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6. Linear Digital Material Symbol Systems (MSS)*

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Abstract. Nonphysical, formal, linear digital symbol systems can be instantiated into physicality using physical symbol vehicles (tokens) in Material Symbol Systems (MSS). Genetics and genomics employ a MSS, not a two-dimensional pictorial "blueprint." Highly functional molecular biological MSS's existed prior to human consciousness in tens of millions of species. Genetic code is conceptually ideal. Not all signals are messages. Encoding employs a conversionary algorithm to represent choices using a symbol system. Encoding/decoding is formal, not physicodynamic. Symbols must be purposefully chosen from alphabets of symbols to generate meaning, instructions, and control. Formal rules must first be generated, and then both sender and receiver must voluntarily adhere to those arbitrary rules. Neither law nor random variation of duplications can generate a meaningful/functional MSS. All known life is cybernetic (controlled, not just constrained) and semiotic (message dependent). Even protocells would require controls, biosemiosis, regulation, and an extraordinary degree of organization that mere mass/energy interactions, or chance and necessity, cannot produce.

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Introduction: Linear digital sign/symbol/token systems

Linear refers to a uni-dimensional, sequential string of representational command characters. The simplest computer programming, for example, is directed by such a linear digital string of purposeful binary choice commands represented by either a "1" or a "0." The sequencing or syntax of these choice-contingent commands provides a growing hierarchy of computational functionality.

Of course, computer programming is about creating semantic constructs that can be translated/compiled to run on a given computational system. The system could just as easily be quaternary rather than binary, as is the case with DNA base 4 prescription of biofunction.

Digital means each unit is discrete and definite. Programming choices have an "excluded middle." Switches must be turned either on or off. There is no in-between. A definiteness and clarity exists with each chosen command. No gray zone exists. Each selection is black or white.

As explained in Chapter 4, section 8, a bona fide "system" is an abstract, conceptual organization generated by choice contingency, not chance or necessity, that typically generates formal processes or procedures with pragmatic results. A "weather system" is not a true system. It is merely a physicodynamic interface of wind, temperature and atmospheric pressure differential. A weather front may involve phase changes and manifest self-ordering; but it is not organized. It manifests no choice contingency, no purposes or goals, no accomplishment of function or utility. Weather fronts have no formal components, no computational achievements, and no algorithmic optimization, no intended purpose given materialistic presuppositions.

The term MSS for Material Symbol Systems was first used by Rocha in his Ph.D. thesis [10, 11]. Recorded signs, symbols and tokens outside of human minds are representational physical entities called "physical symbol vehicles." Any system of communication using these physical symbol vehicles is a material symbol system. But how can a physical symbol vehicle, or group of such physical symbol vehicles in a MSS, *represent* instructions in a purely materialistic world? The Mind-Body problem is closely related to the symbol-matter problem. The symbol-matter problem is known in philosophy as the "problem of reference." How do symbols form to "stand for" or represent material structures? [12-14, 15, pg. 11, 16]

These problems are, in turn, closely related to the measurement problem not only in quantum physics, but in Newtonian physics as well. As physicist Howard Pattee has pointed out in many publications, the measurements of ini-

tial conditions used in the laws of physics are formal representations (mathematical symbols) of physicality, not physicality itself [15].

The first problem encountered by semiotics in a MSS is the *nature* of symbols themselves. Charles Sanders Peirce proposed the triadic interpretation of signs. Meaning is created mentally through consideration of recursive relationships [17]. Peirce's interpretation of signs and semiotics involving representamen, object and interpretant is inseparable from human cognition and agency. Representations are necessarily abstract, conceptual and formal. Peirce's triadic relation work incorporates abundant human psychological and epistemological components. Under no circumstances are such representations "natural" (purely physicodynamic). Representations are never physical. Representations can be arbitrarily assigned to physical tokens in a MSS. But the representations assigned to those physical tokens are always agent-chosen according to formal rules, not physical laws.

No justification exists for trying to circumvent the fact of "volition" using Peirce's category of thirdness (mere "habit formation") [18]. Habits are nothing more than redundant patterns of volitional social behavior. If a pattern does not originate out of true behavior—volitional tendencies—then that pattern is simply reflective of physicodynamic necessity. Such cause-and-effect determinism is ordered by the regularities of nature described by physical law as further refined by statistical distribution curves. Patterns caused by physicodynamic necessity have no formal prescriptive significance and produce no sophisticated utility.

Semiotic and cybernetic functions both employ formal symbolization according to previously agreed-upon, arbitrary rules (not physical laws) in order to convey meaning. Neither cybernetics nor semiosis can be reduced to the mere physicality of its switches or physical symbol vehicles. The uncoerced choice contingency that selects those symbols or that sets those configurable switches is the key.

To ascribe semantic value to physical entities requires both *contingency* and *volition*. Neither necessity (forced, law-like, cause-and-effect determinism) nor chance contingency can generate meaning. Choice contingency is required [1, 4, 6]. Semantics entails "aboutness." Aboutness and meaning are absent from the category of inanimate physicodynamic interactions.

Rosen [19] regarded sign systems as "anticipatory." He argued that conventional physicodynamic theory cannot possibly model a sign system's descriptive behavior. But the problem extends far beyond having to explain the phenomenon of description. Far more important is the function of symbol systems to *prescribe*—to indicate *determinative choices and controls* that will be efficacious in producing utility *in the future* [6]. Undirected natural selec-

tion cannot *select for* not-yet-existent function (The GS Principle [5, 20]). Sophisticated utility only comes into existence via integrated pre-programmed decision nodes, logic gates, and configurable switch-settings. Choice contingency's unique ability to generate pragmatic controls alone accomplishes this.

1. What's the difference between signs, symbols and tokens?

Attempts have been made within the semiotic community to clarify the difference between signs and symbols, the most specific and recent being [21]. In this author's opinion, the latter paper only confuses the distinction rather than clarifying it.

A *sign* is typically a two-dimensional picture or drawing conveying representational meaning to one's senses. The picture or drawing is self-explanatory because we recognize by sight what is being depicted from our every-day empirical world. A visual image of real world objects is delivered by the sign. Our consciousness links the two-dimensional picture with our experience of and with that object. See Figure 1.

A *symbol*, on the other hand, is an arbitrarily-shaped/generated character representing some assigned meaning by definition. A symbol, unlike a sign, conjures no meaning from one's sight memory of physical objects. The letters of most language alphabets are not signs, but symbols. Strings of such symbol characters spell words leading to lexicons of words. Hierarchies of phrases, clauses, sentences, and paragraphs can be constructed from the lexicon of words according to syntactical rules. Sometimes only one letter symbol, such as "H" or "C" on a faucet handle, conveys meaning.

Mathematical symbols such as π, Ω, ξ, Δ, $=$, and $\neq$ are symbols, not signs. We cannot ascertain the meaning of these symbols from the symbol itself, except that we sometimes become so familiar with a certain symbol that it begins to take on a function similar to a picture or drawing, thereby having a sign-effect from our sight memory (e.g., the symbol " = " begins to be recognized visually as the a sign of equality). Such symbols are not pictures or drawings of real-world physical objects that we have previously observed. The meaning of these arbitrary "strokes of pen" is just assigned and agreed to by source and recipient. Otherwise, the message will not have meaning or function at its destination.

Figure 1. An example of a common *sign* (drawing of a cigarette) with overlaid *symbol* (an abstract representation of "No!") conveying the composite meaning of "No smoking**."**

In Figure 1, the drawing of the cigarette is a sign. The universally understood slash through a picture is, by convention, a symbol representing "No!" to whatever is being pictured by the sign beneath the symbol. The cigarette is a physical object. The symbol meaning "No" does not depict a physical object, but a formal abstract concept of prohibition.

Semaphore is technically a symbol system, not a sign system. Each flag position abstractly represents a letter of the alphabet, although our minds quickly begin associating each flag position symbol with a mental picture of the letter represented. The abstract symbols thus begin to function as iconic signs in our minds.

No signs exist within cells. Molecular biology does not create pictures, drawings, or blueprints. But interestingly enough, representational symbols *do* exist within cells. As we shall see below, physical symbol vehicles and material symbol systems are undeniably employed by living cells. Representationalism is a formal function, not a physicodynamic interaction. This fact goes a long way toward addressing the age-old question of whether life can be reduced to inanimate physicality. Mass/energy interactions cannot generate conceptual representationalism. But, in molecular biology, we seem to be talking about *material* symbol systems. Aren't they obviously physical? The answer is "NO!" MSS's *use* physical symbol vehicles, to be sure. But their representational and symbolic function is purely formal. The triplet codon table of molecular biology is purely formal. To understand this reality we

must proceed from a discussion of signs and symbols to a discussion of "tokens."

We must clearly distinguish between *symbols* and *physical symbol vehicles (tokens)*. Physical symbol *vehicles* are physical. Symbols are not. Symbols are *conceptual representations of meaning*. The symbol π represents a formal mathematical idea in our minds when referenced in the domain of geometry, for example. We can instantiate this abstract symbol with its meaning into a physical symbol vehicle through handwriting π onto paper with physical ink, converting the mental idea into physical sound waves in conversation, typing it onto paper or into a word processor physical system. But the recordation and transmission of physical symbol vehicles does not change the fact that the symbols being represented are abstract ideas with arbitrarily assigned meaning. No physicodynamic constraints or causation can explain cognitive representationalism and symbolization.

Cybernetic function requires deliberate selection. First, the actual uncoerced and nonrandom selection must be made. Then, that choice must be formally represented using a mentally-derived symbol. Finally, that cognitive symbol can be instantiated into physicality by selecting a certain physical symbol vehicle (token) in a MSS. Alternatively, choice contingency can be instantiated into the setting of a physical configurable switch to achieve formal pragmatism. We can also choose how to arrange physical parts into a holistic functional device (e.g., a machine). A machine may be physical, but the organization of its physical parts to achieve nontrivial functional capacity is purely formal.

A *token* is merely the physical vehicle *of* a sign or symbol. A Scrabble piece is a token. It is a physical block of wood with a symbol drawn onto or etched into its surface. Such "physical symbol vehicles" are used in MSSs [10, 11] to spell meaningful words of a language, depict computations, or (in the case of sign tokens) to portray larger composite pictures (e.g., holograms). It is all-too-easy for us to forget that the meaning of a string or cluster of tokens has absolutely nothing to do with the physicality of those tokens. The physical tokens are just instantiations of formal arbitrary choices. Each token must be purposefully selected from a phase space—a pool of physical objects, each with an abstract symbol recorded on it. Only then can a MSS be generated to convey formal meaning or achieve formal function at its destination.

Like meaning, functionality is a formal concept, not a physicodynamic interaction. The ability of a machine to perform useful work is formal, not physical. If we redefine work to mean nothing more than heat exchange between two objects, then maybe work can be purely physicodynamic. But that is not the kind of work that makes reality interesting. Usefulness—

pragmatism—is what matters. Such functionality is an abstract formal concept.

Messages are entirely formal, not physical, even though they can be instantiated into a MSS of physical symbol vehicles. Smoke signals can be used to send a message. But that does not mean that the message itself is physical. The same is true of formal programming using physical configurable-switch and logic-gate settings. Language, mathematical computation and programming all traverse The Cybernetic Cut across the one-way-only CS Bridge from the abstract conceptual world into physical manifestations of formal organization [4](see Chapter 3). Thus instantiation of message *meaning* into a physical matrix of retention and transmission is still fundamentally nonphysical.

2. Blueprints vs. linear digital prescription

A blueprint is a two-dimensional drawing (pictorial representation, similar to a sign) of a potential physical construction such as a building or other functional structure (e.g., a bridge, automobile or airplane). Blueprints and schematic diagrams consists of a composite of many signs. A blueprint has little or nothing to do with linear digital symbol systems. The latter consist of a string of symbols, not signs, that conveys meaning and function according to arbitrarily agreed-upon rules (not physicodynamic laws).

It is grossly inaccurate to refer to genetics as a "genetic blueprint." Genetic prescription is non-pictorial. Although genomics is ultimately multidimensional to extraordinary degrees, it is first and foremost a unidimensional linear digital symbol system, not a two-dimensional drawing. All of the other dimensions of genomic Prescriptive Information (PI) follow in secondary, tertiary and quaternary layers of conceptual complexity that emerge from the initial primary structure (sequencing) of monomers (tokens) in a string. All 3'5' phosphodiester bonds between nucleotide monomeric tokens in nucleic acid molecules are the same. All peptide bonds between amino acid monomeric tokens in proteins are the same. The particular selections and sequencing of nucleotides in coding regions, and of the resulting amino acids, are physicodynamically inert or indeterminate—undetermined by physics and chemistry. The opportunity to arbitrarily select each coding nucleotide token to be polymerized next to an existing positive strand provides programming freedom to "spell" meaningful messages, program, compute and prescribe eventual specific three-dimensional molecular machines and catalysts.

3. Signals vs. messages?

Messages could be viewed as a special subset of signals. From this perspective, all messages would be considered signals. But not all signals are messages.

A message is a meaningful transmission intended to relay Functional Information (FI) from a source to a receiver and destination. Often the FI provided by a message provides specific Prescriptive Information (PI) rather than just Descriptive Information (DI). An example of a PI message would be the sending and receipt of instructions for how to accomplish some multi-step task. The successful receipt and utilization of the message requires prior agreement between source and recipient as to what arbitrary "language" (symbol system) will be used. Both parties must use the same symbols, syntactical and grammatical rules in order for the meaning and prescription to be efficacious.

A signal can be nothing more than a string of inanimately generated regular pulses. But such a string of impulses would contain near zero meaning or function. A pulsar sends out a signal. That signal contains almost no Shannon uncertainty. Such redundant, constant-frequency, high-probability, low-bit-content pulses contain almost no potential for information instantiation and transmission. The entire signal can be reduced to an exceedingly-short compression algorithm (e.g., "Emit one electromagnetic pulse of near equal energy per nanosecond, repeat x times." Virtually no meaningful message could be instantiated into such a physicodynamically militated ("necessary") and "certain" physical "matrix" (photon stream). A pulsar signal is much too highly ordered to have significant FI instantiated into it.

To send a message requires freedom from physicodynamic determinacy. Uncertainty in the physical matrix is required for instantiation of language and programming controls. Necessity theoretically eliminates uncertainty. The sender of any message must have the ability to exercise choice determinism at each decision node. Symbols and physical tokens must be freely selectable from among multiple options. The sender must have full control over these *arbitrary* selections. By arbitrary we do not mean random. We simply mean "freedom from fixed law-like determinism and the ability to freely choose from among real options." The receiver must perceive the same freedom from forced order so as to attach any meaning to the symbol selections within the message.

In molecular biology, arbitrariness of selection is made possible by the fact that all monomeric bonds are the same despite varying monomers. A nagging problem for philosophic naturalism is that the physicodynamic inert-

ness that generates the needed combinatorial uncertainty for PI instantiation is the same physicodynamic inertness that makes any physicodynamic explanation for code-origin impossible. If the selection of each particular nucleoside in a single positive strand is not determined by physics and chemistry, how is any meaningful message spelled? We are not talking about base-pairing replication here. We are talking about the origin of initial message meaning in the single positive informational strand.

4. Proper use of the word "code"

For our purposes, the word "Code" is a representational symbol system used to assign associations (e.g. via a codon table), or to convey meaningful/functional messages (e.g., messenger molecules). In an everyday connotation, coding signs and symbols are usually substituted for letters or words. Most codes (e.g., ASCII, Zip code) are "open," (non-encrypted) with arbitrary meaning to communicate between two otherwise independent worlds. The codon/amino acid code is the most widely known code in life, but more than 20 other semiotic codes have been discovered in the past decade, each with no known physicochemical "cause." [22-25].

A peer reviewer questioned whether the "code" produced by a digital voice encoder (vocoder) would fit the above definition. Since numbers can be used as symbols, and measurements and calculations can also be used as formal representations of physicality, the answer is yes. For, a vocoder comprises a built-in mathematical (formal) model of voice (physical sound waves), which includes parameters which vary instantaneously with the voice. These instantaneous parametric values are sampled at some regular interval and the values thus obtained are what actually get encoded and transmitted, thus allowing reconstitution of the voice at the receiving end. In this case, the encoded message is a formal representation of physicality using numerical symbols, measurements, calculations, and a set of formal governing rules, not fixed physicodynamic laws.

The word "code" can also be used to describe a conversionary algorithm that translates one symbol system into another. In this context, a code is a set of rules that governs bijection (substitution or mapping) of one symbol for another between two different symbol systems. Sometimes we can have a two-to-one or a three-to-one bijection (e.g., triplet codons) where multiple symbols in one symbol system prescribe only one symbol in another symbol system. This reduces the likelihood of noise pollution and error in translation. But any translative coding requires knowing and following formal algorithmic rules that relate one arbitrary symbol system to the other. Meaning and function in

the message are retained despite a complete change of language symbols and rules.

In molecular biology, genetic code is specifically used for:

- instantiation of formal, immaterial programming choices into physicality
- efficiency in translation between two different material symbol systems where molecules serve as "physical symbol vehicles" (tokens) in two different material symbol system (MSS) rather than being mere physicochemical interactants/reactants
- ease-of-transmission
- noise pollution prevention in the Shannon channel (e.g., redundancy block coding)
- proof reading and error correction (e.g. the processing of parity bit coding to detect noise pollution)

Shannon's channel capacity theorem precludes a one-to-two or a one-to-three bijection [25-27]. This mathematical fact of reality immediately falsifies any code-origin theory suggesting the slow growth from simpler bijection rules into the current translative system summarized by the codon table [25-27]. Insufficient PI, and even insufficient Shannon uncertainty, is contained in the simpler 1:1 coding system to be able to map to a 1:2 or 1:3 system. In one sense, the sequence of nucleotides in a ribozyme is not itself a code. It is just a linear digital string of ribonucleotide tokens. That string could be random (a stochastic ensemble). But no nontrivial protometabolism, let alone metabolism, has ever been observed to arise from stochastic ensembles.

The word "code" is often used in molecular biology to refer to a specifically selected syntax of many monomeric tokens (nucleosides). A particular functional sequence, all with the required right-handed sugars and correct 3'5' phosphodiester bonds, can successfully prescribe the secondary and tertiary structure of a functionally-folded ribozyme. But, for a stochastic ensemble to produce a single ribozyme is statistically prohibitive without behind the scenes experimenter steering of supposedly-random Markov chains (drunken walks). Ribonucleotides are too difficult to make and activate even with extensive investigator involvement. They are also very unstable. Even the best human-engineered ribozymes have very limited function. Thousands of ribozymes might be needed to substitute for a few dozen protein molecules. Even then the sophistication of function is far less than what proteins catalysts accomplish. The simplest bacteria normally code for two to three thousand proteins. The requirements for any protocell consisting only of ribozymes to spontaneously organize and come to life yields a calculable Universal Plausi-

bility Metric that far exceeds what is allowed by the Universal Plausibility Principle [28]. The latter Principle definitely falsifies any such spontaneous generation-based hypothetical scenario.

But in the sequencing of monomers required for functional ribozymal folding we discover an initial inherent coding feature. Linear digital representational sequencing is "translated" in a very unique way into functional secondary and tertiary physical folding. Thermodynamic tendencies are "used" by this inherent "code" to instruct three-dimensional function. New added dimensions of PI arise from the original primary structure (the linear digital sequence of ribonucleotide tokens). In that sense, the sequencing of ribonucleotides in RNA achieves a unique coding and translative status. The linear digital Prescriptive Information (PI) found in ribonucleotide sequencing makes use of the yet-to-be-realized physicodynamic properties of minimum Gibbs-free energy sinks to instruct the manufacture of the sophisticated molecular machines known as ribozymes and ribosomes (RNA-protein complexes). Highly integrated biological factories contribute to ever more hierarchically organized holistic metabolism.

In the case of DNA, when we introduce the reality of a constant grouping of three nucleotides to represent each amino acid prescription, we have introduced a noise-pollution-reducing Hamming redundancy "block code." The codon "table" is a translative map (a three-to-one bijection) used by the ribosome/tRNA/tRNA-aminoacyl synthetase translative system. The algorithmic processing performed by this system links the nucleotide linear digital prescription of meaning and function to another polyamino acid "language." This is a true "encoding" function where mRNA fragments (triplet codon syntax) through ribosomes cause a "request" of each tRNA molecule through the use of elongation factor protein sets. Human mentation did not devise this noise-reducing translative system. We merely discovered it. It cannot be reduced to human consciousness or epistemology. It prescribed not only us, but every other species before we arrived on the scene to investigate the reality of this coded prescription, bijection of codon to amino acid, and decoding of the formal genomic PI into potential physical metabolic achievements.

In both cases, RNA and DNA, Prescriptive Information (PI) is provided initially as a linear digital string of symbols each selected from an alphabet of symbols (four nucleotide options). The syntax of these symbols represents higher levels of meaning and function through inherent code and translation. The nucleotide (token) sequence must be selected in advance with rigid covalent bonds prior to translation into functional three-dimensional structures. It is incumbent upon materialists, physicalists, and naturalists to explain how chance and/or necessity could possibly have made these *functional selections*

at the molecular/genetic level prior to the existence of any physical folding and phenotypic (organismal) fitness (The GS Principle [5, 20]). Phenotypic fitness is essential for any Darwinian progress to occur. Until such explanation is provided, philosophic naturalism finds itself in the very compromising position of being nothing more than unsubstantiated metaphysical dogma. Justification for its incorporation into the very definition of the science should be called into question. Chance and necessity cannot program (cannot traverse The Cybernetic Cut (Chapter 3) or decode nucleic acid programs into the alternate "language" of polyamino acid [protein] sequencing). See The GS Principle in Chapter 7 to understand why natural selection cannot possibly explain the linear digital PI of genetic/genomic/epigenomic programming and instruction.

No biopolymer could possibly function as a reliable "messenger molecule" without selection of functional base sequences that only later contribute to integrated formal function. Stochastic ensembles do not prescribe contributions to holistic metabolism. Random strings contain zero PI.

In the case of a game of Scrabble, even if stochastic ensembles of Scrabble tokens happenstantially *appear* to spell meaningful words, it would only be our minds ascribing meaningful sequence by association. The stochastic ensemble would still be a random string despite the *appearance* of a meaningful message. In addition, a formal decoding system would still have to be in place to interpret and translate the apparent functional string. Otherwise, that happenstantial string *resembling* PI would be unintelligible at the receiver and destination. The recipient would have to know and exercise the rules and algorithms of that language convention to derive any function from nucleotide sequencing. In short, the appearance of meaning in a random string does not provide meaning or function.

5. Semiotics vs. Cybernetics

Symbol systems allow representation, recordation and transmission of formal choices [29-34]. Symbols represent specific selections from among real options. These selections then become determinative of language and message meaning, of programming function and of computational success. All of these functions can be transmitted as instructions containing PI [6]. Choices of signs/symbols/tokens are always fundamentally cybernetic (controlling), even when only Descriptive Information (DI) is sent. Symbol selection is not made randomly or physicochemically [35]. Symbol selection, if it is to have sophisticated utility at the message's destination, must be made freely and deliberately by the source [2, 36].

Selection of the symbol "1" or "0" represents the simplest binary control decision. Each such purposeful choice is the fundamental unit of PI and instruction [6, 37]. If the "1" or the "0" is selected randomly, one bit of *potential control* is immediately lost. Or, if a single "1" or "0" is determined by prior cause-and-effect chains of physicodynamic necessity, one bit of potential control is also immediately lost. The ability to steer events through many decision nodes toward computational success quickly deteriorates and dies with each new denied binary control choice. When every "choice" is determined the same way by "necessity," the resulting "program" consists of all "1's" (OR all "0's"). Neither chance nor constraints can select the path with greatest function potential. Neither chance nor constraints can program or compute. Constraints exert their physicodynamic influence independent of formal pragmatic considerations. Controls, on the other hand, program pragmatic success at the foundational binary decision-node level of "Yes, No," "Open, Closed," "On, Off." Controls select each ideal configurable switch-setting prior to the realization of any function.

The biological scientific community often seems blind to the fact that selection *for potential* function is something that undirected natural selection cannot do [4-6, 37, 38]. Absolutely no selection pressure exists at the genetic/genomic programming level. The GS (Genetic Selection) Principle reigns at the level of nucleotide selection in forming positive informational strands of nucleic acid [5, 20].

To communicate a meaningful or functional message, first, we must arbitrarily assign an alphabet of usable symbols. Next, we must again arbitrarily assign meaning to letters or small groups of alphabetical characters, the equivalent of words. This is done according to arbitrarily defined rules, not constraints or laws. The rules are freely selectable, not constrained by physicodynamics. In short, symbol systems are entirely free, formal and cybernetic. Each choice of symbol represents a discrete unit of control.

The above cybernetic realities in no way deny, of course, that the execution of the running systems presupposes attention to the constraints of physicodynamics in order to function. Nothing about computer science, engineering or life entails the suspension of the laws of physics and chemistry. But the laws of physics and chemistry are grossly inadequate to explain the biocybernetics and biosemiosis that make life possible. Symbol systems, including MSS's, are fundamentally cybernetic [39-43], whether the information conveyed is descriptive or prescriptive, and whether or not the those formal decision-node choices are secondarily instantiated into physicality.

Cybernetic means steering and controlling. Signs/symbols/tokens must be purposefully chosen from a phase space or alphabet of tokens to generate

any bona fide message. Message generation, therefore, requires traversing the one-way-only CS Bridge from the formalism side of The Cybernetic Cut to the physicality side in order to instantiate formal function into the physical world [4]. Sophisticated processes like language communication/ interpretation, programming and computation must be steered toward functional goals and away from non-functional dead-ends.

All applications of Decision Theory and Systems Theory require steering and control. The creation and refinement of algorithmic processes requires more than mere inanimate physicodynamic constraints. At the very least, *particular constraints must be deliberately chosen* and others rejected to steer a cause-and-effect chain towards formal pragmatic worth [6].

Choice contingency is always formal rather than physicodynamic. The biosemiotic research community must come to terms with the simple reality that chance and/or necessity cannot choose, steer or control. Chance and/or necessity, therefore, *cannot generate meaningful/functional symbol selection.* Semiosis, including biosemiosis, is impossible without choice-with-intent at bona fide decision nodes. This one fact alone should falsify any purely physicalistic notion of spontaneous generation of life. All known life is cybernetic and biosemiotic. Metabolism is steered and regulated by programming choices and linguistic like instructions found in linear digital genetic Prescriptive Information.

6. Could life exist without controls and messaging (biosemiosis)?

Myriad messages are continuously sent between components within a living cell as well as between living cells. In the larger field of biosemiotics, endosemiosis refers to message sending within the same organism. Exosemiosis refers to messages sent between organisms. But in life-origin science we encounter a special circumstance that requires alternate usage of these terms. The first organisms being investigated were unicellular. In researching the derivation of embryonic messages within the first protocell, we use the term endosemiosis to refer to messages sent within that first primordial cell. Exosemiosis then refers to messages sent between unicellular organisms leading to perhaps the first filamentous or colonial type relationships between primitive cells (e.g., cyanobacteria).

Every aspect of metabolism with a single cell depends upon programmed instructions, the messaging of those instructions, and feed-back messaging about how well the initial messages were received and carried out. Messages deliver the PI that controls and regulates metabolism. PI determines the amount and time for small RNA and protein manufacture at the right site within the cell. Availability of each needed metabolite must be communicated

back to the system (feedback) to know when to start and stop production. Without this communication, cellular activity would not only quickly become chaotic, it would be incompatible with life. Spontaneous positive and negative feedback, however, must never be confused with formal controls. Feedback in non-cybernetic life is nothing more than circular constraint. More (positive) or less (negative) of the same can be constrained. But this constraint is never pragmatically adjustable apart from formal PI. It is merely forced physicodynamically without regard to function. Constraints in a prebiotic environment that is devoid of formal pursuits cannot generate feedback *controls*.

The only factor that allows metabolism to move "far from equilibrium" is organization, not inanimate constraints and redundant order. Crystals are highly ordered; crystals are not alive. Formal organization is the key to locally and temporarily circumventing the 2nd Law. But organization is impossible without programming, steering, and the transmission of controlling messages. Apart from organizational choices (e.g., Maxwell's demon choosing when to open and close the trap door), the 2nd Law rather than formal regulation would prevail within any theorized protocell. Without programming and the biosemiosis of those instructions, no progress could be made within any micelle, vesicle or protocell toward eventual life in a true cell.

7. Do symbol systems exist outside of human minds?

Genetic instruction uses a formal linear digital MSS. We tend to assume that symbol systems exist only within human consciousness. Yet MSSs clearly exist apart from human consciousness at the molecular biological/genetic and genomic level. They pre-date human existence. No living organism, including such organisms as non-free-living Mycoplasmas, is known to exist that does not depend upon MSS programming. Human brains themselves are prescribed by molecular/genetic MSSs.

Genetics and genomics not only utilize a linear digital symbol system, but also an abstract Hamming block coding to reduce noise pollution in the Shannon channel (triplet codons prescribing each amino acid). Anti-codons are at opposite ends of t-RNA molecules from amino acids. The linking of each t-RNA with the correct amino acid depends entirely upon on a completely independent family of tRNA aminoacyl synthetase proteins. Each of these synthetases must be specifically prescribed by separate linear digital programming using themselves the same MSS and ribosome processing as they help prescribe for other proteins. These symbol and coding systems not only predate human existence, they *produced* humans along with their anthropocentric minds. The nucleotide and codon syntax of DNA linear digital prescription has no physicochemical explanation. All nucleotides are bound with

the same rigid 3'5' phosphodiester bonds. The codon table is arbitrary and formal, not physicodynamically determined. The semantic/semiotic/bioengineering function required to make proteins requires dynamically inert configurable switch-settings and resortable physical symbol vehicles. Codon syntax communicates time-independent, non-physicodynamic "meaning" (prescription of biofunction). This meaning is realized only after abstract translation via a conceptual codon table. To insist that codon syntax only *appears* to represent amino acid sequence in our human minds is not logically tenable.

In "The Biosemiosis of Prescriptive Information"[6], we asked the question, "Exactly how do the sign/symbol/token systems of endo- and exobiosemiosis differ from those of cognitive semiosis?" Do the biological messages that control, regulate, and integrate metabolism have conceptual meaning? "Meaning" almost invariably relates to achieving function. The purpose of messages is to convey useful information. That information can be descriptive (DI) or prescriptive (PI). Both are subsets of Functional Information (FI). What makes FI intuitive or semantic information is that it imparts pragmatic value to the recipient. We call this meaning. "Messenger molecules" impart such meaning and potential function to their targets within the cell or in neighboring cells. No fundamental difference exists between the use of MSSs within cells at the molecular biological level and the use of MSSs to convey language or cybernetic programming by human minds. According to Chomsky, human consciousness cannot even take credit for human innate language [44].

Metabolism employs primarily proteins. The nucleotide sequences in mRNA prescribe the amino acid sequences that determine protein identity. DNA is largely inert. It plays a minimal direct physicochemical role in protein binding, transport and catalysis. Molecular biology's two-dimensional complexity (secondary biopolymeric structure) and three-dimensional complexity (tertiary biopolymeric structure) are both ultimately determined by linear sequence complexity (primary structure; functional sequence complexity, FSC). The chaperone proteins that aid polyamino acid folding are also prescribed by the linear digital genetic programming instantiated into DNA sequencing.

Figure 2 shows the prescriptive coding of a section of DNA. Each letter represents a choice from an alphabet of four options. The particular sequencing of letter choices prescribes the sequence of triplet codons and ultimately the translated sequencing of amino acid building blocks into protein strings. The sequencing of amino acid monomers (basically the sequencing of their R groups) determines minimum Gibbs-free-energy folding into secondary and tertiary protein structure. It is this three-dimensional structure that provides

"lock-and-key" binding fits, catalysis, and other molecular machine formal functions. The sequencing of nucleotides in DNA also prescribes highly specific regulatory micro RNAs and other epigenetic factors. Thus linear digital instructions program cooperative and holistic metabolic proficiency.

Not only are symbol systems used, but a bijection must occur between two independent symbol systems. Bijection (translation; a symbol system to symbol system correspondence or mapping) is rule-based, not physical law-based. No cause-and-effect necessity exists in the linking of anticodons, amino acids, tRNAs, and amino acyl tRNA synthetases with codons. The correspondence between the two languages is arbitrary and abstract. By arbitrary, we do not mean random. Arbitrary means freely chosen—free from physicodynamic determinism. Bijection (mapping) rules are uncoerced by cause-and-effect physicochemical chains. Translation of this linear digital prescription into functionally specific polyamino acid chains cannot be explained by physicodynamics. It is not law-based, and it certainly is not random. If this were an empirical/inductive contention, "cannot" would have to be replaced with "has not yet been." But the statement is a valid deduction.

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   1 gctagtgtag cttaagcaaa gcataacact gaagatgtta agatgggccg tagaaagccc
  61 cacgggcaca aaggtttggt cctgacttta ttatcagctt taacccaatt tacacatgca
 121 agcctccgca cccctgtgag gatgccctca atcccccgtc cggggacgag gagccggtat
 181 caggcacact ttttagccca agacgccttg cttagccaca cccccaaggg aattcagcag
 241 tgatagacat taagccataa gtgaaaactt gacttagtca gggttaagag ggccggtaaa
 301 actcgtgcca gccaccgcgg ttatacgaga ggccctagtt gattcactcg gcgtaaagag
 361 tggttatgga gaataaaata ctaaagccga agacccctta ggccgtcata cgcacctagg
 421 ggctcgaatt atagacacga aagtagcttt acccctccc accagaaccc acgacagctg
 481 ggacacaaac tgggattaga taccccacta tgccccgccg taaacttaga tattccagta
 541 caacaaatat ccgccagggg actacgagcg ccagcttaaa acccaaagga cttggcggtg
 601 cttcagaccc ccctagagga gcctgttcta gaaccgataa cccccgttca acctcactac
 661 tccttgcttt tcccgcctat ataccaccgt cgccagctta ccctgtgaag gtactacagt
 721 aagcagaatg agtaatactc aaaacgtcag gtcgaggtgt agcgtacgaa gtaggaagaa
 781 atgggctaca ttatctgatc cagattattc acggaaggtt gtctgaaacg acaatccgaa
 841 ggtggattta gcagtaaagg gggaatagag tgcccccttg aagccggctc tgaagcgcgc
 901 acacaccgcc cgtcactctc cccaacaacc gcctacacca aggtaaataa cacaacatcc
 961 gtcacaaggg gaggcaagtc gtaacatggt aagtgtaccg gaaggtgcac ttggaataat
1021 cagggtgtgg ctgagacagt taagcgactc ccttacaccg agaagacatc catgcaagtt
1081 ggatcaccct gaactaaaca gctagctcaa actataaaaa ccaaattaat gatatagata
```

Figure 2. A section of *Alosa pseudoharengus* (a fish) mitochondrion DNA. This reference sequence continues on all the way up to 16,621 "letters." Each nucleotide is a physical symbol vehicle in a material symbol system. The spe-

cific selection of symbols and their syntax (particular sequencing) prescribes needed three-dimensional molecular structures and metabolic cooperative function *prior to* natural selection's participation. (Source: http://www.genome.jp/dbget-bin/www_bget?refseq+NC_009576)

The conclusion is as unequivocal as that produced by balanced mathematical manipulations of any equation. Neither fixed/forced laws nor chance can logically make nontrivial computationally halting programming decisions. It is a logical impossibility for chance and/or necessity to exercise bona fide choice contingency. They are in isolated categories (see Section 8). Neither unaided Markov chains nor physicodynamic determinism can select for *potential* formal function.

The noise-reducing Hamming "block coding" of triplets of nucleotides to prescribe each specific amino acid is all the more abstract and formally conceptual. The triplet codon/amino acid coding table has been shown to be conceptually ideal in a formal sense [45]. Block-coding greatly reduces the ill effects of a noisy channel on transmitted messages. Fewer prescriptive reading errors occur. Translation between the nucleotide and amino acid symbol systems is extraordinarily reliable. In addition, organisms possess amazing repair mechanisms to undo what noise pollution effects do compromise biomessages. Physics and chemistry provide no mechanisms to explain any of these sophisticated formal control and correction capabilities. They clearly traverse The Cybernetic Cut [4]—a great divide in nature between those phenomena that can be explained through the chance and necessity of natural process vs. those phenomena that can only be explained through formal steering and controls.

But the peculiarity of life over inanimate physics extends far beyond the above discussion. DNA requires editing in the course of its transcription to coding mRNA. And we have not even touched on the roles of many other independent players in the formal integration of transcription, translation, regulation, metabolism, and development. Most of DNA's Prescriptive Information is found in its non-protein-coding (prescribing) regions that instruct small regulatory RNA production. In addition, some supposedly non-protein-coding RNA's have been found to prescribe functional peptides and very short proteins [46, 47]. Epigenetic factors controlling differentiation and development are a large part of overall holistic true organization [48-53]. Post-translational editing also plays a role [54-57]. Gene overlaps, anti-sense transcriptions, genes assembled from multiple chromosomes are just a few of the growing list of layers of extraordinary formal PI instructing life.

"Semantic/semiotic/bioengineering function requires dynamically inert, resortable, physical symbol vehicles that represent time-independent, non-dynamic "meaning." (e.g., codons)." [8] No empirical or rational basis exists for granting to physics or chemistry such non-dynamic capabilities of functional sequencing. Neither chance nor necessity (fixed law) can program configurable switches to integrate circuits or organize formal utility.

Linear digital prescription in physical nucleic acid has thus far invariably been associated with life. A fully postmodern anthropocentrism cannot argue a logically consistent macroevolutionary paradigm. If naturalistic/materialistic science believes anything, it believes that an objectively real "physical brain secretes mind as the liver secretes bile" [as Pierre Jean Georges Cabanis (1757-1808), Karl Vogt and many others since have phrased it]. Jakob Moleschott (1822-1893) is generally given credit for the renal version: "The brain secretes thought as the kidney secretes urine." For macroevolution theory to fly, a very real genetic symbol system must evolve through objectively real early eukaryotes, invertebrates, vertebrates, mammals and primates. A purely subjective or solipsistic view of nucleotides and codons—trying to deny that they are real physical symbol vehicles—totally compromises macroevolutionary theory.

Macroevolution theory of necessity presupposes a literal history of progressive adaptation of millions of objectively existent species through changes in objectively existent nucleotide symbol sequencing. The formal, representational codon table not only predates human minds, but humans themselves.

8. Doesn't the physicality of MSSs prove that information is physical?

The addition of each new nucleotide to a single positive polynucleotide strand represents a decision-node *selection* from among four real contingent options. Each nucleotide selection corresponds to the equivalent of a quaternary decision node (a four-way switch) rather than a binary decision node (mere On-Off switch).

The MSS of molecular biology is unique in that the tokens do have direct three-dimensional physicodynamic effects. They are not like Scrabble pieces that are only representational and physicochemically inert in their functionality. The sequence of physical monomers determines minimum Gibbs-free-energy sinks which in turn determines folding function. But this physical determinism is secondary to sequencing (primary structure). And this sequencing of monomers is still dynamically inert (physicochemically indeterminate) in forming the positive single strand of polynucleotides. Even in the case of molecular biology, the meaning and physical function of monomeric

token sequences (Prescriptive Informational polymers) is still fundamentally formal, not physicodynamic, in their origin.

We sometimes see the loss of PI in nucleic acid following critical base substitutions or other mutation events. We also see the loss of protein function from denaturization. It is tempting for some to falsely conclude from these events that PI and the function it prescribes is purely physical. But the loss of function through mutations and denaturization tells us nothing about the *source* of the message found in those strings in the first place. MSS's always have a formal origin. They are invariably derived from the purposeful choice of tokens from an alphabet of tokens. When nucleoside tokens are randomly polymerized, no sophisticated function is prescribed. When physicodynamic causation constrains token "selection," non-functional homopolymers tend to result (e.g., clay adsorption of polyadenosines). *Many scientists consistently confuse the instantiation of message meaning into physicality with physicality itself.* The inference is fallacious.

We don't make this mistake when we look at physical integrated circuits, computer chips, or robots. We unquestionably know that such physical devices resulted only from formal choice contingency causation and control (CCCC) *making use of physicality*, not from physicodynamic determinism. Artificial life models are not created and engineered by spontaneous inanimate physical interactions. They are invariably designed by human intelligence. Sophisticated machines result only from wise programming choices at bona fide decision nodes, logic gates and configurable switches. Physicality alone has never been observed to generate so much as a paper clip spontaneously.

When it comes to life, most biologists fanatically insist for purely metaphysical reasons that the cell was generated by nothing but the chance and/or necessity of physicochemical interactions. Empirical and prediction-fulfillment supports for this belief system are completely lacking. Rationality denies that anything other than gibberish can be generated by random processes. No computational program has ever been produced by a random number generator. But because of prior metaphysical commitment to the religion of physicalism, materialists insist that physicodynamics alone *HAD to have* generated the nonphysical formalisms needed to organize the simplest of living organisms.

Meaningful linear digital biopolymeric syntax is not generated by mere combinatorial uncertainty. Even when duplication of meaningful syntax occurs, there is no reason to believe that mere random variation (noise pollution) of this duplicated meaningful text would improve its meaning or function. We had no expectation of our PhD theses improving from typographical errors when given to typists unfamiliar with our fields of expertise. Why do we

exercise such blind faith in the power of random mutations to improve duplications of the PI in genomes? We have no evidence of semantics and pragmatics being generated by chance or necessity, or any combination of the two [58].

Just because formalisms have been instantiated into physical symbol vehicles in a MSS does not change the fact that that the symbols, symbol system and meaning are purely formal. If this page burns up in a fire, we cannot conclude that the functional information recorded with physical molecules on physical paper was purely physical. The "page" still exists on electronic storage at the book publisher's server. If that physical medium were also lost in a fire, the ideas still remain in the head of this page's author, and in the minds of many who have already read this page. Symbol systems will always be formal, even when instantiated into a MSS.

We are also confused by the fact that linear digital token (amino acid monomer) sequences fold into physical three-dimensional catalysts and physical structures. Binding seems purely physical. We forget that binding depends upon globular tertiary structure. Globular structure depends upon the minimum Gibbs-free-energy sinks determined by monomeric sequencing. Even functional peptides, small and large regulatory proteins and chaperones are themselves prescribed by linear digital semiosis. The nucleotide and codon sequencing that prescribes all of these is physicodynamically inert. Selection of each monomer in the positive informational strand is formal, not physicodynamic. No physical causation exists to explain the particular PI sequence of each positive instructional strand. The chance and necessity of physicalism cannot explain the functional sequencing of the primary structure that determines folding.

Metaphysically disallowing formalism in one's model of reality precludes not only Hamming redundancy coding (codon to amino acid bijection), it precludes semiosis. A purely physical semiotic system cannot exist or function as a messaging system. "Representationalism requires both combinatorial uncertainty and freedom to purposefully select tokens. Naturalistic physical ISness cannot generate representationalism. Formalism alone can send and interpret linear digital messages. This remains true even when a material symbol system with physical symbol vehicles is used by formalism. Polynucleotide genes are such an MSS." [6]

Neither computer programs nor genetic instructions can be written by physicodynamic determinism. We cannot conclude that mathematics is physical just because the equations are written with physical chalk on a physical blackboard. Purposeful choices must be instantiated into computer hardware and software for computation to succeed. The same is true of genetic instruc-

tion. "Both mathematics and life are fundamentally formal. Even most epigenetic factors can be shown to be formally produced and integrated into a conceptual, cooperative, computational scheme of holistic metabolism. Life cannot exist without sophisticated, formal, genetic PI." [6]

The functional sequencing of miRNAs and base-paired negative (yet highly informational) strands points to even more sophisticated dimensions of formal programming. Intron sequencing contains abundant redundancy. Yet the redundancy is clearly highly functional, and is an integral part of the programming of miRNA folding and higher regulatory function. High order is not always the product of physicodynamic necessity. Sometimes repeated selections of the same tokens are deliberate and a vital part of formal programming. What was thought to be junk DNA resulting from pointless duplications in introns is now known to be sophisticated regulatory programming.

9. The genetic code is conceptually ideal

It is widely appreciated that not only the genetic code, but the genomic and epigenomic integrated systems are incredibly optimized [45, 59-61]. Undirected natural selection is generally given credit for having achieved these algorithmic optimizations. A plausible scientific mechanism or model is never provided for how physicality achieved formal optimization. As we shall see in chapter 7, undirected natural selection cannot possibly account for code origin and algorithmic optimization at the molecular/genetic level. Evolution works only on already-programmed, already-living phenotypic organisms through differential survival and reproduction. Random variation of duplicated PI cannot possibly optimize symbol system rules, make purposeful choices of symbols according to those rules, or pursue the goal of integrating systems or achieving potential functionality. All of these are formal functions, not physicodynamic interactions. Some other explanation than differential survival of the fittest already-programmed, already-living organisms is needed.

The source of genetic programming lies in the free selection of nucleotides, and in the unconstrained sequencing of those particular nucleotide selections. Says Fontana and Schuster, "Understanding which phenotypes are accessible from which genotypes is fundamental for understanding the evolutionary process." [62] The sequencing of DNA nucleotides has no meaning or function independent of an overarching formal system of arbitrary (could have been otherwise) symbol assignments to each amino acid.

A representational symbol system is clearly employed in the triplet codon table of amino acid prescription. Codons are a form of Hamming "block code" wherein consistent groups of three symbols are used to represent each

single amino acid prescription. Block coding is a form of redundancy coding used to reduce noise pollution in the transmission channel. These arbitrary assignments have been shown to be conceptually ideal in reducing noise pollution in the Shannon channel [45, 60]. The largest number of redundant codons for the same amino acid "just happens to be" assigned to the most important (frequency-wise) amino acids. Despite wobbles and point mutations, codons are often still able to prescribe the correct amino acid because of this extraordinary redundancy coding. The use of block coding prevents frame shift problems that would occur with a redundancy code of variable characters (nucleotide tokens).

Life-origin models cannot reduce these highly optimized phenomena to human epistemology. They are objective phenomena, not merely heuristic tools of our mental construction. Biosemiosis and biocybernetic management was integrating and engineering life's processes long before *Homo sapiens* appeared on the scene to ascribe their linguistic and cybernetic analogies to molecular biology. How would inanimate chance and necessity have conceived such an effective, formal, noise-reducing scheme?

Additional layers of ideal coding sophistication also exist. Independent coding overlays the genetic code in DNA [61]. A separate set of rules controls the binding of transcription factors and histone proteins to DNA. These additional rules control messenger RNA splicing and folding. The later contribute to regulating protein manufacture. The two coding systems are independent, but they are also coordinated. The two codes jointly control metabolism [61]. The genomic code is far more vast than the genetic code, as if we weren't already burdened trying to explain the genetic code alone through natural process. The genomic code includes the three-dimensional structure of DNA and many additional overlaid codings in molecular biology [60]. Chromosomes are grouped by centromeres into radial clusters that juxtaposition certain segments of different chromosomes so that they can cooperatively interact spatially [63]. Wistar researchers found 465 groups of genes that contribute to related structural or metabolic purposes in fission yeast cells. While linear digital prescription is fundamental to genetics and genomics, multiple 3-dimensional layers of information also prescribe function. Incredibly-optimized spatial organization also integrates virtually every cell function.

The underlying cause of such integration is formal even though physical tokens are used. All of these formally integrated systems require selection contingency, not chance contingency or fixed law, to organize [35]. Selection must take place at the genetic level of nucleotide selection for any phenotype to come into existence, let alone the fittest phenotype. This fact of reality constitutes "The GS Principle" is discussed in Chapter 7.

10. Conclusions

Nonphysical, formal, linear digital symbol systems can be instantiated into physicality using physical symbol vehicles (tokens) in a MSS. Genetics and genomics employ an MSS, not a two-dimensional pictorial "blueprint." Highly functional molecular biological MSS's existed prior to human consciousness in tens of millions of species. Genetic code is conceptually ideal. Not all signals are messages. Code is a conversionary algorithm that translates, bijects or decrypts one symbol system into another. Encode/decode is formal, not physicodynamic. Biosemiosis is cybernetic in that symbols must be purposefully chosen from alphabets of symbols. This is a form of control. All known life is cybernetic. Even protocells would require biosemiosis, controls and regulation to become alive. Neither law nor random variation of duplications can generate a meaningful/functional MSS. Even most epigenetic players are produced by MSS's.

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