MOVING 'FAR FROM EQUILIBRIUM' IN A PREBIOTIC ENVIRONMENT:

The role of Maxwell's Demon in life origin

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Abstract

Can we falsify the following null hypothesis?

> "A kinetic energy potential cannot be generated by Maxwell's Demon from an ideal gas equilibrium without purposeful choices of when to open and close the partition's trap door."

If we can falsify this null hypothesis with an observable naturalistic mechanism, we have moved a long way towards modeling the spontaneous molecular evolution of life. Falsification is essential to discount teleology. But life requires a particular version of "far from equilibrium" that explains formal organization, not just physicodynamic self-ordering as seen in Prigogine's dissipative structures. Life is controlled and regulated, not just constrained. Life follows arbitrary rules of behavior, not just invariant physical laws. To explain life's origin and regulation naturalistically, we must first explain the more fundamental question, "How can hotter, faster moving, ideal gas molecules be dichotomized from cooler, slower moving, ideal gas molecules without the Demon's choice contingency operating the trap door?"

1. How could usable energy arise out of equilibrium?

Maxwell was among the first to ponder how usable energy could spontaneously arise out of equilibrium (Maxwell, 1871). Even the simplest heat engine requires a kinetic energy

differential, or "potential," to accomplish "useful work." Maxwell was searching for a natural process that could produce not only this energy potential, but a spontaneously forming non trivial heat engine capable of harnessing that energy potential and transducing it into usable energy suitable for performing intuitive pragmatic "work."

The proper definition of "work," at least as it relates to abiogenesis, embodies formal utility ("useful work"), not just the mere thermodynamic transfer of energy from one body to another. The physics definition of "work" has its short-comings too. If an object's kinetic energy changes as a result of a force acting upon it, we glibly say "work" is done. Physics defines work as a force causing an object to be displaced. Each unit of energy (joule) incorporates a newton of force moving an object one meter. But one meter in what direction for what purpose? Is there any meaning or function to this movement?

The above two questions are formal queries that cannot be answered by chance or physicodynamic factors alone. The only way the physics definition of work acquires the intuitive, every-day semantic meaning of "work" is that our supposedly naturalistic models smuggle in through the back door a lot of background information along with agent motives, values and pursuits. $W = \Delta E = Fd$ and other "work" related equations of physics by themselves tell us absolutely nothing about utility or how to achieve it. No such agent-valued and pursued factors existed in a prebiotic environment. Yet without achieving abundant practical functions in and between many cooperative systems, not even a protocell could have organized. Life is the most integrated, sophisticated interaction of functional processes known to science or engineering. Thus the problem for life-origin specialists is daunting. Mere spontaneous self-replication is the simplest problem that needs solving.

Far more troublesome is explaining the source of Prescriptive Information (PI) (Abel, 2009a) needed to design, prescribe and engineer a sustained heat engine. In the history of human observation (the corner stone of science), creating sustained and harnessable "useful work" has always required formal engineering choices at true decisions nodes, logic gates, and configurable switch-settings. Goals such as algorithmic optimization must be pursued at each organizational step. Such pursuits are just not common to spontaneous physicodynamics in any amount of cosmic time. Not even evolution has any goals. Plausibility evaluations of life-origin models and hypotheses must take such factors into consideration (Abel, 2009e; Abel, 2010b).

Maxwell could not even find a natural mechanism capable of distinguishing between, let alone separating, the hotter, faster-moving inert gas molecules from the cooler, slower moving inert gas molecules. Once equalized on both sides of a compartmental partition, neither chance nor necessity could create a heat differential. The only model that seemed able to accomplish the task consisted of a thought experiment. A "finite being" had to purposefully choose when to open and close a trap door in the partition. Lord Kelvin later called this finite being, "Maxwell's Demon." When the Demon saw a hotter, faster moving molecule approaching the trap door from the left compartment, he deliberately opened the trap door to let it pass into the right compartment. When he saw a colder molecule approaching the open trap door from the left compartment, he purposefully closed the trap door to keep that colder particle in the left compartment. His choices were reversed with inert gas molecules approaching the trap door from the right compartment. The end result was a kinetic energy potential waiting to be harnessed, transduced, stored and later called up by sophisticated mechanisms and molecular machines capable of accomplishing useful work.
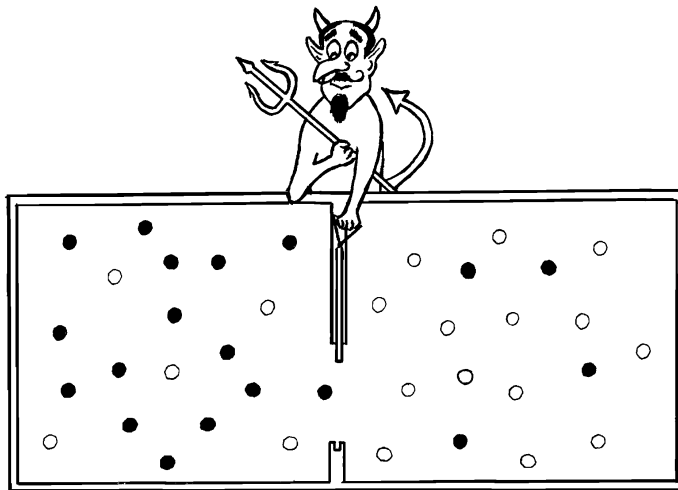
Figure 1. Maxwell's Demon has to purposefully choose when to open and close the trap door to accomplish his goal. Because the gas molecules are inert and ideal, no physicodynamic mechanism seems apparent to explain spontaneous self-ordering, let alone formal self-organization, to the utilitarian end of creating a non-trivial heat engine.

2. Why Do The Gas Molecules Have To Be Ideal?

In order to avoid what is known as the "Gibbs Paradox," the "point particles" must be *indistinguishable* and immune to phase changes and chemical reactions. Ideal gas molecules are inert. They have no physicochemical preference for either compartment, or for each other. Except for temperature and its kinetic relation to heat agitation, each particle's destiny is physicodynamically indeterminate (decoupled and incoherent from physical causation; physicodynamically inert) (Rocha, 2001; Rocha & Hordijk, 2005). The heat agitation of inert gas molecules is devoid of physicochemical affinities. As explained in Section 5 below, this feature is essential to the instantiation of non-physical Prescriptive Information (PI) (Abel, 2009a) into physicality. Decision nodes, logic gates, and configurable switch-settings must be free from physicodynamic determinism in order to program formal function into physical media (Abel, 2008a; Abel, 2008b, 2008c, 2009b). A vast ravine known as The Cybernetic Cut exists between physical causation and formal causation (Abel, 2008b). Non physical causation can be instantiated into physicality using such devices as physical configurable switches set with non-physical formal intent. The Cybernetic Cut ravine cannot be traversed by physicodynamic causation alone. It can only be traversed across the one-way-only CS (Configurable Switch) Bridge (Abel, 2008b) by choice contingency in pursuit of potential formal function.

Suppose that these gas molecules were *not* ideal, not physicodynamically inert. If these molecules were charged particles, for example, they might have natural tendencies to dichotomize themselves from an equilibrium state (Dalenoort, 1989; Demetrius, 1984; Eigen, 1971a, 1971b; Eigen & Schuster, 1977, 1982; Epstein & Eigen, 1979; Gánti, 1975, 1980; Goldbeter & Decroly, 1983; Kuhn, 1972, 1976; Küppers, 1979; Lifson, 1987; Morowitz, 1977, 1981; Morowitz, Heinz, & Deamer, 1988; Nicolis & Prigogine, 1977; Rokhsar, Anderson, & Stein, 1986). They might spontaneously self-order due to charge attraction/repulsion. Or they might have differential tendencies to undergo phase changes or to chemically react. Such physicodynamic factors could spontaneously produce heterogeneity, moving them locally and temporarily away from equilibrium.

Couldn't physicodynamic interaction and self-ordering tendencies be a mechanism important to life-origin? Many publications, to name a few, have promoted this perspective: (Agrawal, 2002; Barab et al., 1999; Batten, Salthe, & Boschetti, 1991; Bedau, 2003; Comazine et al., 2001; Dalenoort, 1989; Deacon, 2006; Demetrius, 1984; Eigen & Winkler, 1992; Feltz, Crommelinck, & Goujon, 2006; Galimov, 2009; Gershenson, 2007; Harold, 2005; Ito & Gunji, 1994; Kauffman, 1995; Kauffman, 1993; Kurakin, 2005; Lehn, 2002a, 2002b; Lozneanu & Sanduloviciu, 2007; Luisi, 2003; Moreno & Ruiz-Mirazo, 2009; Nicholis, 1989; Orgel, 1995; Ponnamperuma, K, & Wickramasinghe, 1995; Rokhsar, et al., 1986; Ruiz-Mirazo, Moreno, & Moran, 1998; Ruiz-Mirazo, Pereto, & Moreno, 2009; Schiffmann, 2007; Seeley, 2002; Senaratne, Hobish, & Ponnamperuma, 1990; Stewart, 2003; Swenson, 1989; Takeuchi & Hogeweg, 2009; Umerez, 2001; Vesterby, 2008; Weber & Depew, 1995; Wills, 1993). Despite all of these publications, and many more, the answer to the question of whether physicodynamic interaction and self-ordering tendencies could generate abiogenesis is, surprisingly, "NO!" Mere heterogeneity and/or order do not even begin to satisfy the necessary and sufficient conditions for life. Self-ordering tendencies provide no mechanism for self-organization, let alone abiogenesis. All sorts of physical astronomical "clumping," weak-bonded molecular alignments, phase changes, and outright chemical reactions occur spontaneously in nature that have nothing to do with life. Life is organization-based, not order-based. As we shall see below in Section 6, order is poisonous to organization.

Stochastic ensembles of nucleotides and amino acids can polymerize naturalistically (with great difficulty). But *functional* sequencing of those monomers cannot be determined by any fixed physicodynamic law. It is well-known that only one 150-mer polyamino acid string out of 10^{74} stochastic ensembles folds into a tertiary structure with any hint of protein function (Axe, 2004). This takes into full consideration the much publicized substitutability of amino acids without loss of function within a typical protein family membership. The odds are still only one functional protein out of 10^{74} stochastic ensembles. And 150 residues are of minimal length to qualify for protein status. Worse yet, spontaneously condensed Levo-only peptides with peptide-only bonds between only biologically useful amino acids in a prebioitic environment would rarely exceed a dozen mers in length. Without polycodon prescription and sophisticated ribosome machinery, not even polypeptides form that would contribute much to "useful biological work."

3. The Trap Door Is Not Constrained; It Is *Demon-Controlled*

Since 1871, many attempts have been made to refine Maxwell's search.   Quantum level models of heat engine generation have been suggested (Kieu, 2004; Quan, Liu, Sun, & Nori, 2007; Quan, Wang, Liu, Sun, & Nori, 2006; Scully, 2001).   Muller and Schulze-Makuch wondered whether the first organisms were sorption heat engines (Muller, 1995).

Szilard (Szilard, 1964) argued that Maxwell's Demon must be "informed."   But to be informed requires semantic information.   This raises the sticky problem of formal "knowledge of being" as opposed to objective physicodynamic being itself.   Worse yet, it brings to the forefront the demon's informed *choices*.   He must not only know when to open or close the trap door, he must have the freedom to choose from among real options. He must have the power to control thermodynamic and physical destiny.

Semantic information has always represented a major problem for philosophic naturalism.   Many have struggled with it, perhaps the most prominent being Bar-Hillel and Carnap (Bar-Hillel & Carnap, 1953); Dretske (1981, 1995); Barwise and Perry (1983); Barwise and Etchemendy (1990); Devlin (1991).   Some have questioned the very existence of information, attempting to reduce it to mere thermodynamics and complex physicality (Barham, 1996; Boniolo, 2003; Godfrey-Smith, 2003; Griffiths, 2001; Kauffman, 1993; Sarkar, 1996; Sarkar, 2003; Stent, 1981; Stonier, 1996; Toussaint & Schneider, 1998).   Deacon has attempted to provide a naturalistic basis for the emergence of teleology (Deacon & Sherman, 2008; Deacon, 2006, 2010; Deacon, Cashman, & Sherman, 2006; Deacon & Sherman, 2006).   Jacob (1974), Wolpert (2002), Stegmann (2005), Barbieri (2004) and Abel (2002; 2005) tend to view genetic and epigenetic information as real.   Norbert Wiener argued that "Information is information, not matter or energy.   Any materialism that fails to take account of this will not survive one day." (Wiener, 1961).   Genetic cybernetics inspired Turing's (1936), von Neumann's (1950), and Wiener's (Wiener, 1948) development of computer science.   Had it not been for their observation of an objective, heritable, linear digital genetic message and control system that predated human consciousness, computers might never have been invented.

4. "Far From Equilibrium" Is Not Unique to Life, or The Key to Life.

As one reviewer of this paper points out, "equilibrium" in contemporary thought is relative to the selection of components. In physical chemistry, "equilibrium" means that the energy distribution is Boltzmann-like for each degree of freedom within each group of identical molecules. The system is "in equilibrium," in a sense, even when it undergoes a chemical reaction. In an alternative convention, different kinds of atomic nuclei and electrons can be used as components. But this still produces a chemical-like equilibrium. When one selects protons, neutrons and electrons as components, however, equilibrium would be reached only with some kind of plasma made up of iron nuclei and free electrons is involved. From this perspective, the entire universe could be considered very far from equilibrium. When a system seems to violate the laws of thermodynamics,

we usually conclude that we have incorrectly identified the components. Thus the reviewer emphasizes that a photochemical process may seem to contradict the laws of thermodynamics until the photon (and possibly the excited state of the photoactive molecule) is identified as an independent component.

Chaos theory deals with many self-ordering phenomena that spontaneously move events far from equilibrium. But candle flames, vortices at bathtub drains, sand piles, and hurricanes have absolutely nothing to do with life. If anything, the "dissipative structures" of chaos theory (e.g. tornadoes) tend to destroy life and any other form of formal organization that they encounter.

The bottom line is that merely "moving far from equilibrium" is not the key to the life-origin problem as supposed. Most would agree that life is indeed "far from equilibrium." But so are hurricanes. It should be readily apparent from hurricane thermodynamics that merely "moving far from equilibrium" doesn't necessarily have anything to do with "life."

If there is any one feature of life that distinguishes it from non-life, it is the exercise of control and regulation through time and extreme environmental insults. And this control is specifically mediated through a unique linear digital material symbol system found no where in the inanimate world. This linear digital symbol system communicates, genetically prescribes, and epigenetically regulates the most exquisite interactions and cooperation of pathways and cycles. The selection of each nucleotide "token" serves to write linguistic-like instructions. Each nucleotide polymerization corresponds to a quaternary configurable switch-setting (Abel, 2000, 2002, 2006; Abel, 2008a; Abel, 2008b). Life is ultimately programmed by decision-node and logic-gate settings found in nucleic acid linear digital sequencing.

5. Order ≠ Organization

Order results from physicodynamic constraints working on otherwise random distributions (e.g., heat agitation) to reduce combinatorial possibilities. Order binds free molecules or individual entities into fewer conglomerates or categories. Structure and patterns arise that reduce disorder (increase order). The physical constraints that produce greater order simultaneously reduce combinatorial possibilities, thereby simultaneously reducing complexity. The higher the self-ordering tendency of physicodynamic interactions, the less complexity remains in hopes of explaining naturalistic abiogenesis.

It is ironic that many investigators simultaneously appeal to "complexity" AND to some yet-to-be discovered "law" of self-organization. Complexity and law-like behavior are not only incompatible, they are in opposition (Abel & Trevors, 2005). The more law-like phenomena are, the less complex they are. Maximum complexity is random behavior, not highly ordered behavior that can be compressed down to a simple algorithmic formula or law. We cannot simultaneously appeal to complexity and law as explanations for life origin.

Organization, unlike law-like behavior, is highly complex and informational (Abel, 2008a; Abel, 2010a). Organization requires selection at bona fide decision nodes (Abel, 2008b, 2008c). In addition, organization requires selection *for potential function*, not just selection of the best existing function (The GS Principle) (Abel, 2009a). Without

prior organization, no sophisticated phenotypic function would exist for the environment to favor. Natural selection does not select at the programming level, and it does not select for isolated function (The GS Principle (Abel, 2009c, 2009d). Selection pressure preserves only the fittest already-programmed, already-living phenotypes (holistic organisms) (Gabora, 2006).

Organization is fundamentally formal, not physical (Abel, 2007, 2008b, 2009b, 2010a). Organization can be instantiated into physicality, but physicality itself is never the source of organization (Abel, 2008b, 2008c). Physicality can self-order, but it cannot self-organize. Organization requires traversing The Cybernetic Cut (Abel, 2008b, 2008c) across the one-way CS Bridge (Configurable Switch Bridge) (Abel, 2008b, 2008c). This unidirectional bridge provides the only passageway across a great ravine (The Cybernetic Cut) that runs through the only objective reality that science has ever observed. On the near side of the ravine are all those phenomena that can be adequately explained with nothing but physicodynamics. On the far side of this great ravine lie all those phenomena that can only be explained by formal choice contingency (e.g., purposeful choices at true decision nodes; circuit integration through the wise setting of logic gates; all forms of programming; computational success achieved through obeying formal rules rather than forced physical laws; artificial intelligence). Much of the confusion between order and organization was fostered by Eigen (1971a, 1971b) and reinforced by Kuhn (1972), Ganti (1975), and Nicholis and Progogine (1977). Their papers and books purporting to explain "Self-Organization" in fact explained nothing more than self-ordering phenomena. Their confusion and conflation of organization with order is never more apparent than in the very title of Nicholis' and Prigogine's famous book: *Self-Organization in Nonequilibirum Systems: From Dissipative Structures to Order Through Fluctuations* (Nicolis & Prigogine, 1977). Their title should have been simply: *Self-ordering into Non-Equilibrium Dissipative Structures.* Neither bona fide "organization" nor algorithmic "systems" can be generated by the self-ordered dissipative structures of chaos theory. Prigogine's later title was far more accurate: *Order out of Chaos* (Prigogine & Stengers, 1984).

In addition to the null hypothesis found in this paper's abstract, we also vigorously invite falsification of the following null hypothesis: *"Self-ordering physicodynamic phenomena alone cannot generate formal organization* (Abel, 2008b, 2009a, 2009b, 2010a; Abel & Trevors, 2005, 2006b)." "Order's" capabilities are no match for those of "organization" (Abel, 2008a). Abiogenesis requires bona fide formal organization, not mere order (Abel & Trevors, 2006b) (Trevors & Abel, 2004). Crystallization produces abundant order, but crystals are not alive. While self-ordering phenomena might be able to locally and temporarily move events away from equilibrium (Galimov, 2009), self-ordering phenomena have never once been observed to algorithmically optimize, program, compute, or organize cooperative formal function. This is one reason Cairns-Smith's intriguing model of clay life fell by the wayside (Cairns-Smith, 1966, 1990).
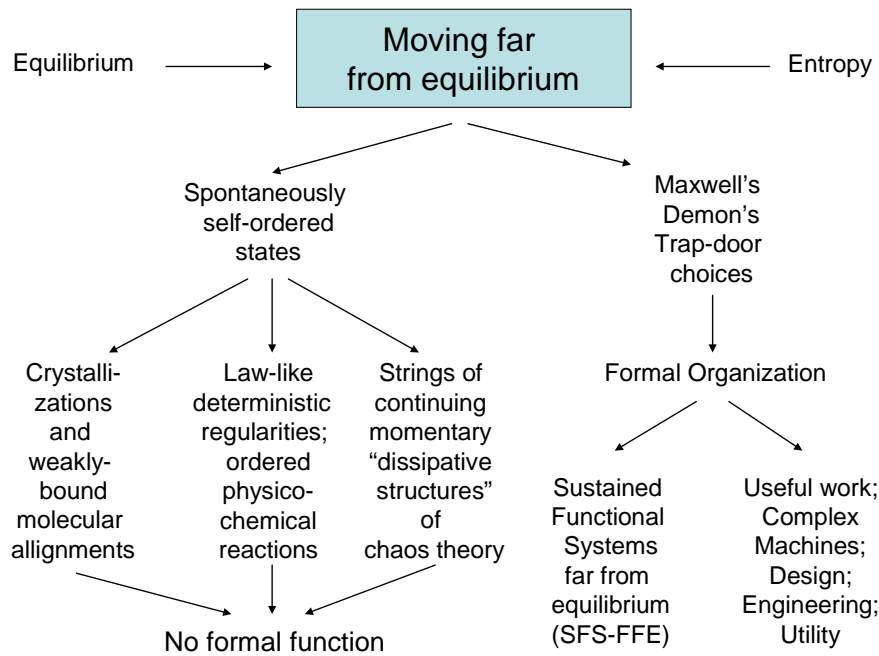
Figure 2. Diagram showing why "order" and merely moving "far from equilibrium" are not synonymous with organization, function or life.

6. Self-Ordering Precludes Organization

There are other reasons why merely "moving far from equilibrium" is *not* the key to life as seems so universally supposed. Disequilibrium stemming from mere physicodynamic constraints and self-ordering phenomena would actually be poisonous to life-origin (Abel, 2009b). The price of such constrained and self-ordering tendencies in nature is the severe reduction of Shannon informational uncertainty in any physical medium (Abel, 2008b, 2010a). Self-ordering processes preclude information generation because they force conformity and reduce freedom of selection. If information needs anything, it is the uncertainty made possible by *freedom from determinism* at true decisions nodes and logic gates. Configurable switch-settings must be physicodynamically inert (Rocha, 2001; Rocha & Hordijk, 2005) for genetic programming and evolution of the symbol system to take place (Pattee, 1995a, 1995b). This is the main reason that Maxwell's Demon model must use ideal gas molecules. It is the only way to maintain high uncertainty and freedom from low informational physicochemical determinism. Only then is the control

and regulation so desperately needed for organization and life-origin possible. The higher the combinatorial possibilities and epistemological uncertainty of any physical medium, the greater is the information recordation potential of that matrix.

Constraints and law-like behavior only reduce uncertainty (bit content) of any physical matrix. Any self-ordering tendency precludes the freedom from law needed to program logic gates and configurable switch settings. The regulation of life requires not only true decision nodes, but wise choices at each decision node. This is exactly what Maxwell's Demon does. No yet-to-be discovered physicodynamic law will ever be able to replace the Demon's wise choices, or explain the exquisite linear digital PI programming and organization of life (Abel, 2009a; Abel & Trevors, 2007). Organization requires choice contingency rather than chance contingency or law (Abel, 2008b, 2009b, 2010a). This conclusion comes via deductive logical necessity and clear-cut category differences, not just from best-thus-far empiricism or induction/abduction.

Programming lies in a formal category, the same as mathematics, language, logic theory, and cybernetics. Logic gates cannot be programmed by chance or physicodynamic necessity (Trevors & Abel, 2004). Even the simplest life form is the most highly controlled and regulated system known to science. It puts our finest hardware and operating systems to shame. No low-informational physical law is going to explain such abstract, conceptual, integrated, logic-gate selections at every nucleotide polymerization event (a quaternary [four-way] configurable switch-setting) (Abel, 2008b).

Appeals to complexity as an explanation for life-origin are better founded, in some respects, than appeals to some yet-to-be-discovered physical law. But maximum complexity is randomness. Randomness has never generated a single complex machine or organized formal "system." Life's genetic and epigenetic programming decision nodes cannot be reduced to mere "bifurcation points." Biogenic controls require wise programming choices to be made at bona fide decision nodes, not just "coin flips" at bifurcation points. No non trivial computational program has ever been written by a random number generator.

The nodes of a neural network cannot just be dumb "buttons" connected by "threads" or "strings." One node firing cannot create an all-or-none depolarization of all other nodes if one expects computational and functional success. Such a lack of selectivity at each node makes fine-tuned control and regulatory mechanisms impossible. A neural net must be organized and controlled to accomplish sophisticated formal tasks. Neither long periods of time nor an imagined helps to circumvent the apparent need for deliberate purposeful selections by Maxwell's Demon at the trap door. It is the Demon's purposeful choices in deciding when to open and close the trap door, not chance, necessity, patterns or order, that alone makes organization and non trivial energy utilization possible. An energy potential alone is not enough to explain life. Energy must be harnessed, transduced, stored, and later utilized in a highly coordinated and cooperative manor. Without such formal organization, metabolism cannot be integrated into the Aristotelian "final cause" of generating and maintaining life.

7. "Disorganization" is a Better Description of Entropy Than "Disorder."

The increase in entropy in accord with the 2nd Law primarily describes events and objects progressing towards disorganization, not necessarily towards disorder. To understand how and why this is, we need only return to Maxwell's diagram. Any attempt to deny the demon his ability to purposefully choose when to open and close the trap door will only result in increased entropy and movement back towards equilibrium. The key to understanding entropy, equilibrium, and "moving far from equilibrium" centers around the Demon's *agency*, not mere order or disorder.

No Demon choice-contingency is needed for inorganic crystallization or a hurricane to self-order. Not surprisingly, the over-all long term effects of crystallization and hurricanes do not generate an algorithmically or cybernetically organized "system," or *keep* it away from equilibrium for very long. Despite short term self-ordering, both crystallization and hurricanes ultimately promote the loss of usable energy and only accelerates the progression toward eventual heat death. Sooner or later crystals will dissolve and release the remaining energy trapped temporarily in their bonds.

It is the Demon's ability to formally categorize and purposefully select for "*potential* usefulness" that makes both "organization" and a *sustained* "far from equilibrium" true "system" possible. "Weather systems" are not true systems. They are merely physicodynamic interfaces, fronts and self-ordered phenomena with no pragmatic algorithmic component. Weather pseudo systems cannot compute, integrate or program any formal function. They are purely physicodynamic.

Potential usefulness cannot be perceived or pursued by physicodynamics. Potential usefulness exists only as an abstract concept, desire and goal. Programming choices lie in the formal realm, not in the physicodynamic realm.

It is only the organizational version of moving far from equilibrium that has any relevance to life origin, not the highly constrained and self-ordered redundancies of mere physicodynamics. Law-like self-ordering makes the instantiation of non trivial formal PI into physicality impossible (Abel, 2008b). Neither chance nor necessity can program instructive linear digital DNA strings or the protein folding they prescribe. The organizational version of moving far from equilibrium necessarily involves cybernetics—bona fide control mechanisms and true regulation—not just formally indifferent, blind physicodynamic constraints(Abel, 2010a).

8. *Sustainable Functional Systems (SFS)* require organization

Maxwell's illustration and Demon are crucial to understanding how any system could have moved not only far from equilibrium, but specifically towards a *Sustainable Functional System (SFS)*. Inherent in any SFS is bona fide *organization*. The role of the Demon reduces the problem of both SFS formation, organization and maintenance to its rock-bottom level. The Demon's *choice contingency* of when to open and close the trap door so as to accomplish the goal of a sustained energy potential represents the very first true decision-node instantiation into physicality. The Demon's first choice is the birth of engineering and the artificial intelligence movement. Deciding when to open and close the trap door is the very first logic gate—the very first configurable switch-setting. The Demon's voluntary (arbitrary) trap-door operation represents the birth of integrated circuits, computational cybernetics, and life's regulatory mechanisms.

Try to metaphysically exclude choice contingency from one's mental construct of reality, and that purely physicalistic worldview immediately becomes a cement body suit. Just too many repeatedly observable phenomena arise from undeniable choice contingency. The very practice of science itself is impossible apart from the reality of physicodynamically indeterminate choice at bona fide decision nodes. We cannot hypothesize, falsify, measure, sort data, dichotomize mere association from causation, evaluate results, or draw conclusions without choice contingency. Deny the Demon's choice of trap door control, and all hope of organization and algorithmic optimization dies. When the physicalist seeks to eliminate choice contingency from physicalistic reality, he only shoots himself in the foot. He cannot even argue for his metaphysical belief system without employing the choice contingency he denies. Without choice contingency, both his materialistic worldview and naturalistic science are dead.

Organization is what makes Sustainable Functional Systems (SFS) far from equilibrium possible. Without SFS's, life is impossible. No finer example of sustained control, organization, function and utility exist than life itself. We cannot begin to understand "systems biology" without first appreciating the reality of organization and its contribution to holistic metabolism. But life's organization depends wholly upon such factors as monomeric sequencing decisions at the primary structure level of biopolymer formation. "Messenger molecules" cannot be reduced to mere linguistic metaphor (Abel & Trevors, 2006a). No fundamental difference exists between the Demon's trap-door choices and those sequencing decisions that program future folding and binding function. They both are a form of undeniable cybernetic programming of *potential* (not-yet-existent) function. Selection pressure cannot favor something that does not yet exist (The GS Principle)(Abel, 2009c, 2009d).

Each purposeful opening and closing of the trap door by the Demon is a true cybernetic "operation." Each operation is a wise binary programming decision. The Demon's trap-door decisions to merely dichotomize hot from cold would not be sufficient to create a heat engine. Additional more anticipatory, sophisticated, and integrative decisions would be required to generate a heat engine to take advantage of the created energy potential.

"Operations" alone are what successfully compute and organize. Operations alone are what design and engineer machines. It is operations that perform "useful work." Useful work is what creates and keeps Sustainable Functional Systems (SFS) far from equilibrium—not only physical work, but formal cybernetic work. Thus we invite falsification of still another null hypothesis: *"Without formal cybernetics, the "work" addressed by thermodynamics and physics will not become organized into Aristotelian 'final' utility."* Mere heat transfer from one particle to another doesn't measure up. A force moving a mass through a distance doesn't measure up either. Only the Demon's purposeful trap-door operations produce sustained formal function and utility in the form of SFS's.

9. Summary:

1) Redundant, low-informational, pragmatically blind "Order" is not the same as imaginative, highly informational, pragmatic, choice-based "Organization." Physico-

dynamic self-ordering in nature precludes both organization and instantiation of Prescriptive Information (PI) into physical media such as RNA and DNA.

2) Constraints are not synonymous with controls. The two terms must not be used interchangeably. Constraints reduce options and impede potential controls.

3) Both self-ordering phenomena (such as the dissipative structures of chaos theory) and true organization can move events away from equilibrium. But only organization, not order, can steer, coordinate, and integrate Sustained Functional Systems (SFS) (e.g., biochemical pathways and cycles) into holistic metabolic schemes. Merely being far from equilibrium, therefore, is not a sufficient definition or cause of life.

4) No hint of formal function or pragmatism is inherent in any of the thermodynamic or physics equations relating to work.

5) Life is not merely physicodynamically constrained. Life is formally controlled with expedient decision node, logic gate, and configurable switch-settings that cybernetically program computational success and that organize Aristotelian "final" utility (integrated holistic metabolism).

6) The birth of ProtoBioCybernetics was Maxwell's Demon's first choice of when to open or close his trap door for the purpose of moving away from equilibrium specifically towards organization and control, not necessarily order.

7) Prediction: *Deny Maxwell's Demon his ability to purposefully select when to open and close the trap door, and no empirical Sustained Functional Systems (SFS) (the key to life-origin) will occur in nature far from equilibrium.*

8) All known life is cybernetic—controlled and regulated by formal computational logic-gate and configurable-switch settings. Chance and necessity cannot explain the arbitrary assignments of the genetic material symbol system, the multiple layers of different kinds of information, the code bijection (translation, correspondence of amino acid to codonic representational prescription), the noise-reducing Hamming block code described by the codon table, the error-correction mechanisms, the epigenetic regulation of already existing instructions, or the linear digital programming of Prescriptive Information (PI) that instructs and organizes life.

9) The best understanding of entropy is not "disorder," but "disorganization."

10. References:

Abel, D. L. (2000). Is Life Reducible to Complexity? Paper presented at the Workshop on Life: a satellite meeting before the Millennial World Meeting of University Professors, Modena, Italy.

Abel, D. L. (2002). Is Life Reducible to Complexity? In G. Palyi, C. Zucchi & L. Caglioti (Eds.), *Fundamentals of Life* (pp. 57-72). Paris: Elsevier.

Abel, D. L. (2006). *Life origin: The role of complexity at the edge of chaos*. Paper presented at the Washington Science 2006, Headquarters of the National Science Foundation, Arlington, VA Abstracts from CapSci06 http://www.washacadsci.org/ See "David Abel, Sunday, 2:30," near the bottom; Powerpoint Lecture with speaker notes on C/D can be requested from life@us.net

Abel, D. L. (2007). Complexity, self-organization, and emergence at the edge of chaos in life-origin models. *Journal of the Washington Academy of Sciences,* **93**(4), 1-20.

Abel, D. L. (2008a). *The capabilities of chaos and complexity*. Paper presented at the Society for Chaos Theory: Society for Complexity in Psychology and the Life Sciences, International Conference at Virginia Commonwealth University, Richmond, VA.

Abel, D. L. (2008b). 'The Cybernetic Cut': Progressing from description to prescription in systems theory. *The Open Cybernetics and Systemics Journal,* **2**, 234-244 Open access doi: 10.2174/1874110X00802010252

Abel, D. L. (2008c). The Cybernetic Cut [Scirus Topic Page] Retrieved Last accessed Feb, 2012, from http://www.scitopics.com/The_Cybernetic_Cut.html

Abel, D. L. (2009a). The biosemiosis of prescriptive information. *Semiotica,* **2009**(174), 1-19. doi:10.1515/semi.2009.026

Abel, D. L. (2009b). The capabilities of chaos and complexity. *Int. J. Mol. Sci.,* **10**(Special Issue on Life Origin), 247-291 Open access at http://mdpi.com/1422-0067/1410/1421/1247

Abel, D. L. (2009c). The GS (Genetic Selection) Principle. *Frontiers in Bioscience,* **14**(January 1), 2959-2969 Open access. doi: http://www.bioscience.org/2009/v14/af/3426/fulltext.htm

Abel, D. L. (2009d). The GS (Genetic Selection) Principle [Scirus Topic Page] Retrieved Last accessed Feb, 2012, from http://www.scitopics.com/The_Genetic_Selection_GS_Principle.html

Abel, D. L. (2009e). The Universal Plausibility Metric (UPM) & Principle (UPP). *Theor Biol Med Model,* **6**(1), 27 Open access at http://www.tbiomed.com/content/26/21/27.

Abel, D. L. (2010a). Constraints vs. Controls. *Open Cybernetics and Systemics Journal,* **4**, 14-27 Open Access at http://www.bentham.org/open/tocsj/articles/V004/014TOCSJ.pdf.

Abel, D. L. (2010b). The Universal Plausibility Metric (UPM) & Principle (UPP) [Scirus SciTopic Page] Retrieved Last accessed Feb, 2012, from http://scitopics.com/The_Universal_Plausbility_Metric_UPM_and_Principle_UPP.html

Abel, D. L., & Trevors, J. T. (2005). Three subsets of sequence complexity and their relevance to biopolymeric information. *Theoretical Biology and Medical Modeling,* **2**, 29 Open access at http://www.tbiomed.com/content/22/21/29.

Abel, D. L., & Trevors, J. T. (2006a). More than metaphor: Genomes are objective sign systems. *Journal of BioSemiotics,* **1**(2), 253-267.

Abel, D. L., & Trevors, J. T. (2006b). Self-Organization vs. Self-Ordering events in life-origin models. *Physics of Life Reviews, 3*, 211-228. doi: 10.1016/j.plrev.2006.07.003

Abel, D. L., & Trevors, J. T. (2007). More than Metaphor: Genomes are Objective Sign Systems. In M. Barbieri (Ed.), *BioSemiotic Research Trends* (pp. 1-15). New York: Nova Science Publishers.

Agrawal, H. (2002). Extreme self-organization in networks constructed from gene expression data. *Physical review letters, 89*(26), 268702.

Axe, D. D. (2004). Estimating the prevalence of protein sequences adopting functional enzyme folds. *J Mol Biol, 341*(5), 1295-1315.

Bar-Hillel, Y., & Carnap, R. (1953). Semantic Information. *British Journal for the Philosophy of Science, 4*, 147-157.

Barab, S. A., Cherkes-Julkowski, M., Swenson, R., Garrett, S., Shaw, R. E., & Young, M. (1999). Principles of Self-Organization: Learning as Participation in Autocatakinetic Systems *The Journal of the Learning Sciences 8*(3/4), 349-390.

Barbieri, M. (2004). Biology with information and meaning. *History & Philosophy of the Life Sciences, 25*(2 (June)), 243-254.

Barham, J. (1996). A dynamical model of the meaning of information. *Biosystems, 38*(2-3), 235-241.

Barwise, J., & Etchemendy, J. (1990). Information, Infons, and Inference. In R. Cooper, K. Mukai & J. Perry (Eds.), *Situation Theory and Its Applications* (Vol. 1, pp. 33-78). Stanford, CA: CSLI.

Barwise, J., & Perry, J. (1983). *Situations and Attitudes*. Cambridge, Ma: MIT Press.

Batten, M., Salthe, S., & Boschetti, F. (1991). Visoins of evolution: self-organization proposes what natural slelction disposes. *Biological Theory, 3*(1), 17-29.

Bedau, M. A. (2003). Artificial life: organization, adaptation and complexity from the bottom up. *Trends in cognitive sciences, 7*(11), 505-512.

Boniolo, G. (2003). Biology without information. *History and philosophy of the life sciences, 25*, 255-273.

Cairns-Smith, A. G. (1966). The origin of life and the nature of the primitive gene. *J Theor Biol, 10*(1), 53-88.

Cairns-Smith, A. G. (1990). *Seven Clues to the Origin of Life* (Canto ed.). Cambridge: Cambridge University Press.

Comazine, S., Deneubourg, J.-L., Franks, N., Sneyd, J., Theraulaz, G., & Bonabeau, E. (2001). *Self-Organization is Biological Systems*. Princeton, N.J.: Princeton University Press.

Dalenoort, G. J. (1989). *The Paradigm of self-organization: current trends in self-organization*. New York: Gordon and Breach Science Publishers.

Deacon, T., & Sherman, J. (2008). The Pattern Which Connects Pleroma to Creatura: The Autocell Bridge from Physics to Life. In J. Hoffmeyer (Ed.), *A Legacy for Living Systems: Gregory Bateson as Precursor to Biosemiotics* Netherlands: Springer Netherlands.

Deacon, T. W. Emergence: The hole at the wheel's hub. In P. Clayton & P. C. W. Davies (Eds.), *Re-Emergence of Emergence*. Oxford: Oxford University Press.

Deacon, T. W. (2006). Reciprocal linkage between self-organizing processes is sufficient for self-reproduction and evolvability. *Biological Theory, 1*(2), 136-149.

Sherman, J. and Deacon, T. (2007) Teleology for the perplexed: how matter began

to matter. *Zygon* 42: 873-901

Deacon, T. W. (2010). 8. What's missing from theories of information? In P. Davies & N. H. Gregersen (Eds.), *Information and the Nature of Reality: From Physics to Metaphysics* (pp. In Press). Cambridge: Cambridge University Press.

Deacon, T. W., Reciprocal linkage between self-organizing processes is sufficient for self-reproduction and evolvability, *Biological Theory*, 2006, **1**: (2) 136-149

Deacon, T. W., & Sherman, J. (2006). How teleology emerged: Bridging the gap from physics to life.

Demetrius, L. (1984). Self-Organization in Macromolecular Systems: The Notion of Adaptive Value. *PNAS,* **81**(19), 6068-6072. doi: 10.1073/pnas.81.19.6068

Devlin, K. (1991). *Logic and Information*. New York: Cambridge University Press.

Dretske, F. (1981). *Knowledge and the Flow of Information*. Cambridge, Mass: MIT Press.

Dretske, F. (1995). *Naturalizing the Mind*. Cambridge, MA: MIT Press.

Eigen, M. (1971a). Molecular self-organization and the early stages of evolution. *Experientia,* **27**(11), 149-212.

Eigen, M. (1971b). Self-organization of matter and the evolution of biological macromolecules. *Naturwissenschaften,* **58**(In German), 465-523.

Eigen, M., & Schuster, P. (1977). The hypercycle. A principle of natural self-organization. Part A: Emergence of the hypercycle. *Naturwissenschaften,* **64**(11), 541-565.

Eigen, M., & Schuster, P. (1982). Stages of emerging life--five principles of early organization. *J Mol Evol,* **19**(1), 47-61.

Eigen, M., & Winkler, R. (1992). *Steps towards life : a perspective on evolution*. Oxford ; New York: Oxford University Press.

Epstein, I. R., & Eigen, M. (1979). Selection and self-organization of self-reproducing macromolecules under the constraint of constant flux. *Biophys Chem,* **10**(2), 153-160.

Feltz, B., Crommelinck, M., & Goujon, P. (2006). *Self-organization and emergence in life sciences*. Dordrecht: Springer.

Gabora, L. (2006). Self-Other Organization: Why early life did not evolve through natural selection. *J Theor Biol,* **241**(3), 443-450.

Galimov, E. M. (2009). Concept of sustained ordering and ATP-related mechanism of life's origin. *Int. J. Mol. Sci.,* **10**, 2019-2030.

Gánti, T. (1975). Organization of chemical reactions into dividing and metabolizing units: the chemotons. *Biosystems,* **7**(1), 15-21.

Gánti, T. (1980). On the organizational basis of the evolution. *Acta Biol,* **31**(4), 449-459.

Gershenson, C. (2007). *Design and Control of Self-Organizing Systems.* Ph.D., Vrije Universiteit Brussel, Brussels. Retrieved from http://complexity.vub.ac.be/~carlos/thesis.pdf

Godfrey-Smith, P. (2003). Genes do not encode information for phenotypic traits. In C. Hitchcock (Ed.), *Contemporary Debates in Philosophy of Science* (pp. 275-289). London: Blackwell.

Goldbeter, A., & Decroly, O. (1983). Temporal self-organization in biochemical systems: periodic behavior vs. chaos. *The American journal of physiology,* **245**(4), R478-483.

Griffiths, P. E. (2001). Genetic information: A metaphor in search of a theory. *Philosophy of Science, 68*, 394-412.

Harold, F. M. (2005). Molecules into cells: specifying spatial architecture. *Microbiology and molecular biology reviews, 69*(4), 544-564.

Ito, K., & Gunji, Y. P. (1994). Self-organisation of living systems towards criticality at the edge of chaos. *Biosystems, 33*(1), 17-24.

Jacob, Francois. (1974). *The Logic of Living Systems---a History of Heredity*. London: Allen Lane.

Kauffman, S. (1995). *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*. New York: Oxford University Press.

Kauffman, S. A. (1993). *The Origins of Order: Self-Organization and Selection in Evolution*. Oxford: Oxford University Press.

Kieu, T. D. (2004). The second law, Maxwell's demon, and work derivable from quantum heat engines. *Physical review letters, 93*(14), 140403.

Kuhn, H. (1972). Self-organization of molecular systems and evolution of the genetic apparatus. *Angewandte Chemie (International ed, 11*(9), 798-820.

Kuhn, H. (1976). Model consideration for the origin of life. Environmental structure as stimulus for the evolution of chemical systems. *Naturwissenschaften, 63*(2), 68-80.

Küppers, B. (1979). Towards an experimental analysis of molecular self-organization and precellular Darwinian evolution. *Naturwissenschaften, 66*(5), 228-243.

Kurakin, A. (2005). Self-organization vs Watchmaker: stochastic gene expression and cell differentiation. *Development genes and evolution, 215*(1), 46-52.

Lehn, J.-M. (2002a). Toward complex matter: Supramolecular chemistry and self-organization. *PNAS*, 072065599.

Lehn, J.-M. (2002b). Toward Self-Organization and Complex Matter. *Science, 295*(5564), 2400-2403.

Lifson, S. (1987). Chemical selection, diversity, teleonomy and the second law of thermodynamics. Reflections on Eigen's theory of self-organization of matter. *Biophys Chem, 26*(2-3), 303-311.

Lozneanu, E., & Sanduloviciu, M. (2007). Self-organization scenario grounded on new experimental results. *Chaos, Solitons and Fractals*.

Luisi, P. L. (2003). Autopoiesis: a review and a reappraisal. *Naturwissenschaften, 90*(2), 49-59.

Maxwell, J. C. (1871). *Theory of Heat*. New York Dover: Reprinted (2001)

Moreno, A., & Ruiz-Mirazo, K. (2009). The problem of the emergence of functional diversity in prebiotic evolution. *Biology and Philosophy, 24*(5), 585-605.

Morowitz, H. J. (1977). Perspectives on thermodynamics and the origin of life. *Adv Biol Med Phys, 16*, 151-163.

Morowitz, H. J. (1981). Phase separation, charge separation and biogenesis. *Biosystems, 14*(1), 41-47.

Morowitz, H. J., Heinz, B., & Deamer, D. W. (1988). The chemical logic of a minimum protocell. *Orig Life Evol Biosph, 18*(3), 281-287.

Muller, A. W. (1995). Were the first organisms heat engines? A new model for biogenesis and the early evolution of biological energy conversion. *Progress in biophysics and molecular biology, 63*, 193-231.

Nicholis, G. (1989). Physics of far-from-equilibrium systems and self-organization. In P. Davies (Ed.), *The New Physics* (pp. 316-347). Cambridge: Cambridge Univ. Press.

Nicolis, G., & Prigogine, I. (1977). *Self-Organization in Nonequilibirum Systems: From Dissipative Structures to Order Through Fluctuations.* New York: Wiley-Interscience.

Orgel, L. E. (1995). Unnatural selection in chemical systems. *Acc Chem Res, 28*(3), 109-118.

Pattee, H. H. (1995a). Artificial Life Needs a Real Epistemology. In F. Moran (Ed.), *Advances in Artificial Life* (pp. 23-38). Berlin: Springer.

Pattee, H. H. (1995b). Evolving Self-Reference: Matter, Symbols, and Semantic Closure. *Communication and Cognition-Artificial Intelligence, 12*, 9-28.

Ponnamperuma, C., K, H. M., & Wickramasinghe, N. (1995). The physicochemical origins of the genetic code. In J. Chela-Flores, M. Chadha, A. Negron-Mendoza & T. Oshima (Eds.), *Chemical Evolution: Self-Organization of the Macromolecules of Life* (pp. 3-18). Hampton, VA: Deepak Publishing.

Prigogine, I., & Stengers, I. (1984). *Order Out of Chaos*. London, 285-287, 297-301: Heinemann.

Quan, H. T., Liu, Y. X., Sun, C. P., & Nori, F. (2007). Quantum thermodynamic cycles and quantum heat engines. *Phys Rev E Stat Nonlin Soft Matter Phys, 76*(3 Pt 1), 031105.

Quan, H. T., Wang, Y. D., Liu, Y. X., Sun, C. P., & Nori, F. (2006). Maxwell's demon assisted thermodynamic cycle in superconducting quantum circuits. *Physical review letters, 97*(18), 180402.

Rocha, L. M. (2001). Evolution with material symbol systems. *Biosystems, 60*, 95-121.

Rocha, L. M., & Hordijk, W. (2005). Material representations: from the genetic code to the evolution of cellular automata. *Artif Life, 11*(1-2), 189-214.

Rokhsar, D. S., Anderson, P. W., & Stein, D. L. (1986). Self-organization in prebiological systems: simulations of a model for the origin of genetic information. *J Mol Evol, 23*(2), 119-126.

Ruiz-Mirazo, K., Moreno, A., & Moran, F. (1998). Merging the Energetic and the Relational-Constructive Logic of Life. . In C. Adami, B. R., H. Kitano & C. Taylor (Eds.), *Artificial Life VI* (pp. 448-451). Cambridge MA: MIT Bradford Books.

Ruiz-Mirazo, K., Pereto, J., & Moreno, A. (2009). Defining life or bringing biology to life. *Orig Life Evol Biosph*.

Sarkar, S. (1996). Biological information: a skeptical look at some central dogmas of molecular biology. In S. Sarkar (Ed.), *The Philosophy and History of Molecular Biology: New Perspectives* (pp. 187-231). Dordrecht: Kluwer Academic Publishers.

Sarkar, S. (2003). Genes encode information for phenotypic traits. In C. Hitchcock (Ed.), *Comtemporary debates in Philosophy of Science* (pp. 259-274). London: Blackwell.

Schiffmann, Y. (2007). Self-organization in and on biological spheres. *Progress in biophysics and molecular biology*.

Scully, M. O. (2001). Extracting work from a single thermal bath via quantum negentropy. *Physical review letters, 87*(22), 220601.

Seeley, T. (2002). When is self-organization used in biological systems? *The Biological bulletin,* **Jun;202**(3), 314-318.

Senaratne, N., Hobish, M. K., & Ponnamperuma, C. (1990). Direct interactions between amino acids and nucleotides as a possible explanation for the origin of the genetic code (abstract). In C. Ponnamperuma & F. R. Eirich (Eds.), *Prebiological Self-Organization of Matter*.

Stegmann, U. E. (2005). Genetic Information as Instructional Content. *Phil of Sci,* **72**, 425-443.

Stent, G. S. (1981). Strength and weakness of the genetic approach to the development of the nervous system. *Annu Rev Neurosci,* **4**, 163-194.

Stewart, I. (2003). Self-organization in evolution: A mathematical perspective. *Phil. Trans. R. Soc. Lond.,* **361**, 1101-1123.

Stonier, T. (1996). Information as a basic property of the universe. *Biosystems,* **38**(2-3), 135-140.

Swenson, R. (1989). Emergent attractors and the law of maximum entropy production. *Systems Research,* **6**, 187-197.

Szilard, L. (1964). On the decrease of entropy in a thermodynamic system by the intervention of intelligent beings. *Behav Sci,* **9**(4), 301-310.

Takeuchi, N., & Hogeweg, P. (2009). Multilevel Selection in Models of Prebiotic Evolution II: A Direct Comparison of Compartmentalization and Spatial Self-Organization. *PLoS Comput Biol,* **5**(10), e1000542.

Toussaint, O., & Schneider, E. D. (1998). The thermodynamics and evolution of complexity in biological systems. *Comp Biochem Physiol A Mol Integr Physiol,* **120**(1), 3-9.

Trevors, J. T., & Abel, D. L. (2004). Chance and necessity do not explain the origin of life. *Cell Biology International,* **28**, 729-739. doi: 10.1016/j.cellbi.2004.06.006

Turing, A. M. (1936). On computable numbers, with an application to the *entscheidungs problem*. *Proc. Roy. Soc. London Mathematical Society,* **42**(Ser 2), 230-265 [correction in 243, 544-546].

Umerez, J. (2001). Howard Pattee's theoretical biology--a radical epistemological stance to approach life, evolution and complexity. *Biosystems,* **60**(1-3), 159-177.

Vesterby, V. (2008). *Origins of Self-organization, Emergence and Cause*. Goodyear, Arizona: ISCE Publishing.

von Neumann, J. (1950). [Letter to physicist George Gamow (first scientist to elucidate *triplet* codons) on July 25, 1950. Cited by Steve J. Heims in "John von Neumann and Norbert Wiener: *From Mathematics to the Technologies of Life and Death*," Canbridge, MA, MIT Press, 1980.].

Weber, B. H., & Depew, D. J. (1995). Natural selection and self-organization. *Biology and Philosophy*.

Wiener, N. (1948). *Cybernetics*. New York: J. Wiley.

Wiener, N. (1961). *Cybernetics, its Control and Communication in the Animal and the Machine* (2 ed.). Cambridge: MIT Press.

Wills, P. R. (1993). Self-organization of genetic coding. *J Theor Biol,* **162**(3), 267-287.

Wolpert, L., Smith, J., Jessell, T., & Lawrence, P. (2002). *Principles of Development*. Oxford: Oxford University Press.