The 'Cybernetic Cut': Progressing from Description to Prescription in Systems Theory

David L. Abel*,§

Primordial BioCybernetics/BioSemiotics, Program Director, The Gene Emergence Project, The Origin of Life Foundation, Inc. (a U.S. Science Foundation), 113 Hedgewood Dr. Greenbelt, MD 20770-1610, USA

Abstract: Howard Pattee championed the term "epistemic cut" to describe the symbol-matter, subject-object, genotype-phenotype distinction. But the precise point of contact between logical deductive formalisms and physicality still needs elucidation. Can information be physical? How does nonphysical mind arise from physicality to then establish formal control over that physicality (e.g., engineering feats, computer science)? How did inanimate nature give rise to an algorithmically organized, semiotic and cybernetic life? Both the practice of physics and life itself require traversing not only an epistemic cut, but a Cybernetic Cut. A fundamental dichotomy of reality is delineated. The dynamics of physicality ("chance and necessity") lie on one side. On the other side lies the ability to choose with intent what aspects of ontological being will be preferred, pursued, selected, rearranged, integrated, organized, preserved, and used (cybernetic formalism).

Keywords: Bifurcation points, configurable switches, decision nodes, formalism, logic gates, biocybernetics, biosemiosis, biosemiotics, self-assembly, self-organization, sign systems, symbol systems.

1. INTRODUCTION

Howard Pattee has championed the term "epistemic cut" to describe the symbol-matter, subject-object, genotype-phenotype distinction [1-8]. An unavoidable gulf exists between knowledge and the physical objects of that knowledge [3], between description and the thing being described [9], between measurement and the physical state being measured [10], and between genotype and phenotype [3, 10-14]. Pattee's epistemic cut separates description from construction, simulation from realization, mind from brain, and the irreversible process of measuring initial conditions from reversible physicodynamic laws. The epistemic cut is related to *the measurement problem* of quantum physics [15-18]. Rosen also dealt with the problem of drawing a boundary between subject and object [19]. The epistemic cut is the demarcation between a physical system and its model [8]. Von Neumann said " . . .we *must* always divide the world into two parts, the one being the observed system, the other the observer." [20, ch. 6]

Given the boundary that exists between a physical system and its model, *semantic closure* must occur between the epistemological descriptions of initial conditions and physical dynamics itself [5, 7, 21, 22]. Matter is seen as having both physical and symbolic aspects of its own. Causal loops within the system are believed to create semantic self-reference [23, 24]. Many artificial intelligence specialists see complex systems as being rich in self-referents.

Semantic closure is seen as a requirement for autonomy. Matter must take on symbolic attributes in a material symbol system (MSS) for evolution to be possible [15]. A system with closed causal loops and self-reference is thought to define its own identity in the process of self-replication [25, 26]. Semantics and pragmatics must be conjoined with syntax to form a non fragmentable closure. Syntax alone is seen as inadequate to describe complex autonomous systems because it provides no basis for a system's closed causal loops and self-reference.

Robert Rosen [27], Luis Rocha Rocha [26, 28], Jon Umerez [21], and others have made contributions to the notion of semantic closure. Rocha in particular has expounded on semantic closure, referring to it as *semiotic closure* [29-33]. "Semiotic" is a more inclusive term that better embodies the synthesis of syntax, semantics, and pragmatics [34]. Pattee has agreed with Rocha on this expansion of meaning [35].

Crucial to understanding semiotic closure is the principle of *Complementarity* between semiotics and physicality [1, 7, 36-38]. Complementarity is necessary to create a relational framework and self-referential whole:

"Complementarity is an epistemological principle derived from the subject-object or observer-system dichotomy, where each side requires a separate mode of description that is formally incompatible with and irreducible to the other, and where one mode of description alone does not provide comprehensive explanatory power." [38, pg. 191]

But Pattee's original description of complementarity acknowledges the need for formal contributions to the science

*Address correspondence to this author at the Primordial BioCybernetics/BioSemiotics, Program Director, The Gene Emergence Project, The Origin of Life Foundation, Inc. (a U.S. Science Foundation), 113 Hedgewood Dr. Greenbelt, MD 20770-1610 USA; Tel: 301-441-2923; Fax: 301-441-8135; E-mail: life@us.net

§Bionote: Dr. David L. Abel is a theoretical biologist focusing on primordial biocybernetics. He is the Program Director of The Gene Emergence Project, an international consortium of scientists pursuing the natural-process derivation of initial biocybernetic/biosemiotic programming and control.

of physics. Physics is the study of matter, energy, and the physicodynamic relationships between the two. But those relationships are formally defined and predicted. By "formal" we are referring to abstract, conceptual, mathematical, logical, deductive, enterprises of mind. Such logic systems with their deductive rules (rather than physicodynamic "laws") have traditionally been viewed as non physical. Measurements, for example, are formal representations of initial conditions, not the initial conditions themselves. Physics consists primarily of mathematical deductions flowing from unproven axioms. *The need for non-physical formalisms exists in physics and the scientific method itself even prior to the introduction of the informational concerns of biology.*

How are formal mathematical equations able to reliably predict physical interactions? We count on such predictions every day in the practice of physics. If formal mathematical structure did not in a sense "control" physical interactions, we would not be able to land a rover on Mars years after blast-off on earth. While we might like to limit the problem of prescriptive information and control to biology, in truth formalism governs physicality in both physics and biology. We find not only living things, but inanimate physicodynamics in a rational context conforming to abstract mathematical deductive logic. In addition, we have not faired well in our relentless quest to reduce mind to physical brain.

The subject/object, symbol/matter, observer/system, genotype/phenotype gap would have to be closed to achieve the full philosophic naturalization of science. Exactly how semantic closure can be accomplished in the absence of intentionality has never been fully clarified. Examples of spontaneous semiotic closure in the inanimate "real world" are also sorely lacking. While Pattee and Rosen never denied the existence of intentionality, prescription, control and creativity, neither investigator has succeeded in explaining *the derivation* of these phenomena from physicality itself. The major challenge to naturalistic science is to elucidate how cause and effect physicodynamics (including heat agitation and quantum uncertainty) could have generated intentionality.

Three pressing questions are of immediate interest here:

1) What are the necessary and sufficient conditions for turning physicodynamics into design, engineering, and computational feats?

2) How did inanimate nature give rise to a formally-directed, linear, digital, semiotic and cybernetic life?

3) How does non physical mind arise out of physicality to then establish control over that physicality?

2. THE CYBERNETIC CUT

Both the practice of physics and biology require traversing not only an epistemic cut, but a Cybernetic Cut. The *Cybernetic Cut* is an extension of physicist Howard Pattee's Epistemic Cut, Complementarity, and Semiotic Closure. Pattee's insights needed further development into a larger more inclusive concept. The Cybernetic Cut defines one of the most fundamental dichotomies of reality. The law-like orderliness of nature along with the seeming chance contingency of heat agitation and stochastic quantum reality lie on one side of the divide. On the other side of this ravine lies the ability to choose with intent what aspects of being will be preferred, pursued, selected, rearranged, integrated, organized, preserved, and used. Thus the Cybernetic Cut goes well beyond mere knowledge, description, and measurement. The Cybernetic Cut explains how and where *formal controls* arise and penetrate the physical sphere to seize arbitrary governance of physicodynamics. This is the realm of prescription of formal function. Traversing the Cybernetic Cut affords engineering-like ability to organize abstract concepts and to instantiate those concepts into physical reality. The far side of the Cybernetic Cut is both instructive and creative. It is controlling and managerial. The Cybernetic Cut must be crossed to program computational halting into any form of physical hardware. To prescribe, instruct or program formal utility is to traverse The Cybernetic Cut.

Traversing the Cybernetic Cut first requires *contingency*. Contingency means that events could happen in multiple ways, or could have happened in a way different from what occurred under the same physicodynamic constraints. But there are two kinds of contingency: *chance contingency* and *choice contingency*. Chance contingency is what we seem to observe in statistically describable quantum events and in the molecular collisions of heat agitation. In the latter, uncertainty is high as to what will happen despite known causal chains. Most theorists attempt to reduce chance contingency to unknown and/or complex causation as summarized by Peale [39]. Thus chance contingency may be only "apparent." In any case, *no deliberate selection from among options occurs with chance contingency.*

Choice contingency, on the other hand, involves purposeful selection from among real options. Unlike chance contingency, with choice contingency an internalized goal motivates each selection [40-42]. The bifurcation points found in the simplest binary system of choice contingency are bona fide *decision* nodes. Crossing the Cybernetic cut requires the ability to purposefully steer through successive bifurcation points down a path toward a desired goal. When purpose, goal, and intent are removed from "choices," the practical capabilities of decision nodes, logic gates, configurable switch-settings, and circuits immediately deteriorate. Integration breaks down with as much reliability as 2nd Law tendencies. The system becomes analogous to random number generation rather than computation. Bifurcation points, in the absence of the intentional choice that would convert them to true decision nodes, consistently fail to generate sophisticated utility. In symbol systems, the randomization of symbols and denial of *intentional* symbol selection quickly leads to the loss of even rudimentary meaning and function.

The capabilities of chance contingency are often greatly inflated. The literature is replete with examples of the capabilities of Markov processes, for example. But we often fail to critically analyze the investigator involvement that goes into such experimental designs. Lewontin and Levins [43] make several good points in this regard:

"Although it is often claimed that statistical techniques are ways of letting the objective data speak for themselves, in both the contrast and correlational modes of statistical inference, all the real work is done by the a priori decisions imported into the analysis--which categories are to be used to create contrasting populations, which categories are to be measured, which categories are to be held constant while others are compared, and which is cause and which is effect?" [43].

Formalism cannot be reduced to mathematics alone. Formalism also includes language constructions, the symbol and sign systems of semiosis, decision theory, non mathematical logic theory, computer science, the larger field of cybernetics (the study of control), and many other fields that depend upon choice contingency rather than chance contingency or necessity. In evolution theory we substitute selection pressure for choice contingency. But the bottom line of crossing the Cybernetic Cut is still *selection* of the fittest from among real options.

Nontrivial formal systems have never been observed to arise from "coin flips" at successive bifurcation points. Decision nodes must be true to their descriptive name. If guesses are made at decision nodes, both reason and empirical experience teach us that little or no utility will be generated. Wise choices must be made with intent to achieve logical, cybernetic, computational, and linguistic function. "Garbage in, garbage out," programmers quip. The criterion of wise choices from among real options is incorporated into the generation of any kind of nontrivial organized system. Algorithmic and computational processes traverse the chasm between formalism and physicality. Appreciating the Cybernetic Cut is the key to understanding the instantiation of any type of formal creativity and engineering success into physicality.

Thus the Cybernetic Cut extends far beyond Pattee's epistemic cut to address two major areas: 1) the gulf or chasm between formal purposeful choices and a materialistic world limited to chance and/or necessity, and 2) crossing that great divide through the instantiation of deliberate choices into physicality to achieve algorithmic utility in the material world. The latter constitute much more than mere constraints. They are controls. The difference between constraints and controls is explained in Section 3 below. The Cybernetic Cut manifests engineering-like ability to organize abstract concepts and to instantiate those concepts into physical reality. Traversing the Cybernetic Cut is instructive, prescriptive, and creative. It is controlling and managerial.

The Cybernetic Cut can be clearly observed in innumerable examples of formal controls of physicality. Pattee's excellent description, measurement, and complementarity points do not fully explain this phenomenon. Table **1** shows the difference between Pattee's description-based Epistemic Cut and its extension to a much more inclusive prescription-based Cybernetic Cut. Table **2** shows the difference between physicality and those aspects of reality that traverse the Cybernetic Cut into the sphere of functional and pragmatic controls.

The term "self-organization" is unfortunately in widespread use in the literature. The terms "organization" and

Table 1. The Difference Between Pattee's Description-Based Epistemic Cut and it's Extension to a Much More Inclusive Prescription-Based Cybernetic Cut

The Epistemic Cut	The Cybernetic Cut
Knowledge based	Decision-node based
Constraint based	Control based
Description based	Prescription based
Measurements taken of existing constraints	Constraints are deliberately chosen
Uses laws	Uses rules
Learns	Instructs
End-user based	Programmer based
Non creative	Creative
Cause and effect	Choice with intent steers the path
Observational	"Makes things happen"
Self-ordering events	Organizational
Describes causal chains of "necessity"	Optimization of genetic algorithms
No choices required	Requires choice with intent
Uses existing laws of motion	Programs configurable switches
Reads semantic information	Writes prescriptive information
Follows orders	Managerial

"self-ordering" should not be confused [44, 45]. No empirical evidence exists of unaided algorithmic self-optimization or spontaneous true self-organization [46]. Bona fide organization requires decision nodes, choice contingency, and purposeful algorithmic optimization [46]. Self-ordering phenomena are simple and redundant. Organized phenomena are typically informationally and cybernetically complex, not just combinatorially complex. They are prescriptively complex and programmatically highly optimized. Prescriptive complexity typically requires choice contingency with intentionality at bona fide decision nodes. The null hypothesis we seek to falsify is this: "Any form of nontrivial organization traverses the Cybernetic Cut, requiring choices with intent to explain."

Single-celled organisms *seem* to make true choices (e.g., approach/avoidance to food sources and noxious stimuli) even though they lack physical brains and formal minds. However at this simple level, such "choices" could easily be pre-programmed (as with robots and AI) by their genetic instructions and various pre-existing epigenetic control mechanisms. We would not attribute "mind" to a robot or bacterium even though they *seem* to make choices. Preprogramming does not require true choices by the robot or bacteria. But the question is, how were bacteria pre-programmed to approach food or avoid noxious stimuli? Typically the environment gets the credit for control. But environmental fluctuations do not constitute control. The control mechanisms lie within the cell, and wisely respond to any environmental eventuality.

Table 2. The Difference Between Physicality and those Aspects of Reality that Traverse the Cybernetic Cut into the Sphere of Functional and Pragmatic Controls

Physicodynamics	Traversing the Cybernetic Cut
Physical	Nonphysical & Formal
Incapable of making decisions	Decision-node based
Constraint based	Control based
Natural-process based	Formal prescription based
Constraints just "happen"	Constraints are deliberately chosen
Forced by laws & Brownian movement	Writes and voluntarily uses formal rules
Incapable of learning	Learns and instructs
Product of cause-and-effect chain	Programmer produced
Determined by inflexible law	Directed by choice with intent
Blind to practical function	Makes functional things happen
Self-ordering physicodynamics	Formally organizational
Chance and necessity	Optimization of genetic algorithms
No autonomy	Autonomy
Inanimacy cannot program algorithms	Programs configurable switches
Oblivious to prescriptive information	Writes prescriptive information
Blind to efficiency	Managerially efficient
Non creative	Creative
Values and pursues nothing	Values and pursues utility

We are hard put to provide empirical evidence or references showing *how* programming can be accomplished without intentional choices of mind (crossing The Cybernetic Cut). It is only our materialistic metaphysical commitments that make this fact difficult to acknowledge, not anything scientific. What we repeatedly observe is that cybernetics is accomplished through bona fide decision nodes, highly specific logic gate configurations and intentional configurable switch settings that integrate circuits and achieve formal computational halting.

Abel has championed the term *Prescriptive Information* (PI) to reduce confusion in the literature and to specify the more intuitive, semantic, instructive, algorithmic, and cybernetic sense of "information" [44, 47-51]. The formal component of prescriptive information (PI) must be appreciated [44, 45, 47, 52]. Objects that are physicodynamically coherent with their environment cannot possibly achieve bona fide organization. The natural inanimate environment does not contain sufficient PI to generate nontrivial organization [47]. Only highly informational life has ever been observed to generate holistic formal integration of components. No autonomous agent has ever been observed to arise from inanimate physicodynamic determinism. Choice contingency at physicodynamically indeterminate logic gates is the key to achieving both PI and organization of any kind [47]. In addition to differentiating mere combinatorial probabilism from prescriptive information, Shannon uncertainty and mutual entropy must not be confused with the Boltzmann thermodynamic entropy of statistical mechanics. The distinction is well defined in the literature [46 Secs 2.1 and 5, 53].

3. PHYSICODYNAMICALLY INDETERMINATE CONFIGURABLE SWITCHES

A unique situation must obtain within any physical system to allow the introduction of formal controls. By controls, we do not mean mere constraints. Constraints manifest no deliberate directionality or purpose. Constraints occur as the result of prior cause-and-effect determinism. Such cause-and-effect chains are oblivious to pragmatic goals. Even evolution has no goal [54-57]. Constraints limit potential freedom indiscriminately with regard to function. Constraints exist in the form of unselected initial conditions and fixed low-informational laws. Constraints are thus utterly indifferent to utility. Controls, on the other hand, steer events toward formal goals such as computational halting, logically sound syllogisms, linguistic communication, and utilitarian physical constructions *via* wise design and engineering decisions.

Constraints can permit some degree of chance-contingency freedom. But controls always manifest the exercise of deliberate selection for function from within that freedom. We have seen that the opportunity to *choose with intent* from among real options (choice contingency) is required in order to leap over the divide known as the Cybernetic Cut. But how can this freedom of purposeful selection get instantiated into a physical world of cause-and-effect determinism? To incorporate choice contingency into physicality requires a device with a unique property. We call this device a *configurable switch*. Configurable switches are physical devices that can register into physicality, and physically utilize, the nonphysical formal choices of mind. The necessary and sufficient conditions to traverse the Cybernetic Cut are 1) the dynamically-inert configurable switch [25, 28] and 2) the choice contingency required to set it.

Purposeful decision-node selections and algorithmic optimizations find no explanation in the mere chance and necessity of physicodynamics. Configurable switches can be set randomly, but no empirical evidence, rational support, nor prediction fulfillments have demonstrated the generation of computational halting *via* random switch-settings. No factual basis in science exists for attributing increasing computational proficiency or organizational prowess to stochastic ensembles or natural processes. "Drunken walks," if they lead to sophisticated function, can invariably be shown to have investigator involvement steering the process from behind the scenes. The usual modus operandi is found in the deliberate selection of sequential iterations. Neither Markov processes nor random number generators have ever been observed to generate functional programs and computational halting apart from this hidden experimenter steering. "Evolutionary algorithms" can be shown from Materials and Methods to example nothing more than "directed evolution." Directed evolution, a self-contradictory nonsense term, is achieved through artificial selection, not natural selection.

Genetic algorithms begin with a population of potential "solutions." Solutions are not physical entities. They are formalisms that inherently incorporate a quest for superior utility. In addition, the optimization process of any genetic algorithm requires intentionality to select for maximum functional efficiency. Thus, both the pool of potential solutions themselves and algorithmic optimization (narrowing down the list of potential solutions to arrive at the fittest solution) require traversing The Cybernetic Cut.

Mere connections in Stuart Kauffman's "buttons and strings" model [58] and in neural nets do not explain integration of circuits so as to organize and accomplish formal pragmatic goals. Physical interactions must be formally steered to achieve sophisticated function and computational halting. Empirically, choice contingency seems to be invariably associated with mind and agency. The reader is challenged to provide a single example of Artificial Intelligence arising spontaneously from inanimate nature. In every published generation of AI with which the author is familiar, AI has been *programmed* by human intentional choice contingency at bona fide "*decision* nodes."

The naturalistic scientific community, and complexity theorists in particular, should collectively pursue falsification of the following null hypothesis: "Spontaneous nontrivial algorithmic optimization is never observed in nature apart from either 1) already existing biological prescriptive information, or 2) investigator involvement in experimental design." Falsification of this null hypothesis could be achieved with a single exception. But great care must be taken to expose hidden artificial controls. Such artificial controls are frequently programmed into supposed evolutionary software (e.g., the embarrassing "target phrase" naively incorporated into Richard Dawkin's "evolutionary" program [59].) It is widely published that "evolution has no goal." If an evolutionary experiment is "directed," how could it possibly be evolutionary? If the process is truly evolutionary, it cannot be deliberately directed toward a goal. When an experimenter directs or steers a supposed "evolutionary algorithm," that experiment constitutes artificial selection, not natural selection, the same as dog breeding.

The term "evolutionary algorithm" is equally self-contradictory. An algorithm is a step-by-step process or procedure for solving a computational problem. Algorithms are formal enterprises requiring optimization. To optimize requires goals and intentionality. By definition, evolution cannot pursue goal-oriented procedures. Evolution is not a programmer of linear digital instructions and code. Natural selection provides no mechanism for the practice of formal representationalism at the genetic level using a symbol system. Selection pressure cannot employ a Hamming "block code" of triplet codons to signify each amino acid. Evolution is after-the-fact differential survival and reproduction of already-living phenotypic organisms. The fittest organisms survive and reproduce best. Less fit living organisms and populations tend to die out faster. Nothing in NeoDarwinianism or punctuated equilibrium theory explains the initial programming of linear digital prescriptive information.

Programmed events and processes leading to sophisticated function are steered by decision-node choice commitments. Even analog and index systems require formal choices to implement. Choices made with intent can become causes of physical effects [42, 60]. These causes originate in a purely formal world, but enter into the physical world *via* specific configurable switch settings to become physicodynamic causes. We call this realization of formal control over physicodynamic causation the *instantiation* of formalism into physicality. Configurable switches must be specifically designed and engineered to open or close purely by formal choice, independent of any physicodynamic determinants. Of course a force must be applied to set the switch. But the question is "Which particular setting?" Whether the binary switch knob on a horizontal switch board is pushed to the right or to the left cannot be addressed by physicodynamics. The law of gravity, for example, acts equally on either option.

Configurable switches must be specifically designed to be "dynamically inert" [7, 21, 25] with respect to their cybernetic function. Rocha sometimes calls this "dynamic discontinuity." The very reason configurable switches are configurable is that their setting is not determined by physicodynamic cause-and-effect. Switch settings are set only by free-will selections from among real options. No laws are broken. But the laws of physics cannot explain what configurable switch-settings accomplish (e.g., integrated circuits, formal computations by physical computers).

The formally determined course of flow of energy through these physical devices produces an *organized* (not merely physicodynamically ordered or constrained) physical output. This formal organization is alone what makes possible local pockets of temporary entropy evasion and seeming entropy reversal. The highly ordered dissipative structures of Prigogine achieve no such local evasions of the Second Law. But by formal programming and design, otherwise useless energy can be transduced by engineered mechanisms into usable energy. Entropy is shifted from the local to the larger peripheral environment. The algorithmic organization that achieves this is not physically derived. Such organization is always formal and decision-node based. Non physical prescriptive information is required.

Weber attempts to summarize the contrast between mental causation and indeterminism while dealing with the mind-body problem [61]. Thus far, very little progress has been made in trying to reduce mind to physical brain. The primary reason is the inability of chance and necessity models to generate and explain the phenomenon of steering events toward nontrivial utility.

4. RULES, NOT LAWS

In language and operating systems, choices of alphanumeric characters are controlled by the arbitrary rule conventions of that language. An example would be the high frequency of occurrence of the letter "u" after the letter "q" in English. Such arbitrary rule controls must never be confused with the physicodynamic law constraints of physicality. No law of nature forces *u*'s to follow *q*'s. The sequencing of letters in language is arbitrary. The formal rule could be broken if desired, but only at the expense of efficient communication of meaning in that language. Utility and efficiency would be compromised due to loss of communication. But no law of motion would be violated if we changed our arbitrary linguistic convention (rule). The letters on this page are physical. But their sequencing and function are formal, not physical. They function as physical symbol vehicles in a formally generated material symbol system [62, pg. 262].

Traversing the Cybernetic Cut is governed by arbitrarily written rules, not by inescapable physicodynamic laws. The word "arbitrary" is often confused with "random." In a cybernetic context, arbitrary refers to choice contingency in the sense that no selection is constrained by cause-and-effect determinism. Neither is it forced by external formal controls. The choice at any decision node is uncoerced by necessity. But it is not just contingent (could occur in multiple ways despite the orderliness described by the laws of physics). Any of the switch options, or any member of a finite alphabet, can be deliberately selected. The chooser has complete freedom of choice with intent without constraint. The weighted means of Shannon uncertainty cannot explain the deliberate choice required for semiosis, for example. The door is opened to formalism because the mind is free to choose any physical option with purpose.

No such freedom exists in any law-determined system. *Laws constrain; they do not control.* To control is to steer. Where there is no freedom of choice, steering is not possible. Laws describe an orderliness that forces outcomes. This is the very reason we are able to predict outcomes in physics. *Laws produce order, not organization.* Organization is formal and choice-based. Little flexibility other than heat agitation and the complexity of interacting causes exist to produce chance contingency in inanimate nature. But such contingency never generates choice with intent, formal computational success, engineering prowess, or true organization. *The laws and constraints of inanimate nature operate without regard to pragmatic goals* [57, 63-65]. To look to laws (especially to "yet-to-be discovered" imagined laws) as an explanation for the derivation of formal controls of physicality is not only empirically unfounded, it is logically fallacious (a category error). No law can produce algorithmic organization. Table 2 shows the difference between inanimate physicality and those aspects of reality that traverse the Cybernetic Cut into the sphere of functional and pragmatic controls.

No laws of physics are violated in the programming of configurable switches. Yet the effects of the particular functional settings of these configurable switches cannot be reduced to laws and constraints. Their functionality stems directly from their formally chosen settings. This constitutes the only known mechanism of bona fide controls. Configurable switches are the key to escaping the bounds of low-informational (highly constrained and ordered) physicodynamics to soar into unlimited formal creativity. Programmatically set configurable switches are also the key to exceeding the relative pragmatic uselessness of chance contingency.

5. EVIDENCE THAT THE CYBERNETIC CUT HAS BEEN TRAVERSED

As with the "laws" of physics and other axiomatic principles of science, epistemological certainty that the Cybernetic Cut has been bridged may not always be attainable. But the total of human experience leaves us with no rational justification for attributing formal nontrivial computation and algorithmic optimization to inanimate physicodynamics. The purposeful setting of a single physical configurable switch constitutes traversing the Cybernetic Cut by definition. This is not only the point of contact between formalism and physicality; it is the point of *governance* of physicality by formalism. Empirical evidence of nontrivial formal causation usually requires multiple cooperative switch-settings, as in integrated circuits. If we know that we have deliberately set a single switch with a goal in mind, we have sufficient justification to consider the selection formal rather than physicodynamic. But in most cases, we may be limited to highly plausible belief in past-tense formal causation. Plausibility is established in the absence of any known natural force causation of formal function. Such a force regularity (especially an imagined yet-to-be-discovered law) would tend to *set all* configurable switches the same way. The combinatorial uncertainty so necessary in any physical matrix for information retention would be precluded. Monod's necessity cannot generate highly informational physical matrices.

Plausibility of belief that the Cybernetic Cut has been crossed also exists when the probability bounds of chance contingency are exceeded. Statistical prohibitiveness cannot be rationally ignored. Probability bounds are generally linked to the number of elementary particles thought to be in the cosmos, and to the number of nanoseconds since the Big Bang. We cannot say with absolute certainty that the number of elementary particles does not change with time. But our best information thus far is that mass/energy is neither created nor destroyed. Phase space tends to be linked to our best estimates of the number of elementary particles in the cosmos. In addition, we can no longer appeal to infinite cosmic time for unlimited trials. Multiverse notions are utterly metaphysical rather than scientific. Thus when the probability of spontaneous self-organization approaches statistically prohibitiveness, we have justifiable Bayesian "plausibility of belief" in assuming that the Cybernetic Cut has been traversed. Those unhappy with such limits to epistemological certainty need to be reminded of the nature of the human condition. Neither reasoning nor empiricism provides absolute knowledge of anything. All reasoning begins with unproven presuppositions. Empiricism is always finite and potentially incomplete. The Big Bang and the "laws" of physics are every bit as unprovable technically as the Cybernetic Cut. The exact same criteria that go into accepting a certain equation as a physical law equally affirm the Cybernetic Cut. Both constitute "best thus far" tentative knowledge and generalizations of either a presumed objective reality, or a consistent solipsistic experience.

6. LIFE TRAVERSE'S THE CYBERNETIC CUT

Base-pairing of existing positive nucleotide single strands to form double strands is a purely physicodynamic phenomenon. Base pairing is mediated by simple hydrogen bonds which themselves are not directly related to informational syntax. Montmorillonite adsorption of ribonucleotides and other forms of templating in primordial models of life-origin are also purely physicodynamic. What physicalism cannot explain, however, is how each template or original positive strand acquired its own prescriptive informational *sequencing*. Physicodynamics such as base-pairing appears to play no role in the determination of which particular monomer is added next to a positive single-stranded instructional biopolymer. Neither the individual nucleotide selections in these positive single strands nor optimization of life's literal genetic algorithms proceeds according to laws. Life provides the very basis for the notion of artificial genetic algorithms [66-68]. Sequencing (primary structure) instructs the folding of both structural proteins and regulatory ncRNA shapes. Life uses these strings of dynamically-inert configurable switch-settings to record formal programming selections. Nothing is more highly informational than life. Even epigenetic regulatory proteins and ncRNAs are genetically prescribed by a vast syntax of sequential nucleotide selections. Such programming is not an effect of physical "necessity." Any law-based selection (e.g., clay surface adsorption) would produce only low-informational redundancy (e.g., a polyadenosine with near zero Shannon uncertainty [69]). For a high prescriptive information content to be instantiated into any physical matrix, high Shannon combinatorial uncertainty is required. This in turn requires freedom from law and necessity. Yet in the absence of physicochemical causation, equally nonfunctional "noise" would occur in the form of stochastic ensembles. Noise produces no more formal function than redundant low-informational laws. Genetic prescription requires uncoerced, arbitrary yet non-random selection of monomers.

The sequencing of initial non-templated positive strands is thus "dynamically incoherent" or "dynamically decoupled" [7, 21, 25]. Turing and von Neumann were inspired by, and modeled computer technology after, the dynamic inertness of genetic cybernetics [36, 70]. Each single-stranded nucleotide selection represents a new "dynamically inert" configurable switch-setting. Any of the four nucleotides is polymerized with relatively equal physicodynamic difficulty. Genes are sequences of specifically set decision-node logic gates. While many selections seem inconsequential, others are absolutely critical to achieving computational function. Each logic gate must be freely configurable. Nucleotide selection and sequencing cannot be determined by chance or necessity. Genetic instruction requires freedom to make efficacious biological programming selections at the genetic level. Open-ended evolution (OEE) [3-5] is impossible without such freedom of selection of physical symbol vehicles. Nucleotides are physical symbol vehicles in a material symbol system (MSS) [25, 26, 30, 31, 71]. The sequencing of these physical symbol vehicles is critical to how the DNA positive strand instructs protein translation. Functional Sequence Complexity (FSC) [44, 49] rather than Ordered Sequence Complexity (OSC) or Random Sequence Complexity (RSC) is instantiated into the physical linear digital matrices known as genes. This instantiation of prescriptive information into physicality makes genetic control possible. Genes are linear, digital, resortable, strings of these physical symbol vehicles [72-75]. The nucleic acid of living organisms contains extraordinarily sophisticated linear digital programming. Particular monomeric sequencing is crucial to life. More than any other characteristic, computational linear digital algorithms distinguish life from non life [73] [76]. Says Yockey,

"The existence of a genome and the genetic code divides living organisms from non-living matter. In living matter chemical reactions are directed by sequences of nucleotides in mRNA. . . . There is nothing in the physico-chemical world that remotely resembles reactions being determined by a sequence and codes between sequences." [74, pg. 54]

Küppers [77, pg 166] makes the same point as Jacques Monod [57], Ernst Mayr [54, 55], and Hubert Yockey [72, 78], that physics and chemistry do not explain life. Niels Bohr argued that "Life is consistent with, but undecidable from physics and chemistry"[63]. What exactly is the missing ingredient that renders life unique from inanimate physics and chemistry? The answer lies in the fact that *life, unlike inanimacy, crosses the Cybernetic Cut.*

These specific switch-settings also determine how RNA strands fold back onto themselves, forming helices, bulges, loops, junctions, coaxial stacking, etc. [79, pg. 682-683]. Not even the hypothesized pre-RNA World and RNA World escape the formal linear digital algorithmic governance of computational function. The generic chemical properties alone of nucleic acid and protein are insufficient to generate life.

In molecular biology, "The 'meaning' (significance) of prescriptive information is the function that information instructs or produces at its metabolic destination" [44]. Szostak has used the term "functional information" [80]. Prescriptive information includes instruction and algorithmic/computational programming, not just description. Genes provide instructions and algorithmic prescription of computational function. The oft used term "complexity" in life-origin literature is grossly inadequate to define the nature of genetic control [44-46, 49, 81]. As Hoffmeyer and Emmeche point out [82, pg. 39], "Biological information is not a substance." Later they repeat, "But biological information is not identical to genes or to DNA (any more than the words on this page are identical to the printers ink visible to the eye of the reader). Information, whether biological or cultural, is not a part of the world of substance." [82, pg. 40]. As stated earlier, the formal, nonphysical, prescriptive selections instantiated into configurable switch settings (nucleotide selections in this case) must never be confused with the physicality of those configurable switches themselves.

Most information theorists are trained to define information from the perspective of an observer. The problem with this perspective is that in the absence of an observer, no information can exist. Yet clearly information was at work in the organization of early life. No observers existed >3.5 billion years ago [83]. Real prescriptive information, therefore, has to have predated animal observation. Certain types of prescriptive information must *objectively* exist. Early prokaryotic genetic programming cannot be reduced to the subjective mental constructs or observation of any animal knower/observer [45]. *A purely epistemological definition of prescriptive information is grossly inadequate.*

The maximum length of oligoribonucleotides in aqueous solution is only 8-10 mers [84]. The genetic programming of longer strands is certainly not "blind." Stochastic ensembles of single-stranded small RNAs or of polyamino acids do not fold into functional shapes. Yet both single nucleotide and dipeptide overall frequencies are close to random in living organisms [85, 86]. Biomessages are unique in nature in that they are formally and functionally sequenced. They are not randomly sequenced, and they are not ordered by physical laws. They are sequenced so as to encrypt programmed instructions for the undeniable goal of achieving homeostatic metabolism. The realization of this goal requires transcriptional editing, decryption (translation), folding, and sometimes even post translational editing [87]. These processes are fundamentally formal, as formal as the mathematical "laws" of physics. The genome and its editing processes not only prescribe, but directly and indirectly compute the end product.

In a Peptide or Protein World model of life origin, efficacious selection of each amino acid must be explained at the level of covalent peptide bond formation. Polyamino acid primary structure (sequence) is formed prior to folding. Primary structure is the main determinant of how the strand will fold. Thus functional shapes must be prescribed by linear digital semiosis. The covalent bonds of these highly informational strings are "written in stone" prior to when weak hydrogen-bond folding secondarily occurs. Instructive sequencing must be completed before tertiary shape and function ever occur. The GS Principle, or Genetic Selection Principle, obtains. This principle [44, 45] states that selection must operate at the genetic level, not just at the phenotypic level, to explain the origin of genetic prescription of structural and regulatory biological function. This is the level of configurable switch-settings (nucleotide selection). Selection must first occur at each decision node in the syntactical string. Initial programming function cannot be achieved by chance plus after-the-fact selection of the already-existing fittest programs (phenotypes). Evolution is nothing more than differential survival and reproduction of already-existing fittest phenotypes. *The computational programming proficiency* that produced each and every phenotype must first be explained. Programming takes place at the genetic level. Even epigenetic prescription, development, and regulation ultimately trace back to the genetic programming of those ncRNAs and regulatory proteins. Thus far, no natural-process explanation has been published for selection at the decision-node, configurable-switch, nucleotide-selection level.

Even the translated polyamino acid language is physically nonfunctional while forming until after it dynamically folds according to the instructions contained within its linear digital programming (its primary structure). Only later does this syntax of covalently (rigidly) bound monomeric sequencing determine minimum-Gibbs-free-energy folding. Even then, not even three-dimensional shape, or tertiary structure, is selectable by the environment. A far more holistic context of differential organismic survival and reproduction are required for natural selection to kick in.

In molecular biology recipe code is translated from nucleotide sequence language into a completely different conceptual amino acid language *via* code bijection. Bijection is a correspondence of representational meaning between arbitrary alphanumeric symbols in different symbol systems. Each triplet codon is a Hamming "block code" for a single letter (amino acid) of a long protein word [72]. A prescriptive codon prescribes a certain amino acid letter at the receiver upon decoding. It is often argued that the symbol system and code bijection (translation) of molecular biology are only heuristic. Yet the correspondence between the codon-block-code sequencing and amino-acid sequencing is clearly both real and non physicalistic. Nucleotide sequencing is physicodynamically arbitrary and resortable. Bijection is formal, not physicodynamic. No binding or physicochemical reaction occurs between nucleotide symbols and the amino acid symbols they represent. Anticodon and amino acid are on opposite ends of each tRNA. Amino acyl synthetases are also independent enzyme molecules that have no direct binding affinity to codons. Neither fixed laws nor chance contingency can explain the integration of 20 different kinds of each formally linked entity: amino acyl synthetase, the specific amino-acid end of each tRNA molecule, the specific anticodon opposite end of each tRNA, and the Hamming "block code" of each triplet codon. The number of permutations is staggering. The spontaneous integration of all these individual entities into a formal association capable of promoting even a protometabolism is statistically prohibitive.

7. CONCLUSIONS

The Cybernetic Cut is a fundamental divide of reality. The law-like orderliness of nature along with the seeming chance contingency of heat agitation and statistical quantum reality lie on one side of the divide. Choice contingency lies on the other. Choice contingency is the ability to choose with intent what aspects of being will be preferred, pursued, selected, rearranged, integrated, organized, preserved, and used. Chance and necessity cannot generate choice contingency. The Cybernetic Cut can only be traversed through nonphysical, formal, purposeful, decision-node choice-commitments. Such choices are instantiated into physicality using dynamically-inert configurable switch-settings. Most of what is really interesting in presumed objective reality requires traversing the Cybernetic Cut, not just the epistemic cut of Pattee, to generate and/or explain.

Physicodynamics possesses no ability to choose with intent at decision nodes, to assign meaning to symbols, to ascribe value to functionality, or to pursue utility. Infodynamics (trying to reduce information solely to physicality) provides no mechanism for the spontaneous generation of prescriptive information, including genetic instructions required for metabolic organization and life. Algorithmic optimization requires traversing the Cybernetic Cut. Physicalism provides no plausible explanation for, and no empirical evidence of, unaided self-organization [46] despite use of the term in hundreds of published papers. Chaos theory explains physicodynamic self-ordering phenomena, not formal algorithmic self-organization.

Even inanimate physical relationships require formal mathematical descriptions. As Pattee has pointed out many times, the laws of physics are worthless without inserting *formal representations* of initial conditions into the equations in the form of measurements. To represent initial conditions with measurements not only crosses the epistemic cut, it crosses The Cybernetic Cut. The use of any symbol system requires crossing The Cybernetic Cut because symbols must be deliberately chosen from an alphabet of arbitrary symbols. No materialistic model has been offered in the literature to explain this kind of choice contingency in physics. The problem of formalism's role in physical reality is larger than just a biological one.

The necessity of traversing the Cybernetic Cut in order to instantiate functional controls over physicality is a fully falsifiable principle. The observation of a single case of nontrivial spontaneous computation independent of agent steering would suffice. Illegitimate investigator involvement in experimental design is usually found in computer programming of experimental models or in experimenter choices of which iteration to pursue. Artificial selection, not natural selection, makes such so-called "evolutionary algorithms" possible. Purposeful choices are needed to achieve sophisticated formal utility. The chance and/or necessity of physicodynamics alone have never been observed to generate a nontrivial formal control system. Falsification experiments would have to be free of hidden artificial selection. Iterations cannot be steered by experimenters as we see in SELEX experiments of ribozyme engineering [88-90]. So-called "evolutionary algorithms" are invariably examples of "directed evolution." Both of these last two terms are self-contradictory nonsense terms. If a process is directed, it is not evolutionary. If the process is evolutionary, it is not directed. Algorithmic optimization is invariably steered toward the goal of ideal utility by programmer choices. Evolution has no such goal [56]. Traversing the Cybernetic Cut is the necessary and sufficient condition for generating any formal control system's governance of mass/energy interactions.

Principles of science must not only be falsifiable, they must provide an historical metanarrative and explanation across a wide range of phenomena. In addition, they should foster verifiable predictions in unrelated fields. What scientific predictions does the Cybernetic Cut afford?

1) No nontrivial computational function will ever spontaneously arise in any inanimate physicodynamic medium or environment independent of formal intervention and controls.

2) No sophisticated algorithmic optimization will spontaneously proceed in any inanimate environment upon removal of hidden experimenter choices and steering of iterations.

3) No nontrivial functional controls of inanimate physical phenomena will be realized independent of the programming of dynamically-inert (dynamically-incoherent) configurable switches that alone instantiate formal agent choices into physical reality.

A single verifiable occurrence of any of these three null-hypothesis predictions will falsify the Cybernetic Cut.

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ABBREVIATIONS

RSC	=	Random Sequence Complexity
OSC	=	Ordered Sequence Complexity
FSC	=	Functional Sequence Complexity
PI	=	Prescriptive Information
The F®P Principle	=	Formalism precedes, prescribes and governs Physicality
The GS Principle	=	The Genetic Selection Principle—Selection must occur at the decision-node level of rigid covalent bond linkage of specific monomers (syntax), not just after-the-fact selection of already-computed phenotypic fitness.

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