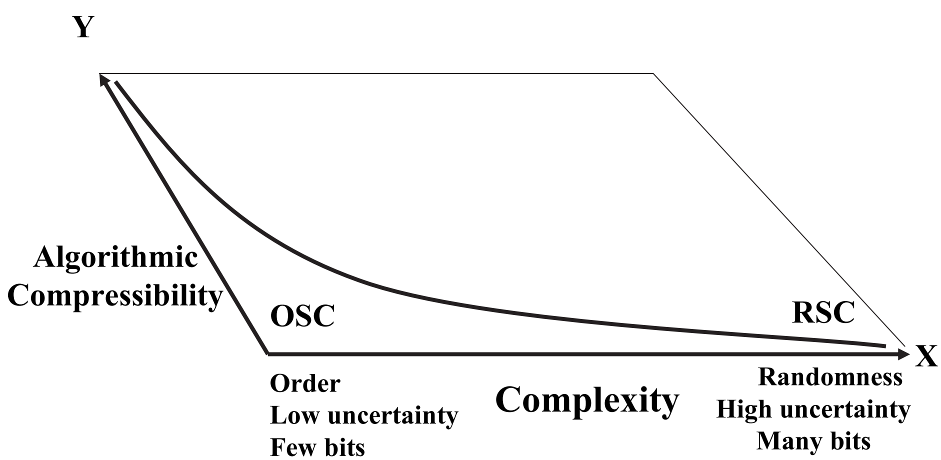


Figure 2. The adding of a second dimension to Figure 1 allows visualization of the relationship of Kolmogorov algorithmic compressibility to order and complexity. The more highly ordered (patterned) a sequence, the more highly compressible that sequence becomes. The less compressible a sequence, the more complex it is. OSC = Ordered Sequence Complexity. RSC = Random Sequence Complexity. A random sequence manifests no Kolmogorov compressibility. This reality serves as the very definition of a random, highly complex string.

Table 1: The difference between "order" and "complexity"

Order	Complexity
Regular	Irregular
Repeating	Non-repeating
Redundant	Non-redundant
Predictable	Non-predictable
Symmetrical	Asymmetrical
Periodic	Aperiodic
Monotonous	Variable
Crystal-like patterning	Little patterning; none if random
Reducible	Largely irreducible
Compressible	Largely non-compressible

High order, such as we see in homopolymers of nucleic acid (with all the nucleotides in the string being the same), possesses little or no uncertainty. High order, therefore, possesses little ability to retain information. Ribozymes and genomes are not homopolymers of DNA for good reason. Sequencing is highly variable depending upon the prescribed function. Highly specific sequencing matters. The reason life uses carbon chemistry to instantiate Prescriptive Information (PI) is the ability of carbon-based polymers to provide unlimited Shannon uncertainty in biopolymer combinatorialism. Consequently, high complexity comes closer to explaining sophistication than does high order. We can see that to attribute sophisticated organization, function and work to high degrees of order doesn't make sense. And to appeal to high degrees of order and complexity simultaneously is logically impossible. Is it complexity that explains organization and sophisticated function, then? If we *had* to pick between the two as the source of organization, we would have to go with complexity rather than order.

But now we have a new problem. Maximum complexity is randomness. Maximum complexity is noise. Since when did randomness and noise ever produce anything with sophisticated function? Would the results of an algorithm that produces supposedly random numbers ever produce a meaningful computational program? Neither order nor complexity is the answer when it comes to explaining the derivation of organization, sophisticated function, computation, algorithmic optimization, and useful work. As mentioned above, it is certainly true that sophisticated formal systems are almost always complex. But complexity is just a secondary feature of highly organized systems, not the cause of that organization. Randomness and noise (maximum complexity) cannot organize anything. Something major is missing from the equation.

We have invested so much confidence and anticipation in "complexity" as a potential source of spontaneous prescriptive information and organization that our senses should be jolted by the pristine mathematical definition of sequence complexity:

$$H = \sum_{i=1}^{M} p_i(-\log_2 p_i) \tag{1}$$

This, of course, is Shannon's basic measurement of uncertainty in linear sequence complexity. This metric of uncertainty also measures linear digital complexity in bits. The minus sign is necessary to invert the log of a fraction (a probability) so as to render the measurement of negative uncertainty in positive bits. Normally, the minus sign is just placed in front of the entire expression.

This mathematical measurement should remind us that maximum complexity is nothing more than maximum uncertainty and randomness. Complexity, therefore, has nothing to do with generating formal function. Complexity possesses no creative or computational talents. No justification exists for attributing exquisite formal organization to mere complexity.

The relation of order and complexity remains the same as we begin to add dimensions. The secondary structure of ribozymes, for example, is represented by a linear digital string of ribonucleotides folded back onto itself into two dimensions forming helices, bulges, hairpin loops, internal loops, and junctions [17, pg. 683]. The more ordered (redundant the sequence of nucleotides) in the initial polymer, the less sophisticated secondary structures tend to form. Of course stochastic ensembles of ribonucleotides (random strings) don't tend to form functional folds either. The initial primary structure of linear digital sequence of ribonucleosides in catalytic ribozymes is highly varied; they are unpredictable with a non-deterministic, non-ordered sequence of nucleotides. But, this complexity is only secondary. The real issue is that of having a particular needed sequence (the *programming*) that allows a string to fold back onto itself to form the requisite secondary and tertiary structures. High order (unimaginative redundancy of nucleotide or amino acid sequencing) only limits sophistication of three-dimensional molecular machine folding. The lack of order (randomness) does no better at prescribing catalytic secondary structures.

Shannon equations only quantify uncertainty and reduced uncertainty (the measured uncertainty of the "before" state minus the measured uncertainty of the after state = acquired knowledge). Randomness (maximum complexity) contains the maximum number of bits of non-compressible Shannon uncertainty. The objective of Shannon theory is to compare two sequences: the one sent by the transmitter with the other received at the receiver. Shannon quantifications have nothing to do with meaning or function [18]. Shannon uncertainty measurements should never be used to refer to information. Shannon himself objected to calling his theory of communication engineering, "information theory" [19]. Shannon stated very clearly from the beginning of his work that his measurements of uncertainty would have nothing to do with meaning, function and intuitive information [13, 18]. The von Weizsäckers [20] pointed out that Weaver understood very well that the negative logarithm of an event's probability could not differentiate a meaningful message from nonsense: "Two messages, one heavily loaded with meaning, and the other pure nonsense, can be equivalent as regards information." [21]. Yet Weaver still unfortunately allowed himself to refer to quantifiable uncertainty as "information." Reduced uncertainty (mutual entropy) does not provide what Abel has termed, "Prescriptive Information (PI)" [2, 8, 22]. PI either instructs or produces (with formal algorithmic processing) nontrivial optimized function.

As we have pointed out in previous chapters, the missing ingredient needs to explain the phenomenon of "organization" and the achievement of sophisticated function/work. This missing ingredient is *formal choice contingency* at bona fide decision nodes, logic gates, and configurable switch settings. Without choice contingency, nothing will get formally organized from randomness/uselessness into nontrivial usefulness.

Complexity can arise from chance contingency or choice contingency. Table 1 fails to differentiate between the two kinds of contingency. Chance contingency has minimal patterning, reducibility, or compressibility. Choice contingency tends to reuse programming modules or linguistic constructions, giving rise to more patterning, reducibility and compressibility than randomness. The highly functional programs resulting from choice contingency are much more complex than ordered. They are more proximate to the high complexity, high uncertainty end of the bidirectional vector in Figure 1 than to the ordered end. But the complexity of the sequence is not the cause of its functionality. It is only a secondary result.

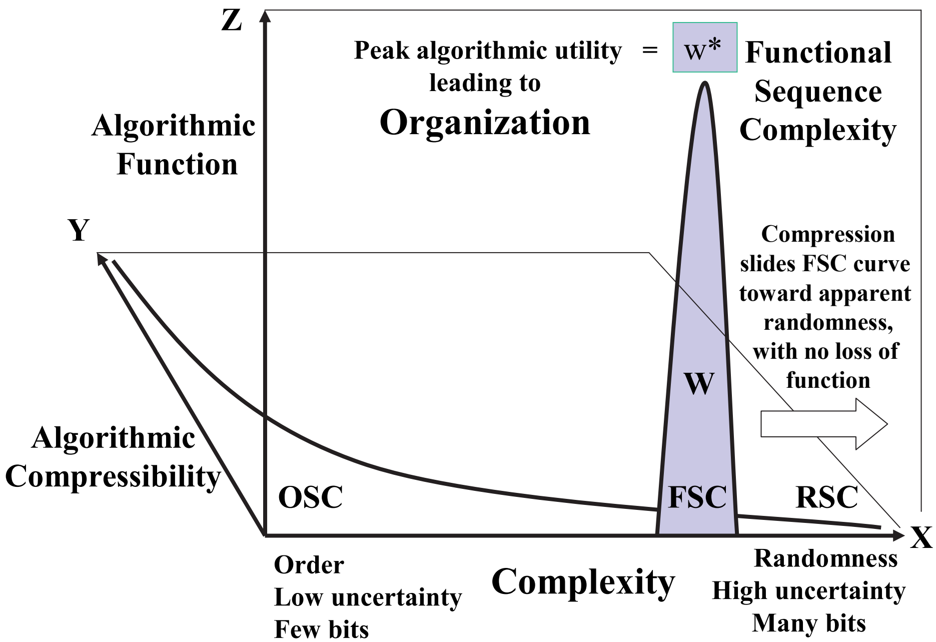


Figure 3. Superimposition of Functional Sequence Complexity (FSC) onto Figure 2. The Y axis plane plots the decreasing degree of algorithmic compressibility as complexity increases from order towards randomness. The Z axis plane shows where along the same complexity gradient (X-axis) that highly instructional sequences are generally found. The Functional Sequence Complexity (FSC) curve includes all algorithmic sequences that work at all (W, inside the shaded steep curve). The peak of this curve (w*) represents the particular algorithmic sequence that "works *best.*" The FSC curve is usually quite narrow and is located closer to the random end than to the ordered end of the complexity scale. Compression of an instructive sequence slides the FSC curve towards the right (away from order, towards maximum complexity, maximum Shannon uncertainty, and seeming randomness) *with no loss of function* (assuming decompression).

When we see sophisticated function of any kind, we have strong evidence suggesting that the Cybernetic Cut has been traversed across the one-way CS Bridge [4, 7] [See chapter 3]. Nonphysical formalisms are the product of purposeful choice contingency [4, 7, 23]. Choice contingency is instantiated into physicality via logic gates and configurable switch settings. The purposeful selection of tokens from an alphabet of "physical symbol vehicles" (tokens) is a second means of instantiating choice contingency into physicality. A third way is cooperative integration of physical components into formal systems or conceptually complex machines [1, 3, 4, 7, 8, 24]. Mere physicodynamic constraints can accomplish none of the above examples of formal organization. Organization and sophisticated function in the physical world are all the products of formalisms instantiated into physicality. Physicality cannot generate nonphysical formalisms. Figure 3 shows the relation of order, complexity, and compressibility with functionality.

The third dimension of utility and organization is when each alphabetical token in the linear string is selected for meaning or potential function. The string becomes either language or a cybernetic program capable of computation only when signs/symbols/tokens are chosen to represent utilitarian configurable switch settings. What is the common denominator to all aspects of design and engineering function? Choice contingency: not chance contingency, not law, not physicodynamics, but formal choice contingency—traversing The Cybernetic Cut across the one-way CS Bridge from formalism to physicality (Chapter 3). The FSC curve is usually quite narrow and is located closer to the random end than to the ordered end of the complexity scale. Compression of an instructive sequence slides the FSC curve towards the right (away from order, towards maximum complexity, maximum Shannon uncertainty, and seeming randomness) with no loss of function. This further demonstrates that neither order nor complexity is the determinant of algorithmic function. Functionality arises in a third dimension of selection that is unknown to the second dimension of compressibility. This is one of most poorly understood realities in information theory and life-origin science. Selection alone produces functionality. Without selection, evolution would be impossible.

Suppose stochastic ensembles of oligoribonucleotides were forming out of sequence space in an hypothesized "primordial soup." Since only 4 different nucleosides could be added next to a forming single positive strand, then in Equation 1 above would $M = 4$. Suppose next that the prebiotic availability p_i for adenine was 0.46, and the p_i's for uracil, guanine, and cytosine were 0.40, 0.12, and 0.02 respectively. This is being presumptious for cytosine, given that cytosine would have been extremely difficult to make in any prebiotic environment [25]. Using these hypothetical base-availability probabilities, the Shannon uncertainty would have been equal to:

Adenine	0.46 ($-\log_2 0.46$)	= 0.515
Uracil	0.40 ($-\log_2 0.40$)	= 0.529
Guanine	0.12 ($-\log_2 0.12$)	= 0.367
Cytosine	0.02 ($-\log_2 0.02$)	= 0.113
	1.00	1.524 bits

Notice how unequal availability of the four nucleotides (*a form of ordering*) greatly reduces Shannon uncertainty at each locus, and in the entire sequence, of any biopolymeric stochastic ensemble (Figure 1). Maximum uncertainty would occur if all four base availability probabilities were 0.25. Under these equally available base conditions, Shannon uncertainty would have equaled 2 bits per independent nucleotide addition to the strand. A stochastic ensemble formed under aqueous conditions of mostly adenine availability, however, would have had little information-retaining ability because of its high order [8].

As pointed out in the above reference, even less information-retaining ability would be found in an oligoribonucleotide adsorbed onto montmorillonite [26-31]. Clay surfaces would have been required to align ribonucleotides with 3' 5' linkages. The problem is that only polyadenosines or polyuridines tend to form. Using clay adsorption to solve one biochemical problem creates an immense informational problem (e.g., high order, low complexity, low uncertainty, and low information retaining ability. See Figure 1). High order means considerable compressibility. The Kolmogorov [11] algorithmic compression program for clay-adsorbed biopolymers (Figure 2) would read: "Choose adenosine; repeat the same choice fifty times." Such a redundant, highly-ordered sequence could not begin to prescribe even the simplest protometabolic contributor. Such "self-ordering" phenomena would not be the key to life's early organization or algorithmic programming.

The RNA Word and pre-RNA World models [17, 32] still prevail despite daunting biochemical problems. Life-origin models also include clay life [33-36]; early three-dimensional "genomes" [37, 38]; "Metabolism/Peptide First" [39-42]; "Co-evolution" [43-46]; "Simultaneous nucleic acid and protein" [47-49]; and "Two-Step" models of life-origin [50-52]. In virtually all of these life origin models, "self-ordering" is confused with "self-organizing." No mechanism is provided for the development of a linear digital prescription and oversight system to integrate metabolism. No known life form exists that does not depend upon such genetic instruction.

Well, what about a *combination* of order *and* complexity? Doesn't that explain how Prescriptive Information (PI) or true organization comes into being? Combinations of stochastic elements with ordered structures do nothing more to generate utility than either separately. No basis exists for steering events toward computational success or algorithmic optimization in a combination of order and mere combinatorial complexity. No goal of pragmatism exists. Function is not even perceived or valued in such an inanimate system of mixed order and random combinatorial elements.

2. Pattern vs. Noise

If order is not the key to formal function, what about pattern? SETI looks for patterns as evidence of extraterrestrial intelligence. Couldn't patterning prescribe function? The answer is no! To understand why, we must also define pattern. Starting with a single dimension, pattern in a sequence is defined by an increasing probability of occurrence of a single symbol or symbol sequence. As the probability of an event increases towards 1.0, its Shannon uncertainty decreases towards 0 bits [18]. So a recurring pattern is found to be a form of order. The more patterned a sequence, the more ordered. The more ordered, the fewer bits of uncertainty, and therefore the less information retaining potential the signal would have. Highly patterned sequences contain minimal complexity. Recurring pattern is therefore antithetical to complexity. They lie at opposite extremes of the same bidirectional vector found in Figure 1. [8, 13, 53]. The literature is filled with misunderstanding of the relationship between pattern and complexity, and how they both relate to formal function.

What is noise? Noise is pollution of a meaningful/functional message by random combinatorial influences. Both randomness and noise may be defined by some as extremely complex, poorly understood interactive physicodynamic necessity. But randomness and noise still spell a non-choice-contingent, nonsensical degradation of the transmission of recorded purposeful choices. We go to great lengths to protect our meaningful language transmissions and programming decisions from noise pollution. Chance contingency is the enemy of meaningful communication and instruction. To whatever degree chance contingency replaces purposeful choice contingency, function, usefulness and biologic metabolism will deteriorate concomitantly.

It also true that most messages manifest relative degrees of both combinatorial complexity and patterns in varying segments. But, like complexity, patterning in and of itself does not account for the functionality of the message. They are just secondary results of re-use of linguistic letter associations (e.g., "qu" in English), words, phrases, and programming modules. Any language has frequencies of letter reuse. But the reason a sequence is able to impart Prescriptive Information (PI) and programming function is because that sequence instantiates *cybernetic determinism*, not physicodynamic determinism, into its formal material symbol system (See chapter 6). Combinatorial complexity is just the secondary effect of unconstrained freedom of choice. Theoretically, choice contingency can be just as complex as chance contingency. A string of programming choices can appear patternless and measure the same number of Shannon bits as a random string. But clearly complexity alone does not provide the answer of why choice contingency is able to generate such high degrees of utility.

Highly patterned strings can be greatly compressed algorithmically. In nature, ordered strings frequently contain repeating patterns. The most patterned string is exampled by a string of identical letters, or, in nature, by a sugar polymer or a DNA homopolymer consisting of all adenosines. A polyadenosine has maximum order, no uncertainty, and therefore no complexity. A polymer of 200 adenosines can be fully enumerated by the very short compression algorithm, "Give me an adenosine; repeat 200 times." This compression algorithm for a polyadenosine contains almost no uncertainty, and therefore almost no information potential. It is an example of Ordered Sequence Complexity (OSC)[8]. Note that this polyadenosine can base pair its full length with thymine. What makes DNA important to life is not just base-pairing or the double-helix structure of DNA. What is most important is the programming of the particular sequence of nucleosides in the single positive prescriptive strand of DNA, before ordinary base-pairing ever occurs.

Of course, we now know that the supposed "anti-sense" complementary strand sequence that is base-paired by hydrogen bonding to the "sense" strand also contains additional layers and dimensions of Prescriptive Information (PI). Both micro- and coding m- RNAs exist in this complementary strand, for example. The complementary microRNA can regulate many other metabolic activities, including in some cases the regulation of protein production prescribed by its own complementary "sense" strand sequence [54, 55]. He et al. [56] found that individual transcripts are derived from both the plus and minus strands of chromosomes. These authors found evidence for antisense transcripts in 2900 to 6400 human genes. Human cells are a long way from theoretical protocells. But, such formal organization and multi-layered, multi-dimensional PI could not have arisen out of chance and necessity. It also could not have arisen out of natural selection which operates only at the post facto phenotypic level of favoring the fittest pre-programmed, already-living organisms (see *The GS Principle* reviewed in Chapter 7).

Formal organization is not limited to linear digital prescription. Genetic structure exposes genes to regulation and chromosomal cross-communication [57]. Say Duan et al.:

> Layered on top of information conveyed by DNA sequence and chromatin are higher order structures that encompass portions of chromosomes, entire chromosomes, and even whole genomes. Interphase chromosomes are not positioned randomly within the nucleus, but instead adopt preferred conformations. Disparate DNA elements co-localize into functionally defined aggregates or 'factories' for transcription and DNA replication. [58]

Synergistic regulation between the multi-units has long since become apparent in molecular biology [59]. "Bi-enzyme nanomachines exist where the binding partner is crucial for ligand-binding processes" [60]. Wang [61] goes into great detail in pointing out just how much the cell is like a computer, discussing the "multi-step information flow from storage level to the execution level." He goes on to say,

> Functional similarities can be found in almost every facet of the retrieval process. Firstly, common architecture is shared, as the ribosome (RNA space) and the proteome (protein space) are functionally similar to the computer primary memory and the computer cache memory, respectively. Secondly, the retrieval process functions, in both systems, to support the operation of dynamic networks—biochemical regulatory networks in cells and, in computers, the virtual networks (of CPU instructions) that the CPU travels through while executing computer programs. Moreover, many regulatory techniques are implemented in computers at each step of the information retrieval process, with a goal of optimizing system performance. Cellular counterparts can be easily identified for these regulatory techniques. [61]

Wang utilized theoretical insight from computer system design principles to sketch "an integrative view of the gene expression process, that is, how it functions to ensure efficient operation of the overall cellular regulatory network." Wang found the computer analogy to be a credible source of information with which to decipher regulatory logics underneath biochemical network operation. The credibility of those who deny the role and necessity of Prescriptive Information (PI) to organize cellular life is becoming increasing strained with each new month of journal publications.

Returning to the far simpler discussion of contrasting mere order and pattern from PI, a pulsar signal has abundant order and pattern. But it doesn't DO anything useful. It contains no meaningful or functional message. It knows nothing of decision nodes, choice contingency programming, or PI. The signal generates no formal utility at the receiver.

The probability of encountering the next element of a repeating pattern like polyadenosine is high; the probability of coming across any uniqueness is low. Note that statistical order and pattern have no more to do with function and formal utility than does maximum complexity (randomness). Neither order nor complexity can program, compute, optimize algorithms, or organize.

Three subsets of linear complexity have been defined in any environment [8]. These subsets are very helpful in understanding potential sources of Functional Sequence Complexity (FSC) as opposed to mere Random Sequence Complexity (RSC) and Ordered Sequence Complexity (OSC) [8]. FSC requires a third dimension not only to detect, but to produce formal utility. Neither chance nor necessity (nor any combination of the two) has ever been observed or demonstrated to produce nontrivial FSC [9]. Nontrivial useful function and formal work arise only within the narrow FSC curve seen in Figure 3.

Durston and Chiu, at the University of Guelph, developed a method for measuring what they call *functional uncertainty* (H_f) [62]. They extended Shannon uncertainty to measure a *joint variable* (X, F), where X represents the variability of data, and F the variable of functionality. This explicitly incorporated the empirical knowledge of embedded function into the measure of sequence complexity:

$$H(X_f(t)) = - \sum P(X_f(t)) \log P(X_f(t)) \qquad (2)$$

where X_f denotes the conditional variable of the given sequence data (X) on the described biological function f which is an outcome of the variable (F). The state variable t, representing time or a sequence of ordered events, can be fixed, discrete, or continuous. Discrete changes may be represented as discrete time states. Mathematically, the above measure is defined precisely as an outcome of a discrete-valued variable, denoted as $F=\{f\}$. The set of outcomes can be thought of as specified biological states.

Using this method allowed Durston and Chiu to compare quantifications of 2,442 aligned sequences of proteins belonging to the Ubiquitin protein family, among many other protein families evaluated. All of these sequences satisfied the same specified function f, which might represent the known 3-D structure of the Ubiquitin protein family, or some other function common to Ubiquitin. The definition of functionality used by Durston and Chiu relates to the whole protein family. Thus this data can be inputted from readily available databases. Even subsets (e.g., the active sites) of the aligned sequences all having the same function can be quantified and compared. The tremendous advantage of using $H(X_f(t))$ is that *slight changes* in the functionality characteristics of biosequences can be incorporated and analyzed.

Subsequently, Durston and Chiu have developed a theoretically sound method of actually quantifying Functional Sequence Complexity (FSC) [63]. This method holds great promise in being able to measure the increase or decrease of FSC through evolutionary transitions of both nucleic acid and proteins. This FSC measure, denoted as ζ, is defined as the change in functional uncertainty from the ground state $H(X_g(t_i))$ to the functional state $H(X_f(t_i))$, or

$$\zeta = \Delta H\,(X_g(t_i), X_f(t_j)) \qquad 3)$$

The *ground state g* of a system is the state of presumed highest uncertainty permitted by the constraints of the physical system, when no specified biological function is required or present. Durston and Chiu wisely differentiate the ground state *g* from the *null state* $H_ø$. The null state represents the absence of *any* physicodynamic constraints on sequencing. The null state produces bona fide stochastic ensembles, the sequencing of which is *dynamically inert* (physicodynamically decoupled or incoherent [64, 65]). The FSC variation in various protein families, measured in Fits (Functional bits), showed that the highest value sites correlate with the primary binding domain [63].

As we add dimensions, highly patterned waveforms, signal structures, short sequences of events, or crystalline structures might form [12]. But all of the multidimensional high redundancy structures preclude information retaining ability in any object. Repeating patterns generate high order, low complexity, few bits of uncertainty, and little information retaining possibility.

A law of physics also contains very little information because the data it compresses is so highly ordered. The best way to view a parsimonious physical law is as a compression algorithm for reams of data. This is an aspect of valuing Ockham's razor so highly in science. Phenomena should be explained with as few assumptions as possible. The more parsimonious a statement that reduces (algorithmically compresses) all of the data, the better [66, 67]. A sequence can contain much order with frequently recurring patterns, yet manifest no utility. Neither order nor recurring pattern is synonymous with meaning or function.

Those trained in information theory will be quick to point out at this point that "information is always defined in terms of an observer or knower." They argue that information is not in the law's parsimonious statement or equation, but in the difference (R) between all of the uncertainty of the raw data, and the lesser amount of uncertainty generated by knowing the law. But the problem with this concept of information is that for most of life's history, linear digital genetic instructions have been prescribing exquisite metabolic organization long before any observers or knowers existed on earth. Observers and knowers themselves would not exist except for the extraordinary amount of cellular programming and organization that produced human brains. Prescriptive Information (PI) [6] cannot be reduced to an exlcusive endeavor of human creation or epistemology. To attempt to define information solely in terms of human generation, observation and knowledge is grossly inadequate. Such anthropocentrism blinds us to the reality of life's *objective* genetic programming, regulatory mechanisms, and biosemiosis using symbol systems such as codon translation [2, 68-76].

3. Structure vs. chaos

Well what about "structure"? Surely structure is the answer as to what makes functional physical objects. Look at proteins. Is not folded protein structure the key to what enables molecular machines to work?

The answer is, "Yes and No." Some structures are functional and others are not. What makes the difference? In the everyday practical world, we might want to ask, "What specific structure?" "How was the structure assembled, and for what purpose?" "What was the structure designed and engineered to do?" Structures performing sophisticated functions don't just spontaneously self-assemble. Returning to the ordinary paper clip analogy from Chapter 1, we have never observed a single simple paper clip spontaneously spring from the iron ore in the ground in *any* environment. A paper clip is nothing more than a long solid cylinder of relatively constant diameter that is folded back onto itself in a certain way so as to make it useful for temporarily binding sheets of paper. Even if a paper clip spontaneously formed out of inanimate nature, an agent would still have to choose to *use* the paper clip for its optimized purpose. Like proteins, the ore had to be processed into an alloy (the correct mix and sequence of 20 left-handed, biological-only amino acids, all with peptide-only bonds) and elongated into exceedingly long cylinders (wires) of uniform diameter. The wire than had to be folded in 3 dimensions (with one dimension kept deliberately constant). A chaperone-like bending machine then had to made that could make 3 bends at the best places using 3 wheels, all according to the specifications that would engineer an optimized clasp for paper.. The wire then had to be cut appropriately. Why have we never observed or demonstrated a single spontaneous occurrence of a paper clip from inanimate nature? How much more conceptually organized and efficacious is a bacterium than a paper clip? If paper clips do not spontaneously form, why would we entertain the ridiculous notion that sophisticated protein molecular machines, along with their highly specific contribution to cooperative metabolic schemes, would spontaneously spring from happenstantial molecular interactions? How does this blind belief differ from superstition?

Inorganic crystals provide a great deal of highly ordered/patterned three-dimensional structure. Even these well-ordered structures contain noise pollution in the form of occasional crystal irregularities. The Cairns-Smith clay-life model fell by the wayside mostly because clay crystals are so regular, so ordered and patterned, that they cannot have any significant amount of PI formally instantiated into their physicality. Crystal irregularities provide the only freedom with which to program, but if those irregularities are only generated by chance contingency rather than choice contingency, no meaningful/functional PI will be contained in those crystal irregularities.

Thus the mere presence of structure as opposed to heat agitation-like molecular chaos tells us little about function and utility. Many rigid, sustained structures exhibit no function. In chaos theory, candle flames and tornadoes manifest seemingly sustained structure from a continual string of momentary self-ordered dissipative states. Neither kind of structure computes or optimizes any algorithmic function. None of Prigogine's "dissipative structures" generates a Sustained Functional System (SFS) [23]. It is for good reason that Prigogine named them "dissipative." But, regardless of how long dissipative structures last, they certainly produce no sophisticated functions. SFS's do.

Neither chaos or the edge of chaos is a

1) Calculus
2) Algorithm
3) Program that achieves computational halting
4) Organizer of formal function
5) Bona fide system

Chaos is a bounded state of *disorganization* that is extremely sensitive to the effects of initial conditions. Note that chaos is a disorganized state of matter, *not a disordered* state of matter. A considerable amount of order can arise spontaneously out of chaos. This is what chaos theory is about. All we have to do to observe spontaneous self-ordering is to pull the stopper out of our bathtub drain. Water molecules quickly self-order into a swirl—a vortex—from purely physicodynamic complex causation. We mistakenly call this self-organization, but the vortex is not in the least bit organized. It is only self-ordered [9]. What is the difference? No decision nodes are required for a bathtub swirl to self-order out of seemingly random Brownian motion. Proficient programming choices are not required for heat agitation of water molecules to self-order into a vortex. No configurable switches have to be purposefully set, each in a certain way, to achieve self-ordering. No pursuit of a goal is involved. No algorithmic optimization is required. In addition, Prigogine's dissipative structures do not DO anything formally productive. They possess no ability to achieve computational halting. They do not construct sophisticated Sustained Functional Systems (SFS) [23]. Dissipative structures are momentary. They only appear sustained (e.g., a candle flame) because of we observe through time a long string of momentary dissipative events or structures. This is where their name comes from. They cannot generate a sustained functional machine with optimized functionality.

Chaos is capable of producing incredibly complex physicodynamic behavior. But we must never confuse this complexity with formal function. Order spontaneously appears out of disorder in the complete absence of any formal creative input or cybernetic management. But no algorithmic organization is produced by a candle flame. What seems to be a totally random environment is in fact a caldron of complex interaction of multiple force fields. The complexity of interactive causation can create the illusion of randomness, or of very real self-ordering. There may also be as-of-yet undiscovered physical causes. But dissipative structures self-order; they do NOT self-organize. The dissipative structures of chaos theory are unimaginative. Highly ordered structures contain very little information. Information retention in any physical medium requires freedom of selection of configurable switch settings. Switches must be "dynamically inert" with respect to their function to serve as logic gates.

Dissipative structures are

1) highly ordered
2) monotonous
3) predictable
4) regular (vortices, sand piles)
5) low informational
6) strings of momentary states

Dissipative structures are usually destructive, not cybernetically constructive (e.g., tornadoes, hurricanes). Trying to use "chaos" and "complexity" to provide mechanism for "self-organization" is like trying to use the Shannon transmission engineering to explain intuitive information, meaning and function. Shannon's equations define negative "uncertainty," not positive "surprisal." Functional "surprisal" requires the acquisition of positive specific semantic information. Just as we cannot explain and measure "intuitive information" using Shannon combinatorial uncertainty, we cannot explain a truly organized system appealing to nothing but a mystical "edge of chaos." Reduced uncertainty ("mutual entropy") in Shannon theory comes closer to semantic information. To achieve this, however, we have to mix in the formal elements of human knowledge gained by mathematical subtraction of "after uncertainty" from "before uncertainty." We measure the reduced uncertainty of *our knowledge*. Prior background knowledge and agent processing of that knowledge is already at play. At that point, we are no longer talking about objective information in nature. We are only talking about human epistemology. Human consciousness is highly subjective. The second we insist on defining information solely in terms of a human observer and knower, we have destroyed all hope of elucidating the derivation of objective information in evolutionary history, especially at the intra-cellular level.

The disorganization of chaos is characterized by conceptual uncertainty and confusion. Disorganization lacks sophisticated steering and control. Disorganization pursues no purpose. Even if chaos had purpose, it would lack all means of accomplishing purpose. If chaos by definition is a bounded state of disorganization, how could we possibly attribute self-organization to chaos? No scientific basis exists for granting formal capabilities to chaos, complexity or catastrophe. None of these three has ever been observed to produce formal integration and algorithmic organization of any kind.

Scientists accomplish impressive feats using the applied science of "nonlinear dynamics." But the capabilities of this applied science all-too-easily get confused with the capabilities of chaos itself. Chaos generates nothing close to formal function. We overlook the considerable degree of "investigator involvement" and artificial steering that goes into nonlinear dynamic experiments. Formal mathematics is invariably employed by agents to achieve some goal.

Sophisticated algorithmic optimization has never been achieved by duplication plus mere random variation. Function must be "selected for" at the logic-gate programming level prior to the realization of improved function. Selection *for potential* fittest function is necessary to achieve computational success. This is called The GS Principle (Genetic Selection Principle) [5]. Natural selection favors only the fittest already-computed, already-living phenotypes. Configurable switches are "set in stone" with rigid covalent bonds before folding begins. The selection of each nucleoside constitutes a rigid programming choice that, in turn, determines eventual folding and functional structure.

Three-dimensional conformation of molecular machines is largely determined by the minimum-free-energy sinks of primary structure folding. The primary structure of any protein or sRNA is the already-covalently-bound sequence of particular monomers that serve as configurable switch settings.

4. Self-ordering vs. the illusion of "Self-organization"

The term "self-organization" is, unfortunately, in widespread use in the literature. The terms "organization" and "self-ordering" should not be confused [2, 8]. No empirical evidence exists of unaided algorithmic self-optimization or spontaneous bona fide self-organization [9].

Organization ≠ order. Disorganization ≠ disorder. Organization is abstract, conceptual, nontrivial and algorithmic. Organization is formal, not merely physicodynamic. Organization requires choice contingency at bona fide decision nodes. Organization integrates and correlates cybernetic choices into holistic functional systems. Organization typically contains high ratios of Prescriptive Information (PI) to noise. PI either instructs or indirectly produces (through algorithmic processing) nontrivial optimized function at its destination. Prescription requires choice contingency rather than chance contingency or necessity. Organized phenomena are typically informationally and cybernetically complex, not just combinatorially complex (high uncertainty as to how components might come together). They are prescriptively complex and programmatically highly optimized. Prescriptive complexity typically requires intentional choices at bona fide decision nodes. The null hypothesis we seek to falsify is this: "Any form of nontrivial organization traverses the Cybernetic Cut, requiring formal choices with intent to explain." Inanimacy cannot "organize" itself. Inanimacy can only self-order. "Self-organization" is without empirical and prediction-fulfilling support.

Organization often utilizes a sign/symbol/token system to represent multiple 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.

Self-ordering phenomena are not examples of self-organization. Self-ordering phenomena are simple and redundant [7, 8]. Self-ordered structures, whether sustained (e.g. crystals) or dissipative (e.g., the chaos theory first investigated by Prigogine) *contain no organization at all.* Self-ordering events occur spontaneously every day. But they do not involve decision nodes or dynamically-inert, purposeful, configurable switch settings. No logic gates need to be programmed with self-ordering phenomena. Self-ordering events involve no steering toward algorithmic success or "computational halting." Self-ordering phenomena are purely physicodynamic and incapable of organizational attempts. Laws and fractals are both compression algorithms containing minimal complexity and information. Inanimate physicodynamics cannot exercise purposeful choices or pursue potential function. No model of undirected evolution pursues the goal of future utility.

Order cannot compute. Much life-origin literature appeals to "yet-to-be discovered laws of self-organization." Laws, however, describe highly ordered/patterned behavior. Because they are parsimonious compression algorithms of data, they contain very little information. Given the high information content of life, expectation of a new law to explain sophisticated genetic algorithmic programming is ill-founded. Considerable peer-reviewed published literature is erroneous because of failure to appreciate that the "complexity of life" could never arise from such highly "ordered," low informational physicodynamic patterning. Tremendous combinatorial uncertainty is required. The complexity of life will never be explained by the highly-ordered behavior that is reducible to the low-informational laws of physics and chemistry.

A crystal is highly-ordered. Its description can be easily algorithmically compressed. A crystal is about as far from being "alive" as any physical state we could suggest. Every member of a 300-monomer string of adenosines (a homopolymer) can be specifically enumerated by stating: "Give me a set of adenosine molecules; repeatly connect one to another 300 times." This is called a compression algorithm. The simplicity and shortness of this compression algorithm is a measure of the extremely low complexity and uncertainty of this polymer. Such a parsimonious statement of the full sequence is only possible because that sequence is so highly patterned. Such a highly ordered sequence lacks uncertainty, complexity, and the ability to instantiate prescriptive information. Such a parsimonious compression algorithm can enumerate each and every member of the 200-mer string with only seven words. This reality defines high order or pattern along with low information retaining potential.

The spontaneous self-organization of ever-improving hypercylces [77-81], stoichiometric self-assemblies [82], and Ganti's chemotons [83] have never been observed, let alone repeatedly observed. No prediction fulfillments have ever been realized. "Self-organization" provides no mechanism and offers no detailed verifiable explanatory power. The hypotheses of chemotons ever-growing capabilities are not even falsifiable. No lack of evidence or the repeated observation of hypercycle's failure to arise is capable of providing falsification. So the notion is conveniently and indefinitely protected from any scientific challenge. It must just be accepted by blind faith. Any scientist who raises an eyebrow of healthy scientific skepticism is immediately labeled a heretic from the hierarchy of scientism's presupposed imperative of metaphysical naturalism.

We value Ockham's Razor in science because we wish to reduce physical reality down to concise reductive statements. We consider a law to be elegant and beautiful because of its ability to compress our interpretation of reams of empirical data down to a single parsimonious equation. When we look for new laws of physics, we look for new algorithms as a proxy for compressing reams of data.

Figure 4. 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."

Used with permission from: Abel DL, Trevors JT: Self-Organization vs. Self-Ordering events in life-origin models. *Physics of Life Reviews* 2006, 3:211-228

For biology, however, we encounter not only the highest degree of complexity known, we encounter linear, digital, cybernetic encoding along with Prescriptive Information (PI) of the most sophisticated, abstract, and conceptual nature. Complexity gets all the press. But, complexity is not the remarkable issue. The phenomenon of cybernetics and how it could have arisen in a prebiotic chance-and-necessity environment is the issue. The world's fastest, parallel-architecture main-frame computer systems (e.g., the K computer) cannot hold a candle to the central nervous system of any mammal. The "processing" units and the interconnect fabric of that computer has nowhere near the connections of, for example, the human brain (10^{15} neuraltransmitter/receivers. No yet-to-be-discovered parsimonious law will ever be able to explain the programming found in a single cell [84]. Neither order nor mere combinatorial complexity can generate algorithmic organization. Bona fide organization results from algorithmic optimization. The best solutions to any problem must be selected from a formal "possible solution space" to achieve optimization. Apart from such purposeful selection, noise will increase within any system. A tendency toward randomization and loss of function unfolds from noise. Complexity increases while algorithmic optimization decreases. Any attempt to exclude choice-with-intent from the mix results in the deterioration of programming function, computational halting, integration, and organization.

Table 2: The difference between spontaneous "self-ordering phenomena" and "organized systems" in living organisms.

SELF-ORDERING PHENOMENA	ORGANIZED SYSTEMS
Increases redundancy	Decreases redundancy
Increases predictability	Decreases predictability
Increases symmetry	Decreases symmetry
Increases periodicity	Decreases periodicity
Increases monotony	Decreases monotony
Produces crystal-like patterns	Produces linguistic-like patterns
Decreases complexity	Increases complexity
Short-lived (highly dissipative)	Long-lasting (minimal dissipation)
Produced by cause-and-effect	Still lacking natural process mechanism
Observed	Bona fide self-organization unobserved
Consistent with 2^{nd} Law	Seems inconsistent with the 2^{nd} Law
Non-integrative	Integrative
Non-conceptual	Conceptual
Not particularly functional	Produces extraordinary function

Fractals are often cited as evidence of self-organized complexity arising out of simple order. But fractals are examples of neither complexity nor organization. They only create the illusion of complexity. And, fractals certainly have nothing to do with organization. Organization requires steering cybernetic choices at bona fide decision nodes and logic gates. Representative symbols can be used to denote antithetical binary choices (e.g., On vs. Off, Yes vs. No, 0 vs. 1). Figure 4 helps visualize the fact that fractals are really nothing more than highly ordered, highly compressible, low-informational, redundancies.

Self-ordering of many kinds occurs spontaneously every day in nature in the absence of any organization. Spontaneous bona fide self-organization, on the other hand, has never been observed. Certainly no *prediction* of bona fide *self*-organization from unaided physicodynamics has ever been fulfilled. Of course, if we fail through sloppy definitions to discern between self-ordering phenomena and organization, we will *think* that evidence of self-organization is abundant. We will point to hundreds of peer-reviewed papers with “self-organization” in their titles. But when all of these papers are carefully critiqued with proper scientific skepticism, embarrassment only grows with each exposure of the blatant artificial selection that was incorporated into each paper’s experimental design. Such investigator involvement is usually readily apparent right within Materials and Methods of the paper. Organization depends upon PI. The self-ordering phenomena of physical nature provide no PI, and therefore no bona fide organization.

5. Can spontaneous combinatorial complexity generate organization?

Order, pattern, noise and complexity have little to do with prescription of function. Attempts to demonstrate self-organization via mere combinatorial complexity are too numerous to cite [9, 85-88]. Under careful scrutiny, however, these papers seem to universally incorporate investigator agency into their experimental designs. To demonstrate the viability of any molecularly evolved hypothetical scenario, it is imperative that we provide *stand-alone natural process* evidence of nontrivial self-organization at the edge of chaos. We must demonstrate on sound scientific grounds the *formal capabilities* of naturally-occurring physicodynamic complexity. So-called evolutionary algorithms, for example, must be stripped of all artificial selection and the purposeful steering of iterations toward desired products. The latter intrusions into natural process clearly violate sound evolution theory [89, 90]. Undirected evolution has no goal [91, 92]. Evolution provides no steering toward *potential* computational and cybernetic function [3-5, 9, 24, 93, 94].

The theme of naturalistic ProtoBioCybernetics is the active pursuit of falsification of the following null hypothesis: *“Physicodynamics alone cannot self-organize itself into formal, functional systems that would require algorithmic optimization, computational halting, and circuit integration.”* At first glance the falsification of this hypothesis might seem like a daunting task. But a single exception of nontrivial, unaided, spontaneous optimization of formal function by truly natural process would quickly falsify this null hypothesis. Such falsification would once and for all silence Intelligent Design intrusions into naturalistic science.

Science celebrates positive and parsimonious descriptions of presumed objectivity. But we must never forget that our knowledge is only “best thus far.” Even the most fundamental laws of physics technically must be viewed as “tentative.” We rightly eschew diatribes of metaphysical pontifications. Science proceeds through open-mindedness and the falsification of null hypotheses, not through the rhetorical pronouncement of dogmas. Popper— and many since—have exposed the problems associated with trying to prove any positive hypothesis [95, 96]. Neither induction nor deduction is foolproof. Theses that cannot be proven ought not to be proclaimed as absolute statements of fact.

At the same time, naturalistic science has spent most of the last century, and especially the first decade of the new millennium, arguing to the lay community that science *has* proved the current biological paradigm. Unfortunately, very few in the scientific community seem critical of this indiscretion. One would think that if all this evidence is so abundant, it would be quick and easy to falsify the null hypothesis put forward above. If, on the other hand, no falsification is forthcoming, a more positive thesis might become rather obvious by default. Any suggestion that programming is required would only be labeled metaphysical by true-believers in spontaneous self-organization. Those same true-believers would disingenuously fail to acknowledge the purely metaphysical nature of the current Kuhnian paradigm rut [97]. A better tact is to thoroughly review the evidence. Let the reader provide the supposedly easy falsification of the above null hypothesis. Inability to do so should cause pangs of conscience in any scientist who equates metaphysical materialism with science. On the other hand, providing the requested falsification of this null hypothesis would once-and-for-all end a lot of unwanted intrusions into science from philosophies competing with metaphysical materialism.

While proof may be evasive, science has an obligation to be honest about what the entire body of evidence clearly *suggests*. We cannot just keep endlessly labeling abundant evidence of formal prescription in nature “apparent.” The fact of purposeful programming at multiple layers gets more “apparent” with each new issue of virtually every molecular biology journal [98-100]. Says de Silva and Uchiyama:

> Molecular substrates can be viewed as computational devices that process physical or chemical 'inputs' to generate 'outputs' based on a set of logical operators. By recognizing this conceptual crossover between chemistry and computation, it can be argued that the success of life itself is founded on a much longer-term revolution in information handling when compared with the modern semiconductor computing industry. Many of the simpler logic operations can be identified within chemical reactions and phenomena, as well as being produced in specifically designed systems. Some degree of integration can also be arranged, leading, in some instances, to arithmetic processing. These molecular logic systems can also lend themselves to convenient reconfiguring. Their clearest application area is in the life sciences, where

> their small size is a distinct advantage over conventional semi-conductor counterparts. Molecular logic designs aid chemical (especially intracellular) sensing, small object recognition and intelligent diagnostics. [100]

What scientific evidence exists of spontaneous physicodynamics ever having programmed a single purposeful configurable switch-setting? If we cannot present any such evidence, we should be self-honest enough to ask ourselves, "How long are we going to try to maintain this ruse that the cybernetic programming we repeatedly observe is only 'apparent' rather than real?"

Has "natural process" ever been observed to write conceptual instructions? Neither reason nor empiricism has justified believing in spontaneous algorithm-writing and optimization by inanimate nature. The inanimate environment does not generate meaning, or program and optimize sophisticated formal function. Physics and chemistry do not symbolize meaning or pursue and prescribe ideal utility. Physicodynamics does not translate linear digital PI from one language into another. All of these functions are as nonphysical and as formal as mathematics itself.

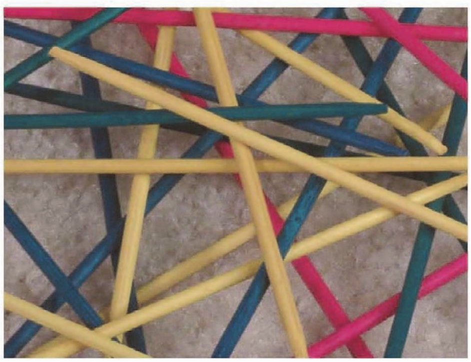
The association of complexity *or* patterns with most forms of bona fide organization should never be confused with causation [101]. Neither order nor complexity is a cause of organization or any other form of formal algorithmic optimization. We sling the words "chaos," "complexity," "order" and "pattern" around with vivid imagination and a great deal of blind faith in their capabilities. None of the latter states has ever been observed to produce the slightest amount of algorithmic organization. Stand-alone chaos and complexity have absolutely nothing to do with generating formal function. Neither do order and pattern. Self-ordering phenomena produce boring, unimaginative redundancy. Self-ordering phenomena, just like chaos and complexity, have never been observed to achieve

1) programming,
2) computational halting,
3) creative engineering,
4) symbol systems,
5) language
6) bona fide organization [9].

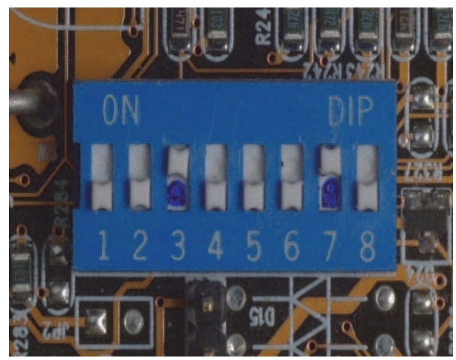
The latter are all formal processes, not physicodynamic processes.

"Self-organization" is logically a nonsense term. Inanimate objects cannot organize themselves into integrated, cooperative, holistic schemes. Schemes are formal, not physical. To organize requires choice contingency, not just chance contingency and law-like necessity. Sloppy definitions lead to fallacious inferences, especially to category errors. Organization requires

1) decision nodes
2) steering toward a goal of formal function
3) algorithmic optimization
4) selective switch-setting to achieve potential integration of a circuit
5) choice with intent



a)



b)

Figure 5 a) Complexity is often confused with programming controls and formal organization. The degree of three-dimensional structural complexity within a pile of pick-up sticks is staggering. But what exactly does this enormous degree of structural complexity DO? If we poured glue on this pile to freeze its structure, what sophisticated formal function would this complex pile of objects generate? Mere combinatorial complexity must never be confused with organization or formal utility. **b)** A row of dip switch settings depicts a different category of complexity—algorithmic, cybernetic programming complexity. Choice contingency is incorporated into purposeful configurable switch settings that collectively prescribe and integrate formal function.

Used with permission from: Abel DL: The capabilities of chaos and complexity. *Int J Mol Sci* 2009, 10:247-291

The only entity that might be able to organize itself is an agent. But not even an agent self-organizes. Agents organize things and events in their lives. They do not organize their own molecular biology, cellular structure, organs and organ systems. Agents do not organize their own being. Agents do not create themselves. They merely make purposeful choices with the brains and minds with which they find themselves. Artificial intelligence does not organize itself either. It is invariably programmed by agents to respond in certain ways to various environmental challenges found in the artificial life data base.

Thus the reality of self-organization is highly suspect on logical and analytic grounds even before facing the absence of empirical evidence of any spontaneous formal self-organization.

If formal self-organization phenomena are so objectively real and common, one would think that we could make abundant reliable predictions of very rudimentary future instances of self-organization. If all of the incredibly integrative cybernetic complexities of tens of millions of different species have resulted from spontaneous physicodynamic self-organization, we should find *exhaustive* empirical evidence on a daily basis of fulfillment of minor self-organization predictions. How many such prediction fulfillments has the scientific community observed?

Prediction fulfillment is a cardinal parameter of scientific investigation. The complete absence of prediction fulfillment is strong evidence that spontaneous self-organization of formal utility in nature is the product of vivid imagination rather than repeated observation of a presumed objective reality. No prediction fulfillments have been realized of progressing hypercycles, spontaneously computational neural nets, genetic and evolutionary algorithms, or cellular automata self-organizing out of inanimate physicodynamic interactions.

To evaluate whether any such predictions have been fulfilled, we would have to be careful to make sure that what we are calling formal self-organization isn't in reality mere physicodynamic self-ordering events. The latter have no integrative ability. Self-ordering phenomena cannot organize anything into potential nontrivial formal utility. No basis exists in cause-and-effect physicodynamic interactions for organizing events into needed or desired or expedient formal function. The laws of physics do not consider utilitarian expediency.

6. The mystical "Edge of Chaos" and the magical "Adjacent Other"

If chaos is inadequate to explain self-organization, what about "the Edge of Chaos" or "the Adjacent Other." [3, 88, 93, 102-124] The edge of chaos is somehow much more appealing to us than just plain chaos. The edge of chaos is more poetic. And "the Adjacent Other," now there's some scientific content we can really sink our teeth into! Both phrases are wonderfully inviting. They offer incredible mystical allure. The question is, does either phrase actually exist as a physical state? If these states are objectively real, what exactly are they? Where in time/space can we find them, what are their initial conditions, what are their physical characteristics, and what exactly can they independently DO? Are "the Edge of Chaos" or "the Adjacent Other" scientifically addressable? How would we go about falsifying such nebulous metaphysical notions? How do they differ from superstition?

Let us first examine the potential interface of the “edge” of chaos with natural order—with the regularities of nature described by the physical laws. Can “order” program configurable switches? If “order” programmed configurable switches, they would all be programmed the same way. They would all be set to “On’s,” OR. . . they would all be set to “Off’s.” Either way, the configurable switches would not be formally programmable into any algorithmic function. No more creativity would exist at the interface of chaos with forced order than in either single entity. No reason exists to expect any increased cybernetic potential at the edge of chaos than squarely in the middle of chaos (bounded disorganization). The fact that chaos is extremely sensitive to the effects of initial conditions adds no formal attributes. The latter certainly increases its changeability and the number of bits of uncertainty in the bounded state. But mere changeability and combinatorial uncertainty provide no optimization of formal function.

“The edge of chaos” [88, 102-107] affords mesmerizing visions of potential accomplishment. While poetic and wonderfully inviting, the concept is sorely lacking in scientific content. The functional reality of “the edge of chaos” has been challenged [3, 93, 110, 117]. Have we had any prediction fulfillments since it was first described in 1992 by Waldrop[102]? Is the notion of vast formal capabilities arising from the edge of chaos falsifiable? One has to wonder if the notion is worthy of serious discussion in a peer-reviewed science journal paper. It would not be were it not for the fact that so many peer-reviewed papers already cite this nebulous dream as an objective source of self-organization.

What about the interface of the bounded state of disorganization with heat agitation and Brownian motion? Maximum complexity would set all configurable switches randomly. What synergistic capabilities could emerge from the interface of disorganization with randomness? The two are not synonymous. But neither contributes anything to programming proficiency.

Switches must be set a certain way to achieve integrated circuits. If chaos sets configurable switches, the result will predictably “blue screen,” as is known in Microsoft’s “crash” terminology. Without steering towards sophisticated function at each decision node, sophisticated function has never been observed to arise spontaneously. Only destructive self-ordering (e.g., tornadoes) and disorganization accumulates. No prediction fulfillments have been realized of cooperative integration of biofunction arising spontaneously in nature. Dreaming of an “edge of chaos” doesn’t help.

What scientific substance does “the Adjacent Other” provide? What is this magical “other”? Is this “other” physical? Is it observational reality? Can it compute and organize systems? What is the logic behind such hoped-for capabilities of this "Adjacent Other"? What empirical support do we have of formal function arising spontaneously from the interface of "otherness" with physicodynamic chance and necessity? How can an otherwise intelligent and skeptical scientific community possibly buy into such an unadulterated fairy tale?

Unfortunately, neither "the edge of chaos" nor "the adjacent other" mysticisms has provided detailed scientific mechanism to explain the efficacious selection of pragmatic configurable switch settings. Organization requires algorithmic optimization. The latter requires expedient decision-node commitments that are instantiated into specific physical configurable switch settings. To explain life origin requires elucidating how these particular logic gates were selected at the genetic level. Phenotypes must first be computed before the fittest living organisms can exist to be preferred by any environment.

In every case that provides the illusion of spontaneous emergence, investigator involvement can be demonstrated in the Materials and Methods section of so-called "evolutionary algorithm" papers. The experimenter's goal and steering are apparent in faulty experimental designs. This is usually evident in the choice of each successive iteration to pursue. Undirected evolution has no goal. Iterations cannot be steered toward experimenters' goals (e.g., a desired ribozyme using SELEX [125-127]). Quality science requires brutal self-honesty. We must be open-minded enough to consider the possibility that emergence and self-organization are closer to metaphysical presuppositions than observed scientific facts."

7. What about neural nets?

Bipartite graphs of neural nets showing vertices (nodes) and edges (lines) are frequently featured in attempts to explain the derivation of self-organization. "Buttons and strings" are supposed to provide the answer for how circuitry and selective switching arises. But bipartite graphs show only the Aristotelian "final" edges and connections that allow computational success and optimized function. Such graphs correspond to mere Descriptive Information (DI), not Prescriptions Information (PI). No explanation is provided by these graphs as to *how* the elements got connected in their unique functional relationships. Graphing the state of functional affairs does not provide the ability to generate such a state. A description of a Lamborgini automobile does not provide the ability to manufacture Lamborginis.

How do the signals get selectively steered through the circuitry of a spontaneously self-assembled neural net? How did the nodes get *functionally* associated? How is successful computation accomplished? Neural net graphs fail to explain efficacious programming choices at a single decision node, let alone all of them working in concert to achieve a potential formal goal.

How did a prebiotic environment make so many wise programming decisions? All of the programming errors and "wild goose chases" are never shown; only the final product. Even then the picture of the final product does not tell us how it steers signals and computes. "Why did this edge (string connecting the buttons) [104] form rather than the 293 other possible edges that this node could have formed?" Or why did the signal traverse only certain edges from the node, and not all the other edges that emanate from that node? The model of a bunch of interconnected buttons and strings does not address the question of selective Boolean logic gating. Yet selective gate openings and closings is the essence of programming, circuitry, control and regulation. To prescribe all of the integrated controls through the connections (edges) between elements (nodes) in bipartite graphs requires programming choices that neural network graphs do not provide.

If all nodes in a neural net fire with any impulse introduction into the net, as with an all-or-none muscle depolarization, no selectivity, steering or integration of circuitry is possible. Pathways of conduction must be specific and uniquely selectable. A "buttons and strings" model [104] never explains the phenomenon of circuit integration or computational success.

8. Systems theory

Evolutionary (undirected) biological systems theory regularly presupposes the metaphysical belief of physicodynamic self-organization into formal function. One would think that systems theorists could readily offer a crystal-clear definition of "system." Sadly, this is not the case. It is not surprising, therefore, that chaos and such phenomena as weather fronts are also referred to as "systems" with no eyebrows raised. Bona fide systems require organizational controls. True systems are cybernetic. The definition of "system" is "an organized assembly of parts and/or controlled procedures designed and engineered to produce utility." Any attempt to eliminate parts of this definition results in a breakdown of the system and a compromise of optimized functionality. A term like, "Chaotic system," therefore, is an oxymoron—a self-contradiction. If it is chaotic, it cannot be a bona fide system. If it is a system, it cannot be chaotic.

Weather fronts are at best self-ordered by complex degrees of interactive physicodynamic causation. They are not formally controlled or organized to achieve sophisticated utility of any kind. A weather front is a physicodynamic interface complete with criticality and phase changes. A weather front may become a highly self-ordered tornado or a hurricane. But it's not a true system because it is not formally organized or cybernetically programmed. No representational symbol system is used. No abstract conceptualizations are employed by weather fronts. They are simply physicodynamic interfaces totally lacking in algorithmic organization. We simply "murder the King's English" by referring to a weather front as a system. Such sloppy word usage may not cause problems in everyday usage. But it leads to a great deal of confusion in understanding fundamental physics and the relation of physics to biology.

The temporary and local circumvention of the 2nd Law is made possible by the formal algorithmic processes that comprise true systems. Chaos is neither organized nor a bona fide system, let alone "self-organized." As pointed out above, organization is not the same as order. A bona fide *system* requires *organization*. Chaos by definition lacks organization. That's why we call it "chaos" even though it manifests extensive self-ordering tendencies. What could possibly be more self-ordered than a massive hurricane? But what formal functions does a hurricane perform? A hurricane possesses no PI [6]. It has no programming talents or creative instincts. A hurricane is not a participant in Decision Theory. A hurricane does not set logic gates according to rules of inference or deduction from axioms. A hurricane has no specifically designed physicodynamically-decoupled configurable switches. No means exists to instantiate formal choices or function into physicality. A highly self-ordered hurricane destroys organization. To call a hurricane "self-organized" constitutes one of the most egregious errors in science stemming from sloppy definitions, category errors, and non-sequiturs.

Complexity is not a system, either, as we saw in the highly complex pile of pick-up sticks (Figure 5). No programming is involved. No algorithms are optimized. No steering toward formal function occurs. A true PI-based system requires organization.

Systems theory is literally taking over in biology today. "Systems biology" is considered to be the in-vogue descriptor by research institutes and academics. A growing number of molecular and cell biologists are arguing not only for the insufficiency of genetic control, but even of genomic regulation, to explain the holistic integration of metabolic pathways and cycles. The organization of the cell is attributable to many epigenetic factors and subsystems in addition to genomics. All of these subsystems contribute to an overarching, conceptual, cooperative system. Development, error repair, control and regulation all contribute to a formal *metasystem* within each prokaryotic cell. These metasystems only grow with eukaryotes, and grow even more astoundingly with multi-cellular organisms.

Epigenetic factors do not negate the continuing reality of extensive genetic and genomic controls. No rational or empirical justification exists for attributing linear, digital, encrypted, genetic recipes to stochastic ensembles OR to physical laws in *any* amount of time. Yet thousands of peer-reviewed papers exist in the literature appealing to materialistic "self-organization." The latter cannot generate formally organized bona fide systems.

A phenomenal amount of *objective* Prescriptive Information (PI) instructs and organizes each cell. A great deal more objective PI is required to integrate cell systems, organs, organ systems, and holistic organisms. From an evolutionary history perspective, no observers or knowers were around when bacteria were being prescribed and their metabolisms organized into replicating formal metasystems. Human observers are Johnny-come-lately *discoverers* of biological Prescriptive Information (PI) [6]. Human epistemology is not an essential component of what objective genetic prescriptive information *is* in nature. Nor is human mentation a factor in a "systems biology" that predates the very existence of *Homo sapiens*.

Many scientists across a wide array of disciplines exercise a surprisingly blind faith in the amazing formal capabilities of spontaneous molecular chaos and combinatorial complexity. Phenomenal systems are just blindly believed to self-organize. Achieving sophisticated formal function consistently requires regulation and control. Control always emanates from choice contingency and intentionality, not from spontaneous molecular chaos.

9. Cells are exquisitely organized systems that accomplish formal work

Formal work is not just heat transfer. Formal work achieves functionality. If ever there were an example of an object achieving formal functionality, it is a living cell. Staying alive has ultimate value to a living organism. Organisms pursue the goal of remaining alive and reproducing. Metabolism is the most highly integrated, holistic, conglomerate of organized formal functions known to science. How did life get so organized and goal-oriented? What forces integrated life's formal systems?

The answer is that life is programmed. The scientific community has been invited in many peer-reviewed science journal papers over the last decade to falsify the following null hypothesis: "All known life is cybernetic." [5-7, 84, 128] Cybernetic simply means "formally controlled" rather than merely "physicochemically constrained." All that is needed to falsify this null hypothesis is a single living cell that is free of metabolic and reproductive controls. No falsification has been provided.

Biological controls are accomplished through the use of material symbol systems, logic gates, configurable switches, and the functional organization of cellular components. Say Ramakrishnan and Bhalla,

> Just as complex electronic circuits are built from simple Boolean gates, diverse biological functions, including signal transduction, differentiation, and stress response, frequently use biochemical switches as a functional module. [129]

Genetic cybernetics inspired Turing's, von Neumann's, and Wiener's development of computer science [130-136]. Genomic and epigenomic cybernetics cannot be explained by models that metaphysically pre-assume the all-sufficiency of mass-energy interactions and the chance and necessity of physicodynamics alone. Genetic and genomic algorithmic controls are fundamentally formal, not physical. But like other formalisms, they can be instantiated into a physical medium of retention and channel transmission using a material symbol system or dynamically-inert configurable switches. Neither parsimonious law nor mere combinatorial complexity can program the efficacious decision-node logic-gate settings of algorithmic organization observed in all known living organisms.

Any life-origin chemist, whether a nucleic acid RNA-World advocate, or Peptide/Polypeptide-First or Lipid Metabolism-First advocate, can readily relate innumerable nightmares of cross-reactions and catastrophes experienced as bench scientists have tried to model theoretical abiogenesis models. The extreme difficulty of making cytosine, even with the best minds in the world steering biochemical events, is a classic example [25]. Difficulties in making common components like ribose sugar, and its instability once made, are constantly throwing a wrench into any theoretical mechanism of spontaneous generation of any protosystem, let alone life. Says Shapiro with regarding the formation of D-ribose on prebiotic earth,

> Polymerization of formaldehyde (the formose reaction) has been the single reaction cited for prebiotic ribose synthesis. . . .The complex sugar mixture produced in the formose reaction is rapidly destroyed under the reaction conditions. Nitrogenous substances (needed for prebiotic base synthesis) would interfere with the formose reaction by reacting with formaldehyde, the intermediates, and sugar products in undesirable ways. The evidence that is currently available does not support the availability of ribose on the prebiotic earth, except perhaps for brief periods of time, in low concentration as part of a complex mixture, and under conditions unsuitable for nucleoside synthesis. [137]

Homochirality issues arise in trying to generate pure populations of right-handed sugars and left-handed amino acids. Activation of monomers necessary for polymerization of long chains is no small issue. Polymerization of more than ten residues in aqueous solution is almost impossible when dehydration synthesis is needed for polymerization. When heat is applied, cyclical cAMPs and cGMPs can form with up to 100 mers, but these homopolymers are informationless [138]. Adsorption of nucleosides onto montmorillonite clay surfaces allows polymerization of chains of 30-50 monomers [139]. But these too are informationless homopolymers, usually polyadenosines or polyuridines. These spontaneous reactions are so physicodynamically ordered that they cannot have any significant PI instantiated into them. Information instantiation into any physical matrix requires Shannon *uncertainty*. This, is turn, requires freedom from self-ordering physicodynamic determinism. Sequencing must be arbitrary (freely selectable) and inert (physicodynamically indeterminate; decoupled from and incoherent with physical causation.) Homopolymers, therefore, could not possibly be the source of highly informational genetic instructions.

Multiple chicken-and-egg dilemmas arise such as the need for protein to supplement the extremely sophisticated ribozyme component of the ribosome—a veritable molecular computer. Yet no protein can be made for the ribosome's construction without the ribosome itself already being there to make those protein components. Multiple problems arise in trying to develop the genetic code piecemeal over a long period of time. Francis Crick's Central Dogma will not be overturned by any amount of empirical evidence. Formally absolute mathematical prohibitions exist for trying to build the genetic code table from bottom up (with fewer codons) rather than top down [13, 84].

We could go on ad infinitum with the train wrecks that occur in any abiogenesis model given real-world biochemical and formal realities. The bottom line is that any Composomal or Metabolism-First model of life-origin must have control mechanisms in place almost from the first instance of any protometabolism for any hint of progress to be made towards an imagined protolife. There must be manifold directionality to system composed of cooperative functional processes. These processes must be steered toward energy utilization and other utilitarian formal goals if any hope of organization of protometabolism is possible. Highly selective active transport across bilipid pseudomembranes is needed very early on in any miceller model of a developing protocell. Osmotic pressure alone is enough to kill one's vivid imagination of the first protocell. Nothing is more crucial to life or any envisioned protolife, than control and regulation mechanisms. As we saw in Chapter 3, such controls cannot be generated or explained by mere physicodynamic constraints

[4, 7]. The only exception is when certain constraints are deliberately chosen by experimenters in their experimental design so as to steer outcomes toward the experimenters' desired results. But this does not model "natural process" in inanimate prebiotic nature. This is artificial selection. The latter is nothing less than human engineering. It hardly qualifies as a naturalistic life-origin model.

10. Conclusion.

Chance and necessity produce no useful nontrivial organization or work. Will some yet-to-be discovered new law be able to explain or produce sophisticated utility? Nontrivial formal functions require high levels of Prescriptive Information (PI) to steer, control and regulate. High levels of PI require high levels of physical combinatorial uncertainty into which to record purposeful choices. Law-like physicodynamic behavior, on the other hand, manifests minimal uncertainty. It is highly ordered, patterned and redundant. The high degree of order found in "necessity" (the regularities of nature described by the "laws" of physics) only restricts PI instantiation into any physical medium. No yet-to-be-discovered law, therefore, will ever be able to explain the high information content of even short prescriptive programs or algorithms. In a deductively absolute sense, no new law will be able to generate nontrivial pragmatic work. The latter requires *formal* control of physicality.

The mind/body problem has only become more enigmatic with the latest and best neurophysiological research findings [140-149]. Mind cannot be adequately explained with the physical brain alone. Even more perplexing are the many phenomena in pre-vertebrate biological nature with extraordinary programming and integrational attributes. Life is undeniably cybernetic at almost every stage and level. The organization of even *Mycoplasmal* life is as choice-contingent as the intentional operation of Maxwell's Demon's trap door.

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