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2. The Three Fundamental Categories of Reality*

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Abstract. Contingency means that events could unfold in multiple ways in the midst of, and despite, cause-and-effect determinism. But there are two kinds of contingency: Chance and Choice/Selection. Chance and Necessity cannot explain a myriad of repeatedly observable phenomena. Sophisticated formal function invariably arises from choice contingency, not from chance contingency or law. Decision nodes, logic gates and configurable switch settings can theoretically be set randomly or by invariant law, but no nontrivial formal utility has ever been observed to arise as a result of either. Language, logic theory, mathematics, programming, computation, algorithmic optimization, and the scientific method itself all require purposeful choices at bona fide decision nodes. Unconstrained purposeful choices must be made in pursuit of any nontrivial potential function at the time each logic gate selection is made. Natural selection is always post-programming. Choice Contingency (Selection *for potential (not yet existing)* function, not just selection *of the best already-existing* function) must be included among the fundamental categories of reality along with Chance and Necessity.

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Introduction: The big three: Chance, Necessity and Choice/Selection

Three fundamental categories of reality exist: Chance, Necessity (law-like determinism), and choice/selection [1, 3, 7, 10]. Why must Selection be included along with "Chance and Necessity" [11] as a fundamental category of reality?

First, biological science currently presupposes natural selection as its primary organizing Principle. Without *selection*, evolution is impossible.

Second, linear digital genetic instructions represent *selection-based* cybernetic programming. An essential biological process in life, transcription to translation, uses a semiotic symbol system and encryption/decryption as evidenced by the conceptual codon table. No direct physicochemical reactions take place between codons and amino acids. Symbols are formal representations of meaning, not merely physical objects. Each triplet codon not only represents, but prescribes a single codon or stop instruction. Each triplet codon is a Hamming "block code" that reduces noise pollution in the Shannon communication channel. These are abstract conceptual formalisms, not physical objects.

In computer programming we use a fixed block of 7 bits to prescribe each ASCII symbol (letter). The reason is to reduce the likelihood of noise scrambling the signal transmission, meaning and function of each ASCII symbol. This is a Hamming redundancy "block code." A constant number of bits is used to represent each "letter" of the "alphabet." The Postal Service also uses a redundancy block code (in the form of a bar code) to represent *each digit* of every zip code [12]. In the same way, life uses a redundancy block code—three nucleotides to symbolically prescribe each codon symbol That symbol not only represents, but prescribes each amino acid or stop instruction.

Two bits of Shannon uncertainty exist for each potential nucleotide selection. This is evidenced by the are four options at each locus in a nucleic acid string. Thus, a triplet codon is a 6-bit symbol (2 additive bits of uncertainty X 3 loci each in the string), similar to a 7-bit ASCII symbol representing each textual letter.

Symbols must be *chosen* from an alphabet of symbols. Nucleotides must be selected from a phase space of four token options at each locus in the nucleic-acid single positive informational strand. The single positive informational strand corresponds to the first RNAs in an "RNA World" model of life origin, except that codonic prescription of amino acid sequence would not have been a factor.

Base-pairing is not the issue when it comes to investigating the origin of the Prescriptive Information (PI) [6]. The sequencing of nucleosides provides linear digital prescription of cybernetic function. This would also have been true of ribozymes in theoretical preRNA and RNA Worlds. A single primary structure (one long particular sequence of ribonucleotides) must fold back onto itself to make the secondary structure of an RNA ribozyme.

The third reason selection must be recognized as a fundamental category of reality is that the scientific method itself presumes the reality and reliability of formal rationality, mathematics, algorithmic optimization, cybernetic programming, and successful computations. All of these operational tools depend not upon physicodynamic necessity, but upon formal decision theory [13-15]. Decision theory in turn depends upon choice contingency. The practice of science would be impossible without purposeful choices at bona fide decision nodes and logic gates. Chance and necessity are completely inadequate to describe the most important elements of what we repeatedly observe in intra-cellular life, especially. Science must acknowledge the reality and validity not only of a very indirect, post facto natural selection, but of purposeful selection for potential function as a fundamental category of reality. To disallow purposeful selection renders the practice of mathematics and science impossible.

1. Necessity

The order and regularity of nature observed in cause-and-effect determinism can be expressed in the form of parsimonious mathematical formulas, equalities and inequalities. These formulas work as compression algorithms for reams of data because of fixed force and mass/energy relationships in nature. These relationships even incorporate numerical constants. We can count on these formal, mathematical regularities to predict future physical interactions. Given initial conditions, we can calculate in advance what is going to happen physicodynamically. The effects are determined by known combinations of causes and their mathematical relationships.

Cause-and-effect determinism produces highly-ordered sequences of events containing almost no uncertainty or information. Such sequences of events can be described using a compression algorithm much shorter than the sequence of events being described. Reams of experimental data can be reduced to one small equation such as $F = ma$. The latter ability is the very definition of high order, low uncertainty, and minimal Shannon "information" content [12, 16-19].

Physicodynamic determinism is often referred to as "necessity" [11]. Some origin-of-life specialists believe that life arose from cause-and-effect physicochemical determinism—"it had to happen, it could not have been otherwise," as Pier Luigi Luisi summarizes the perspective [20]. Eors Szathmary calls this "the gospel of inevitability" [21]. Christian de Duve and Harold Morowitz are prominent advocates of this view.

2. Chance Contingency

"Chance" is the word used by Nobel laureate Jacques Monod in his famous book *Chance and Necessity* [11] to contrast "necessity" in a false dichotomy. In recent years the term "chance" has been largely replaced in scientific literature by the word "contingency." But this too has its problems, as more than one type of contingency exists. Not all contingency is random. Thus we will use the term "chance contingency" to specifically refer to the kind of "chance" referred to by Monod.

The single word "contingency" means that events could have happened other than what unfolded despite physicodynamic constraints [22] (See also OLEB journal **40** (4-5), October, 2010 for an excellent series of papers on contingency vs. determinism). Outcomes are not fully determined by prior cause-and-effect chains. Variability and degrees of freedom exist. Complex outcomes, at least, are not "necessary"—they are not mandated by natural laws working on initial conditions. More precisely, so many independent cause-and-effect chains interact that the result appears to be random, as in a very unlikely car accident with multiple interactive causative factors. Monod and Gould were prominent advocates of contingency. Luisi contrasts the two perspectives this way: contingency argues, "It could have not happened;" necessity argues, "It must happen." [23] For metaphysical naturalists viewing chance as nothing more than extremely complex or as-of-yet-unelucidated physicodynamic causation, contingency is nothing more than "the outcome of a particular set of simultaneous concomitant effects that apply in a particular point of time/space" [23].

Chance contingency is exemplified by heat agitation and Brownian Motion of molecules in gas and fluid phases. Some argue that all physical behavior is ultimately caused, and that chance contingency is only an illusion. Combinations of forces and their effects can be extremely complex. Undiscovered forces, matter and their relationships may also be at work [24]. But functionally, on both the macroscopic and microscopic quantum levels, distinct advantages obtain from regarding chance contingency as real and for quantifying possible outcomes statistically. Thus, we tentatively refer to chance contingency as "randomness." We might prefer to say, "Functionally, we treat chance-contingent events as though they were random."

A succession of "fair" coin flips provides an example of independent *chance-contingent* events with unweighted means. Physicodynamic constraints exert no bias on whether the outcome is heads or tails with a theoretical "fair" coin. Physical constraints act equally on both physicodynamic possibilities. Chance contingency allows the outcome to be statistically predictable because of the absence of both law-like necessity *and* controls (choice contingency). The coin toss is said to be "fair" because the mean is not weighted by physicodynamic influence *or* experimenter preference. The statistical outcome is not prejudiced or biased.

In a very general sense, chance contingency can be considered predictable (e.g., Gaussian curves). Relative degrees of determinism and chance contingency can also co-exist. Weighted means can be calculated for situations with seemingly incomplete determinism.

Chance is never a physical cause. Chance is a formal, mathematical and statistical mental construction. Chance can have no physical effects because chance is not a physical cause. We cannot attribute the Prescriptive Information (PI) [6] in nucleotide and codon sequence to chance because chance is a cause of nothing. We can describe— even predict—combinatorial outcomes using formal statistics. But statistical *descriptions* do not cause physical interactions, biofunctional syntax, or anything else.

Noise is closely related to chance and randomness. Noise has never been observed to cause nontrivial formal function either. Extreme measures are taken in communication engineering to minimize the deleterious effects of noise pollution on meaningful messages traveling through a Shannon channel. The redundancy coding explained in the Introduction of this chapter is designed to compensate for and overcome relentless noise intrusions into communication efforts. Noise is consistently counterproductive to meaningful and functional communication.

Probabilistic combinatorialism measures chance contingency. It cannot measure choice contingency. But even probabilistic combinatorialism has its boundaries that limit possible outcomes. These too are an indirect form of constraint.

Whatever one's perspective on chance, chance contingency at least *appears* not to be forcefully determined. Even though chance may be a combination of complex and unknown causations, chance is still considered *operationally*, at least, to be physicodynamically inert. This means that chance contingency is, from a practical standpoint, physicochemically indeterminate. It is decoupled from and incoherent with straightforward cause-and-effect chains of law-like "necessity." But even if we view chance contingency as nothing more than unelucidated interactive and complex physical causation, no naturalistic mechanistic explanation exists for the generation of formal utility from chance. Neither physicodynamic determinism nor random noise has ever been observed to generate programming, algorithmic optimization, computation, or nontrivial formal function of any kind.

3. Choice Contingency and Selection

Contingent events sometimes have an additional unexpected attribute. Not only do they appear not to be caused by physicodynamic determinism, they don't appear to be random either. They can look like a random string, but at the same time can instruct or produce (along with algorithmic processing) very sophisticated molecular machines. Protein sequences are found to be within 1% of an expected random sequence [25], yet clearly are not just stochastic ensembles. Only one 150-mer stochastic ensemble out of 10^{77} folds into a shape with *any* known biologic function [26-28]. To organize any protometabolism, scores, if not hundreds, of folds with highly specific functions would have to be marshaled at the right place and time and integrated into one holistic scheme. Given all of the available probabilistic resources since the Big Bang [29], the happenstantial spontaneous generation of even the simplest protometabolism would violate the Universal Plausibility Principle [30] (be definitively falsified with a $\xi < 1$).

This protein example highlights a key point: contingent events can manifest *evidence of formal control* even in the absence of physical constraints. When contingency is steered or controlled by purposeful selection from among real options, *choice contingency* is at work, not chance contingency. Choice contingency, like chance contingency, shares the operational property of physicodynamic inertness. But choice contingency introduces determinism back into the mix at the moment of purposeful selection. It's just a completely different kind of determinism. It is not a physicodynamic determinism. It is a formal determinism—choice or *cybernetic determinism.* Events are neither constrained nor random. They are choice contingent. Such events become the effects of formal cybernetic causation.

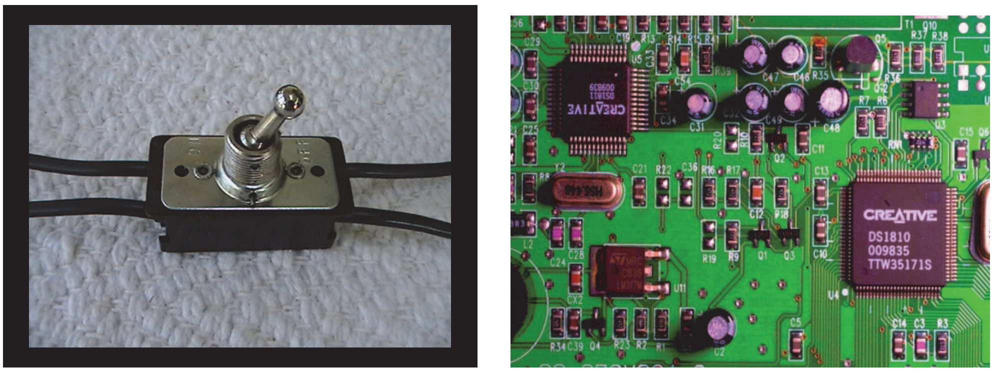
The effect of "pawn to King's bishop 4" is not caused by any law of physics and chemistry. The effect is caused by arbitrary choice contingency—by cybernetic determinism—not by environmental constraints or physical law. Environmental constraints (e.g., a flood or fire) may preclude or terminate the chess game altogether. But the inanimate environment will not choose specific moves that win chess games (formal function).

Choice Contingent Causation (CCC) can generate extraordinary degrees of *unique functionality* that has never been observed to arise from randomness or necessity. Highly pragmatic choice contingency is consistently associated with purposeful steering toward potential utility.

The kind of contingency associated with sophisticated cybernetic function is invariably associated with what philosophers of science call "agency." The hallmark of agency is *the ability to voluntarily pursue and choose for potential function.* Potential means "not yet existent." If anything is repeatedly observable in science, it is abundant evidence of agency's unique ability to exercise formal CCC in generating potential formal functionality. The only exception to human agency's unique ability to do this is life itself, which is of course what produces agency. Life itself is utterly dependent upon cybernetic programming—a phenomenon never observed independent of agency. Thus we are confronted with still another chicken-and-egg dilemma of life-origin science. Whatever the resolution of this riddle, one thing is for certain. We are forced to consider two kinds of contingency, 1) Chance contingency and 2) Choice contingency as fundamental categories of reality along with law-like necessity.

Sometimes both chance contingency and our choice contingency are partially constrained by environmental circumstances. An engineer, for example, has to work around physicodynamic reality in designing and engineering machinery and buildings. Choice contingency itself is exercised solely within the degrees of freedom available to it. But this does not keep choice contingency from being 100% formally determined. Choice contingency is never *determined* by constraints or physicodynamic necessity. If it were, no Shannon uncertainty or choice potential at decision nodes would exist. The sole determinate of choice contingency is deliberate, unencumbered, purposeful selections in pursuit of potential function. Agents merely make these formal free choices in the midst of whatever physical boundaries exist. We choose around those constraints, and at times even chose to make use of those constraints in our design and engineering plan.

The simplest choice contingent systems are digital binary ones with discrete Yes/No logic gates. These represent binary decision nodes providing totally free choice-contingent selection opportunities. A well-designed configurable binary switch has no middle-ground setting—it provides a logical "excluded middle." It is either on or off at all times. The number of binary decision nodes (logic gates, binary configurable switches) is measured in "bits." Note that *bits never measure binary choices.* Bits measure only the number of binary decision *nodes*. Bits are a measure of binary choice opportunities, not the specific binary choices themselves that are the essence of Prescriptive Information (PI). The ability to choose "On" or "Off" without any physicodynamic constraints provides the ideal choice-contingent opportunity. Choice contingency is the major component of any kind of nonphysical, abstract, conceptual formalism.



a) **b)**

Figure 1. a) A binary configurable switch. Though physical, the switch-setting is nonetheless physicodynamically inert ("dynamically decoupled or incoherent"[31, 32]). No physical force field determines the direction this knob is pushed. The vector of knob push is determined by formal choice contingency alone, not by chance or necessity, and not by order or complexity.

Figure 1. b) An integrated circuit board arises only out of unified, coherent, purposefully cooperative, truly organized logic-gate switch settings. The number of permutations of voluntary (choice-contingent; configurable) switch setting combinations quickly becomes staggering. Often only one configuration achieves a certain functional computational halting.

(Used with permission, Abel, D.L. 2009, The capabilities of chaos and complexity, Int. J. Mol. Sci., 10, (Special Issue on Life Origin) 247-291)

Figure 1a shows an old-fashioned binary configurable switch. Such a switch represents the simplest decision node. Everything computational and organizational stems back to binary decision nodes. Binary decision nodes are the basis of all formal function. Even analog and index systems are ultimately based on binary choices. An analog rheostat knob, for example, must be designed to increase power when turned in one direction (e.g., clockwise) and to decrease power when turned in the opposite direction (e.g., counterclockwise).

Configurable switches are dynamically inert (dynamically incoherent; dynamically decoupled from physicodynamic causation) [31, 32]. This means that on a horizontal switch board, the force of gravity works equally on all potential switch positions. Physicodynamics plays no role in which way the switch knob is pushed. This is the very meaning of "configurable" switches. Their setting is completely decoupled from physicodynamic causation. They can only be set by formal choice contingency, not by chance or law. It is the freedom of formal choice at configurable switches that makes all forms of formal sophistication possible in any physical system. Nonphysical formalism alone determines each switch setting. The switch is a "dynamically-inert configurable switch."

Mere "bifurcation points" (forks in the road) are not synonymous with bona fide *decision* nodes. Bifurcation points can be traversed by chance contingency. A path can be taken randomly. When we come to a fork in the road, we can flip a coin to decide which way to go, but only with likely failure to reach the desired destination. The more forks in the road on our journey, the less likely chance contingency is to get us there. Organization and formal utility are achieved through rationally wise purposeful selections of what path to take at each fork in the road, not through the selection of a path based on coin tosses. When pseudo-selections are made randomly at bifurcation points, it has the same effect as noise pollution on the transmission of meaningful instructions. Rapid deterioration of programming function and computational success occurs with randomization of "selection" at bifurcation points. Logic gate settings are reduced to uneducated guesses (See Figure 2).

The existence of bifurcation points and mere "nodes" in neural nets does not account for computational success. Random selections lack purpose and goal, with predictable results. Choice with intent alone steers rats through a maze with increasing speed as their learning progresses. What exactly is learned? The best successive *choices* at true decision nodes needed to escape the maze are learned. Anticipation and planning are involved prior to each decision node commitment. The same is true of controlled openings and closings of logic gates or configurable switches. The latter requires bona fide choices made with wise steering and programming intent if any sophisticated formal function is expected to arise. Chance and necessity have nothing to do with purposeful choices in pursuit of potential function. Neither chance contingency nor law can program or be programmed into sophisticated function. Purposeful programming choices alone make possible unlimited design and engineering successes.

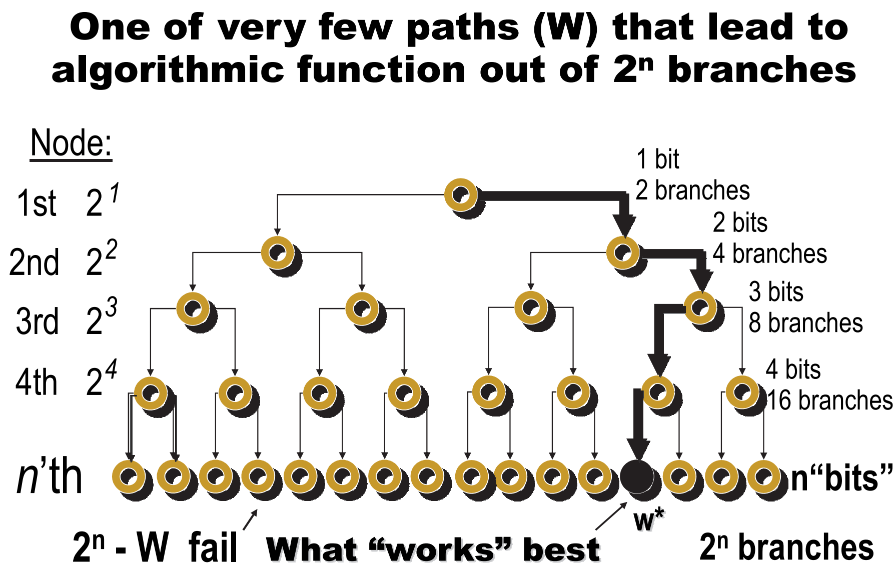


Figure 2. A dendrogram showing all possible sequences (branches or paths) of decision node options. "w*" represents the best algorithmic path to achieve maximum function. The "W" in "2^n-W" represents all paths that produce any degree of algorithmic utility. Notice that *all* paths contain equal (n) bits of Shannon so-called "information" regardless of whether the sequence of specific choice commitments accomplishes anything useful. (Used with permission, Abel DL: Complexity, self-organization, and emergence at the edge of chaos in life-origin models. *Journal of the Washington Academy of Sciences* 2007, **93:**1-20.)

Nontrivial function is only achieved through selection *for potential function* at each individual decision node (Figure 1). This is the essence of "programming." When purpose, goal, and intent are removed from the equation, "choice" becomes the equivalent of "stabs in the dark," random number generation and noise. No one has ever observed a nontrivial computational program arise from a random number generator. This is all the more significant given that not even the so-called "true random number generators" have been proven not to be technically random. Atmospheric noise and even the points in time at which a radioactive source decays continue to be subject to the critique of hard determinists. It remains to be seen whether the very recent (Sept/2010) random number generator at Max Planck Institute is truly random [33]. But either way, we can rest assured, no random number generator will be found generating any sophisticated formal function. Neither randomness nor the cause-and-effect determinism of nature has ever been demonstrated to generate nontrivial algorithmic utility. The blind belief that physicality alone can generate nonphysical formalisms is unfalsifiable, and therefore not a scientific hypothesis. It is a violation of The Cybernetic Cut [4] (See Chapter 3). It is totally without empirical support. No prediction fulfillments exist. More importantly, perhaps, is that the notion is a logically deductive impossibility.

Algorithmic optimization typically produces highly informational instructions and control. As James Harding points out [personal communication], "The process of optimizing algorithms is that of making choices to transform one set of instructions with another set for the purpose of improving along one or more axes of control (e.g., speed, size, simplicity or clarity)." Any physical matrix capable of retaining large quantities of PI must offer high degrees of Shannon uncertainty and high bit content [2, 8, 34]. High bit content refers only to combinatorial possibilities within the physical matrix. But a high number of combinatorial possibilities are an essential requirement of any physical medium if PI is to be instantiated into that medium.

No known natural process exists that spontaneously writes meaningful or functional syntax. Only agents have been known to write or program meaningful and pragmatic linear digital PI [6, 35, 36, pg 46]. Physicality cannot compute or make arbitrary symbol selections according to arbitrarily written rules. Physicality cannot compress. Physicality cannot value or pursue formal utility. Physicality is blind to pragmatic considerations, all of which are formally valued and pursued. The physicodynamics of inanimate mass and energy cannot selectively steer physical events toward algorithmic optimization. Many epigenetic factors notwithstanding, genes and genomic processes largely *program* phenotypes using a formal material symbol system (MSS) [31, 37, 38]. Neither chance nor necessity can explain this undeniable and repeatedly observable phenomenon.

3.1 Selection *OF EXISTING* Fitness (Natural Selection)

Two kinds of selection exist: 1) Selection *of existing* function (e.g., natural selection; differential survival and reproduction of already-programmed, already-living organisms) versus: 2) Selection *for potential* function (e.g., artificial selection at decision nodes in pursuit of formal function that does not yet exist for the environment to favor).

Not all selection by agents is for potential function. Agents can also select the best existing function. We pick the best commercial software package off the shelf for purchase. Based on word of mouth recommendations, we judge it to be the "fittest" software because we have heard it is the most helpful, most reliable and least expensive. Less fit software, and the companies that produce it, tend to die out. We may not know anything at all about programming or how the software came into existence. The market just favors the best software that already occupies the shelf.

Selection *of existing* fitness, but not *for potential* fitness, can also be accomplished by "selection pressure." Natural selection consists of differential survival and reproduction of the fittest already-computed, already-living phenotypes. But it occurs only at the organismic level of already-living small populations of organisms. "Survival of the fittest" is the very indirect environmental "selection" of the best existing genera of organisms. It is a stretch to call evolution "selection" in that all that really happens is that inferior organisms tend to die off quicker. It is an even bigger stretch to call evolution "selection pressure." Environmental stresses challenge all living organisms to survive. Less fit organisms (poorly programmed) tend to fail more often than the fittest organisms (well programmed for all environmental challenges). Evolution is nothing more than differential survival and reproduction of the fittest already-programmed, already-living organisms. Thus natural selection is a unique case of after-the-fact, very indirect "selection" by default. Selection is not intended; it just happens secondarily. No purpose guides natural selection events. No true decision nodes are involved because evolution has no goal. In this sense, selection "pressure" is a complete misnomer. No pressure exists to choose anything. Except for environmental stress, evolution occurs more in a vacuum than under any directional pressure. Differential survival is more happenstantial than pushed. No selection occurs at the genetic programming level where biofunction must be integrated and life organized [5, 39]. Differential survival and reproduction of already-programmed, already-living phenotypic organisms is purely eliminative [36]. It plays no role in the programming of new organisms[5, 39]. Differential survival and reproduction is always after-the-fact, never pursued.

Natural selection is selection only of existing living phenotypic fitness. Natural selection cannot select for potential fitness. Environmental selection favors only the best already programmed, already living organisms and small groups of organisms.

We must also remember that *natural selection does not favor isolated biofunction.* Selection pressure favors only the survival-of-the-fittest holistic, already-living organisms. No organism would be alive without thousands of cooperating molecular machines, integrated biochemical pathways and cycles, and the formal goal of maintaining a homeostatic metabolism. All of these algorithmic processes must be optimized and in place before any organism can live, let alone constitute the fittest selectable life. Chang *et al.* [18] state:

> Chemical evolution' should not be confused with Darwinian evolution with its requirements for reproduction, mutation and natural selection. These did not occur before the development of the first living organism, and so chemical evolution and Darwinian evolution are quite different processes.

3.2 Selection *FOR POTENTIAL* Fitness (Artificial Selection: Choice)

Selection for potential fitness is always artificial rather than natural. Selection for potential fitness is a formal, not a physical enterprise. Selection for potential fitness occurs at decision nodes. Symbols systems and configurable switch settings are used to represent those decisions. Examples of formal selection include language, cybernetic programming, logic, math, computation, algorithmic optimization, design and engineering function, organization of any kind.

Artificial selection is the essence of formalism. Artificial selection always involves purposeful choices at true decision nodes, logic gates and configurable switch settings. As is the case with Maxwell's Demon's trap door operation [40], the door must be opened and closed with intent, not randomly, and not by fixed law, if a heat-energy gradient (work potential) is expected to arise from an ideal gas distribution. An agent invariably exercises choice to program nontrivial formal function. The same is true in any form of semiosis—messaging. To generate a message requires purposeful selection of symbols from an alphabet of symbols according to formal rules to spell meaningful words and sentences. Semiosis is impossible without choices for *potential* function made at individual decision nodes in a string of decision nodes. Despite decades of concentrated research on consciousness and artificial intelligence, choice contingency remains elusive when approached from the direction of physicodynamics and naturalism alone. The mind/body problem is alive and well in the philosophy of biology [4, 7, 41-45]. Ultimately, the mind/body problem boils down to the fact that chance and necessity cannot generate choice contingency—the essence of any formalism.

Natural selection lies in the Selection of Existing (phenotypic) Fitness category. The fittest already-programmed, already-living organisms. differentially survive and reproduce better than less fit living organisms. Evolution in the end is nothing more than differential survival of the fittest already existing organisms. Evolution tells us nothing about how any organism came into existence. Organisms have to be programmed to exist and be alive. They consist of operating systems, software, and millions of nanocomputers running constantly in every living cell [36, 46, pg 47].

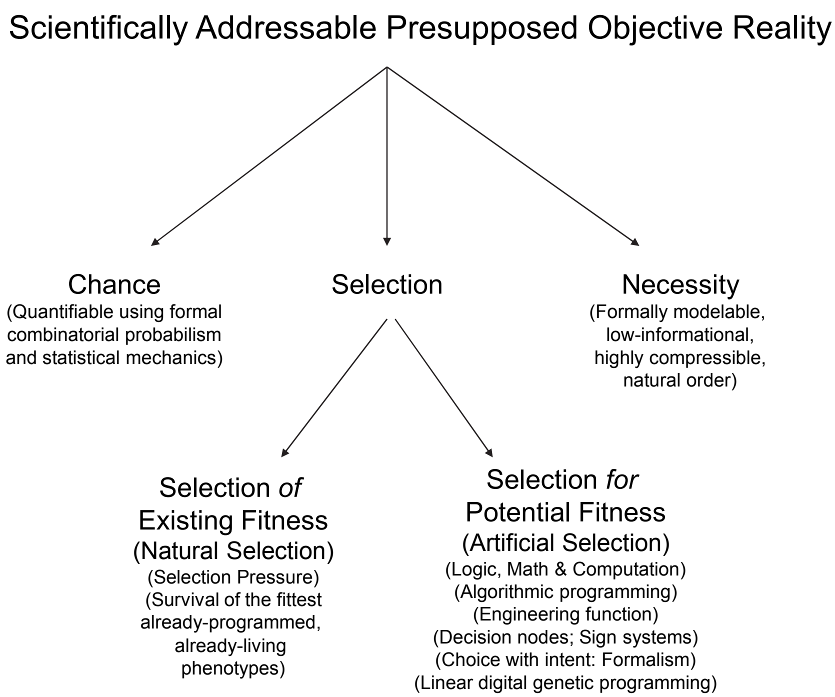


Figure 3. The scientific method itself presumes the reality and reliability of choice-contingent language, formal rationality, mathematics, cybernetic programming, and predictive computations. In addition, biological science presupposes natural *selection* as its most fundamental paradigm. Science, therefore, must acknowledge the validity of Selection as a foundational category of reality along with Chance and Necessity.

(Modified from: Abel DL: The biosemiosis of Prescriptive Information (PI). *Semiotica* 2009, **2009:**1-19)

It is well known that Chance Contingency alone cannot generate the programming or computation needed to organize any organism, let alone the fittest organisms. Chance contingency plus selection of the best already living organisms cannot generate life's programming and computation either. Programming and computation have never been observed to arise from any source other than Choice Contingency, never Chance Contingency or Necessity.

The sign/symbol/token systems employed by language, logic theory, mathematics, cybernetics, engineering function, and linear digital genetics all reside in the category of Selection *for* Potential Fitness. Nucleotides must be selected at the molecular/genetic level prior to the realization of any function or life. The differential survival known as "natural selection" and "evolution" is not operational when nucleotide sequencing must be programmed into nucleic acid to prescribe amino acid sequence in proteins, and simultaneously mRNA regulatory control in its complementary strand.

Linear digital genetic programming using a Hamming block code of 3 nucleotide selections to represent and prescribe each amino acid selection is a form of selection for potential fitness, not selection of existing fitness [2, 6, 8]. Genetic programming cannot be explained by natural selection [5]. The environment cannot select for potential function. Evolution has no goal or programming ability at the genetic level.

As discussed above, the selection of each nucleotide corresponds to the setting of a four-way quaternary configurable switch. Three quaternary switch settings in a row prescribe each amino acid "letter" of a very long protein "word." No fitness exists for the environment to favor or select at the level of 3'5' phosphodiester bond formation between nucleotides. These informational biopolymers must be sequenced prior to the realization of any prescriptive, enzymatic, or regulatory function. Selection at the level of nucleotide sequencing clearly falls within the category of "Selection for potential function" rather than the category of "Selection of existing function." This is called the GS (Genetic Selection) Principle[5]. The GS Principle states that selection must occur at the decision-node level of rigid covalent bond linkage of specific monomers to form functional syntax. After-the-fact selection of already-computed phenotypic fitness is not sufficient to explain genetic programming or the metabolism it organizes.

4. Constraints vs. Controls

Great confusion has resulted from sloppy interchangeable use of the terms "constraints" and "controls" [1, 4, 46, 47]. Science emphasizes precise definitions for good reason. In the case of constraints vs. controls, however, contributors to scientific literature have often been grossly negligent. As a result, numerous fallacious inferences have been propagated. Sloppy definitions often cause "category errors" in particular. Varying contexts, hierarchical levels of application, and subjective word connotations have further blurred the dichotomy. Proper definitions of these two terms hold the key to understanding whether life is truly unique from inanimate physics and chemistry.

The orderliness of nature exists in fixed mass/energy relationships and constants described by "laws." These best-thus-far generalizations describe highly probable cause-and-effect chains of behavior. Despite our quantum world enlightenment, determinism in the macroscopic world is still a highly useful and reliable concept. "Necessity" refers to this highly predictable determinism. Since the probability of law-like cause-and-effect chains approaches 1.0, the uncertainty of outcome is therefore very low. Under conditions of such low uncertainty (low Shannon bits), the prescription of sophisticated organization becomes impossible [6, 8, 48]. Uncertainty and freedom are first required before PI can be generated [6, 7]

The laws of physics and chemistry are basically compression algorithms for reams of experimental data. The laws themselves contain very little information (e.g., $F = ma$). We celebrate the parsimony and universality of these low-informational laws. Life, on the other hand, is highly informational. Metabolic organization and control is highly programmed. Life is marked by the integration of large numbers of computational solutions into one holistic metasystem. No as-of-yet undiscovered law will ever be able to explain the highly informational organization of living organisms. The latter would be a mathematical/logical (deductive) impossibility that cannot be overturned by any amount of future observation, abduction or induction. There are simply not enough bits of uncertainty in any law, nor enough "information" (reduced uncertainty, "mutual entropy" in applying a law to the data) to *prescribe* the integration of so many complex pathways, cycles and regulation schemes into a holistic metabolism.

Whereas chance contingency cannot cause any physical effects, *choice contingency* can. But choice contingency, like chance contingency, is formal, not physical. So how could nonphysical choice contingency possibly become a cause of physical effects? The answer lies in our ability to *instantiate* formal choices into physical media. As we shall see below, formal choices can be represented and recorded into physicality using purposefully chosen physical symbol vehicles in an arbitrarily assigned material symbol system. Choices can also be recorded through the setting of configurable switches. Configurable switches are physicodynamically indeterminate (inert; decoupled from and incoherent with physicodynamic causation) [31, 32]. This means that physicodynamics plays no role in how the switch is set. Physicodynamic factors are equal in the flipping of a binary switch regardless of which option is formally chosen. Configurable switches represent decision nodes and logic gates. They are set according to arbitrary rules, not laws. Here arbitrary does not mean random. Arbitrary means “not physicodynamically determined, but freely chosen” [12, 49, 50]. Arbitrary means “freely selectable”—choice contingent.

Below are listed the necessary and sufficient criteria for differentiating constraints from controls.

4.1 What are constraints?

Constraints consist of 1) initial conditions (when not chosen by experimenters), 2) the orderliness of nature itself (the “laws” of physics and chemistry), and 3) the bounds of statistical variation (e.g., standard deviation) stemming from factors such as heat agitation, complex interaction of forces, quantum indeterminacy, etc.).

Initial conditions are usually viewed as the result of prior cause-and-effect physicodynamic chains. Initial conditions in combination with the high dependability of precise physical interactions severely constrain outcome space. No local intent or purpose is involved in these constraints. The constraints just ontologically exist. Our various epistemological and metaphysical slants of interpretation are irrelevant to the fact of these objective 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 [11, 51-53]. 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.

Forces act physicodynamically with great regularity upon initial state conditions. Quantum indeterminism at the microscopic level does not prevent the reliable mathematical prediction of nature’s macroscopic orderliness. Events are said to be caused by physical forces and their resulting mass/energy interactions. The force constants and the regularity of natural force interactions constitute a form of constraint. Thus, not only are the local initial conditions viewed as constraints, but also the high dependability (orderliness; regularity) of physicodynamic interactions.

Finally, statistical curves describing random variation allow us to predict the relative limits of variation. While statistical descriptions do not constitute a cause of physical effects, they do provide an indirect practical sense of constraint on possible outcomes.

Inanimate nature has no goals. This includes evolution. The use of the term "constraints" to refer to any formally *steered* utilitarian process is therefore erroneous. Likewise, referring to a pragmatically blind physicodynamic causal chain or to the spontaneously self-ordering dissipative structures of chaos theory [54] as a "process" is technically incorrect.

"Natural process" proceeds without regard to formal function or any goal of pragmatic outcome. This raises the question of the legitimacy of using the term "process" in the commonly used phrase "natural process." A certain wish fulfillment emerges from our naturalistic metaphysical presuppositions that uncontrolled physicodynamic phenomena will spontaneously self-organize into extraordinary degrees of formal ingenuity. Empirical support, logic, and prediction fulfillment evidence is sorely lacking for this blind, unfalsifiable belief.

The etymology of "process" traces back to "processus" and relates to "procedure." A procedure is a *formal* undertaking involving decision nodes, directionality, purpose, and goal. Processes and procedures are undertaken to achieve Aristotelian "final" function. Processes and procedures require wise anticipatory programming decisions. Utility is desired and sought after in any bona fide process.

Mere physicodynamic constraints and cause-and-effect deterministic chains cannot prescribe formal goals or generate cybernetic processes and procedures. They can only generate ordered sequences of physicochemical cause-and-effect chains with no orientation toward utility. Mere cause-and-effect chains may lead to self-ordering phenomena such as bathtub drain vortexes and the shapes of a candle flame. But unselected constraints and physicodynamic cause-and-effect chains have never been observed to steer events toward, let alone through, formal utilitarian processes, procedures, algorithmic optimizations, circuit integration, or computational solutions.

Unfortunately, it has become all too common to refer to mere physicodynamic causal chains like star formation as a "process." General scientific concepts and terms were sometimes poorly defined originally (e.g., "work," "system," "constraints" used erroneously to refer to "controls"). Fundamental confusion resulted. Over the last 100 years this same confusion has extended into multiple specialized fields (e.g. solid state physics, weather forecasting, astronomy, information theory, cybernetics). Once incorporated into the many branching specialized fields of science, the linguistic confusion only evolves independently into ever worsening varieties of nonsense in each specific field. Even when fundamental definitional errors are finally corrected, it becomes almost impossible to undo the damage in each specialized field. Astronomers are not going to stop using the word "process" to refer to the uncontrolled, merely constrained chain of deterministic physicodynamic events that cause star formation. But this does not change the fact that star formation is not a cybernetic process. It is just a cause-and-effect physicodynamic chain with some degree of statistical variation. All we can do is to call attention to some of the errors in fundamental scientific thought and terminology, and hope that the correction eventually filters down to each scientific specialty. Until then, the terminology advocated in this paper will seem idiosyncratic and at odds with long established use in multiple fields of science. During the long reign of Ptolemaic astronomy, Copernican concepts and terminology were also initially idiosyncratic.

In the mean time, we must remain clear that bona fide processes are technically controlled, cybernetically guided (programmed), goal-oriented, and organized. They are not merely ordered by the fixed, low-informational, unimaginative orderliness and cause-and-effect chains of nature.

The determinism arising from prior cause-and-effect deterministic chains has nothing to do with pragmatic goals. Constraints are limited in effect to slight statistical variation. Unchosen constraints provide no nontrivial formal function. Only our purely metaphysical commitment to philosophic naturalism sustains our religious faith in a spontaneous physical generation of formalism. This belief is utterly without scientific support.

The roles of quantum indeterminacy and the statistical variations of complex causation are often hotly debated. Even the strictest metaphysical naturalism and cause-and-effect determinism never seem able to totally obliterate chance contingency [24]. Again, both chance and choice contingencies mean that events could unfold with multiple outcomes despite constraining initial conditions and the law-like regularities of nature.

4.2 What are controls?

Constraints can permit some degree of chance-contingency freedom. But controls always manifest the exercise of purposeful selection for function from within that freedom. Controls involve *steering* events toward some *useful* end. Controls are exercised in the pursuit of formal goals such as computational halting, logically sound syllogisms, and linguistic communication.

Cybernetic function requires freedom of selection which law-like determinism precludes. Wise programming always involves choice contingency exercised at bona fide *decision nodes*, not mere "bifurcation points." Bifurcation points do represent the larger category of contingency. Bifurcation points can be traversed with nothing but chance contingency (e.g., coin flips to determine which branch of the fork to take). But no nontrivial formal function has ever been engineered with mere chance contingency at bifurcation points. Only wise choice contingency produces sophisticated utility. And any attempt to reduce decision nodes to mere bifurcation points results in rapid deterioration of any potential nontrivial formal function. The existence of mere bifurcation points, neural net nodes, or "buttons and strings" does not account for computational success. Organization and formal utility are achieved through the controlled opening and closing of logic gates. The latter requires bona fide choices made with steering and programming intent.

Table (1) The contrast between physicodynamic constraints and formal controls

Constraints	**Controls**
Physical / Dynamic	Nonphysical / Formal / Conceptual / Abstract
Naturally-occurring initial conditions	Agent-chosen initial conditions
The fixed orderliness of nature itself constrains	Dynamically-inert configurable switch settings control
Necessity / Chance contingency statistical bounds	Choice contingency
No goal, directionality, or intent	Purpose-driven
Non-pragmatic; *any* cause-and-effect chain prevails	Pragmatic intent and results
Bifurcation points only; No bona fide decision nodes	Decision-node choice commitments
State-based	Deliberately engineered
A string of dissipative structures momentarily occur on a unidirectional physicodynamic time vector	Time-independent programming choices can be symbolically represented and instantiated into switch settings at any time
Simple / highly-ordered / regular Monotonous / redundantly structured	Cybernetically Complex Algorithmically optimized and conceptually organized
Unimaginative	Imaginative
A natural state in physical state space	Choice contingency engineers formal function
Blindly constrains fixed law-like behavior. Deterministic without regard to formal pragmatic benefit.	Deliberately steers toward sophisticated utility through particular settings of configurable switches that are decoupled from deterministic laws.
Constraints are not capable of measuring initial conditions or manipulating formal equations	Formalism measures (*represents)* initial conditions and controls manipulate mathematical equations (e.g., F = ma)
Can not compute	Can compute
Cannot steer toward or pursue pragmatic goals	Steers, integrates circuits, and pursues formal goals
Blind to formal function	Formally prescribes function into physicodynamic reality
Differential survival/reproduction of the fittest organisms *only secondarily constrains* the population.	Linear digital prescription/regulation computes into existence all organisms *prior to* natural selection of the fittest phenotypes.

Nonphysical formal choices made with intent at decision nodes can determine the course of physicodynamic events. Such decisions instantiate purposeful choices (e.g., programming choices) into physicality. Such instantiation of controls into physicality should

never be confused with mere constraints. Constraints are circumstantial elements of prior cause-and-effect chains, not programming decisions. Controls circumvent, "outsmart," and even make use of constraints in order to achieve formal (choice-based) utility. Constraints are purely physicodynamic—physical. Controls are formal and nonphysical.

5. Laws vs. Rules

The physical "Laws" are viewed as "deterministic" of invariant "necessity." They are seen as universally applicable to macroscopic physicodynamic interactions. Physicochemical phenomena unfold according to the dictates of fixed mathematical relationships. We can reliably predict physicodynamic outcomes specifically because they are constrained by invariant laws, not rules. Reliance on the necessity described by laws is what allowed us to put a man on the moon.

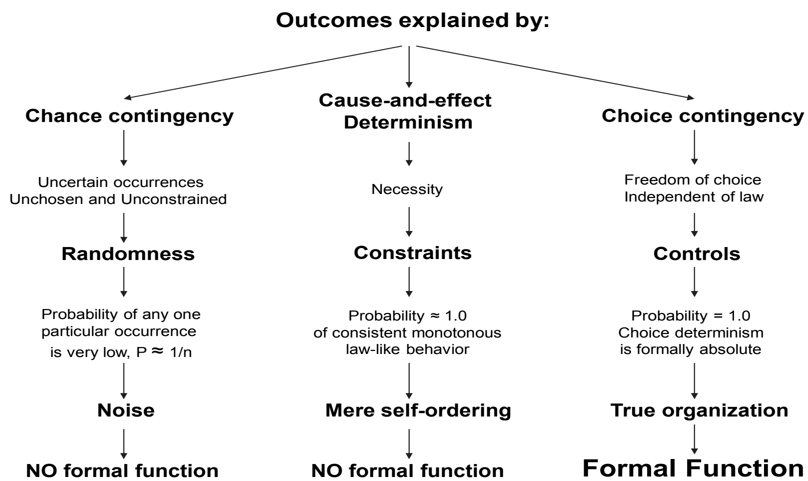


Figure 4. **The three major categories of outcome/behavior.**

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Rules, on the other hand, govern only voluntary behavior and help guide in establishing pragmatic controls. We can break the rules any time we want, though often at the expense of math errors, programming bugs, inefficient function, or punishment. Rules apply only to choice contingency, not physicodynamic determinism.

Physical interactions do not and cannot arbitrarily choose whether to obey the Laws of motion. Invariant laws dictate the outcomes of mass/energy interactions in inanimate nature. Rules apply to formalisms. Great care must be taken in the proper use of the terms "rules" and "laws." Much confusion has resulted from sloppy interchangeable use of the two terms. The so-called "Laws of Logic," for example, are not laws! They should be called "the *Rules* of inference." They can clearly be broken resulting in disastrous fallacious inferences. The limitless functional benefits of choice-contingent freedom (e.g., mathematical manipulations; computation; computer programming) is fraught with the curse of the possibility of loss of that formal function (e.g., math errors and fatal program bugs). What we call "the Law of the Land" (legislative law, even "the Ten Commandments") is technically not law, but *rules* governing voluntary behavior.

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 [55, pg. 262].

Formalisms are 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 purposefully selected. The chooser has complete freedom of choice with intent without constraint. The weighted means of Shannon uncertainty cannot explain the purposeful choices 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* [11, 56-58]. 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 or computational success.

6. The instantiation of Controls into physicality

We have seen that the opportunity to *choose with intent* from among real options (choice contingency) is an essential ingredient of all formalisms. But how can this freedom of purposeful selection get instantiated into a physical world of mass/energy and cause-and-effect determinism?

Controls and formalisms are nonphysical. But "instantiation" allows them to be recorded into and transmitted through physical media. A unique situation must exist within any physical system to allow the introduction of nonphysical formal controls. Controls can steer physical events toward formal goals and can generate utilitarian physical constructions via wise design and engineering decisions. The easiest way to instantiate controls into physicality is to purposefully select the constraints, such as when an experimenter deliberately chooses the initial conditions of an experiment. We can also incorporate choice contingency into physicality using especially designed and engineered physical devices with unique properties. We call these devices *configurable switches* and *logic gates*. Configurable switches and logic gates are physical devices that can register into physicality, and physically utilize, the nonphysical formal choices of mind. These configurable switches and logic gates must first be physicodynamically indeterminate ("dynamically-inert," dynamically incoherent) [31, 32]. But the invention of such switches alone is not enough. We must also have the formal wise choice contingency to set each switch and to coordinate and integrate the succession of all switch settings so as to integrate circuits.

Although statistical differences and patterns distinguish one linear digital prescriptive string from another, no Prescriptive Information exists because of probabilistic combinatorialism [59]. PI only exists at the moment a particular choice for potential function is made [8]. When a nucleotide is rigidly (covalently) bound to the single-stranded string, the four-way configurable switch knob is actually pushed in one of four possible directions. At that moment all Shannon uncertainty is replaced with formal causation. The vector of the four-way switch knob is determined by choice contingency, not by physicodynamics. It is only when one of the four options is actually selected for potential function that PI comes into existence. It is only when that choice initiates movement of the physical switch knob in one of the four directions that formalism is instantiated into physicality.

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 [60, 61]. 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.

How are abstract control choices recorded into mass/energy? How can nonphysical choice contingency wind up controlling physicality? We shall examine 5 different ways.

6.1 Control through choice of constraints

Initial conditions can be chosen by investigators as the starting point of their experimentation. Under these circumstances, the *chosen* constraints rightly can be considered controls [50, 62, 63]. But these constraints become controls only because those constraints were purposefully selected to steer events toward the experimenters' desired results. The constraints themselves do no steering toward any formal utilitarian goal. Choice contingency alone achieves nontrivial integration, organization, and function.

No matter how well a bridge is designed, the river bottom must have adequate physical conditions at the foundation of the main bridge supports. Thus controls cannot be divorced from physicodynamic reality. But no matter how ideal the physical rock bed at these points is, no bridge will spontaneously form from physicodynamics alone. The engineers must either work around or make use of existing physical constraints when they make their design choices according to the formal *rules* (not laws) of safe bridge-building. Engineers must even make choices in view of their anticipation of future circumstantial constraints. An example is the requirement to design a bridge to survive a 100-year flood. But the dichotomy between anticipated environmental constraints (infrequent floods) and controls remains intact.

The choice of constraints, the selection of particular configurable switch settings, the choice of tokens, the choice of which iterative product to proceed with in an optimization process, formal organization schemes, the integration of physical components into a formally functional machine, and the selection of logic gate settings to achieve computation and potential integrated circuits—all of these are functions of choice contingency even though they utilize physical entities. Such formal choice contingency allows us to make use of physical objects to design and engineer physical manifestations of formalisms.

Purely physicodynamic air flow, force and friction cause airplane lift. But the chosen aspects of airplane wing design and engineering are alone what harness those physical factors into airplane flight (formal utility). Lift is ultimately prescribed and produced through physicodynamically indeterminate configurable switch settings. Every individual design enhancement in the wing and fuselage comes in the form of a formal decision-node choice. Flight is not optimized by "bifurcation points" (mere choice *opportunities*). Flight is optimized by wisely choosing which path at each bifurcation point to take. Logic-gate settings must be ideally programmed to optimize the formal utility of desired flight.

In the same way, Maxwell's Demon [64-66] is only able to dichotomize faster moving ideal gas molecules from slower moving ones through *formal choices* of when to open and close the trap door between compartments [67, 68]. Why else would such a ridiculous cartoon personage ever have been introduced into the scientific literature of physics? The reason is that no physicodynamic explanation could be found to explain the sustained nontrivial journey away from equilibrium and disorganization. Only a choosing agent could generate a sophisticated utilitarian heat engine. The Second Law can only be locally and temporarily circumvented to accomplish *useful* work through formal controls, not through spontaneous physicodynamic constraints. Without choice contingency and its controls and regulations, no locally sustained circumvention of the 2^{nd} Law would be possible. Physicodynamic behavior would always quickly revert to obeying the 2^{nd} Law in the absence of formal interventions. In one sense, the 2^{nd} law is always obeyed physicodynamically, even in open systems. But in another sense, the instantiation of formalisms into physicality allows local systems to temporarily overcome the overall natural trend towards disorganization. The ability to purposefully dichotomize physical objects into formal categories and to organize and integrate pragmatic processes and procedures are formal accomplishments, not physicodynamic chains.

Constraints alone simply do not integrate, organize, or optimize algorithmic function. Constraints, including spontaneous initial conditions, forces, and the deterministic cause-and-effect chains of nature, cannot compute, program, or craft nontrivial formally creative machines. Constraints cannot generate representational symbol systems or linear digital prescription of any kind, including the genetic instructions that prescribe regulatory proteins and micro-RNAs. Without formal controls that select and organize physicodynamic constraints, we would have no complex machines, no computers, no buildings, no bridges or any other kind of engineering marvel.

6.2 Configurable switch settings

Configurable switches are physical devices that are designed and engineered to be set by choice contingency alone. Configurable switches are unique physical entities that are specifically designed to record nonphysical formal decisions into physical reality. The switches are themselves physical. Physicodynamic action is required to flip the switch. But with respect to *which switch option is chosen,* they are physicodynamically inert. Controls, therefore, can be instantiated into physicality using physicodynamically indeterminate configurable switch settings [31, 32]. They are not set by chance or cause-and-effect chains. They are physical logic gates with an excluded middle. They provide a means whereby mental choices—formal choices—can be instantiated into physicality.

No more energy is required to flip a quaternary (four-way) switch knob to the right than to the left, or away from than towards the choosing agent. Initial conditions, physical forces, energy requirements, and rate constants are equal for all options afforded by a well-designed quaternary configurable switch. Physicodynamics offers no help in elucidating why a quaternary switch knob was set to one of four possible positions, or why a combination of successive switch settings achieved such impressive correlated formal function.

Can we describe any gradual "degrees of organization" that are possible in the flipping of each binary switch knob? Note that the pictured switch knob cannot be found in a neutral position. The switch is designed with a logical "excluded middle." It will always be found in either the on or off position. Such configurable switches are designed to record yes/no, on/off, 1/0 purposeful programming choices. There is no gradation of selection at each individual binary decision node. The switch knob will be found in either the right or left position.

Configurable switches are physicodynamically inert (physicodynamically indeterminate, dynamically incoherent; dynamically decoupled from physical causation)[31, 32]. Rocha sometimes calls this "dynamic discontinuity." The very reason configurable switches are configurable is that their settings are 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). This means that on an old-fashioned horizontal switch board, the force of gravity works equally on all potential switch positions. Physicodynamics plays no role in which way the switch knob is pushed. This is the very meaning of "configurable" switches. Their settings are completely decoupled from physicodynamic causation. They can only be set by formal choice contingency, not by chance or law. It is the freedom of formal choice at configurable switches that makes all forms of formal sophistication possible in any physical system. Nonphysical formalism alone determines each switch setting. The switch is a "dynamically-inert configurable switch."

The switch in Figure 1a happens to be a binary switch. We could have just as easily photographed a quaternary switch. With a quaternary switch, the knob could be pushed away from you, pulled toward you, pushed to the right, or pushed to the left. A quaternary configurable switch represents 2 bits of uncertainty. The option space of four possible equally available nucleotides also represents 2 bits of uncertainty. Each potential add-on locus in a forming single-stranded oligoribonucleotide in an imagined primordial soup adds an additional 2 bits of uncertainty to the strand. The same is true of a single-stranded (positive, instructional) DNA polymer. Each locus corresponds to a four-way (quaternary) configurable switch. The high degree of uncertainty in a potential single-stranded DNA physical matrix is what allows DNA to retain such tremendous amounts of information. Spinelli & Mayer-Foulkes[69] found specific statistical differences between exon and intron DNA sequences, referring to them as "linguistic DNA features." Large numbers of other researchers have found linguistic like properties in DNA PI as summarized by Searls[70].

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.

The formally determined course of the 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. Nonphysical PI is required.

6.3 The selection of tokens from an alphabet of physical symbol vehicles

We spell formal words in our minds through the arbitrary choice of letters from an alphabet of letters. These choices of letters are completely uncoerced by physicodynamic determinism. We then transmit those words through instantiation into a physical medium—sound waves, emails, morse code, hard-copy letters, smoke signals. We also record nonphysical words into physicality by picking physical Scrabble *tokens* and arranging them in an order that corresponds to the formal letter sequence of words in our minds. These are all forms of instantiation of formalisms, in this case language, into physicality.

6.4 Formal prescription and integration of physical components into machines

A cake is physical. Yet it comes into existence only through organizing a list of needed ingredients and following the (PI) found in a formal recipe explaining the process of how to bake that cake.

Not only does life not spontaneously generate (The First Law of Biology [Rudolf Virchow, 1858], "All life must come from previously existing life," has never been falsified), sophisticated machines do not spontaneously generate. Individual parts must be crafted and manufactured to particular specifications. Then those parts must be assembled in a very specific way so as to generate a device that can perform some desired task. The level of sophistication required to eliminate chance and/or necessity as a plausible hypothesis for generation of a machine is pretty minimal. Consider the relatively simple machine of a paper clip visualized in Fig 1 of Chapter 1. The most common form of paper clip is nothing more than a long cylinder of malleable metal alloy and constant diameter bent back on itself. How many paper clips in the history of human observation have been observed to spontaneous self-organize from iron ore in the ground?

Science is about repeated observation and predictability. If a simple paper clip has never been observed to spontaneously generate from inanimate nature, what gives us permission to declare as scientific fact that the lowest order conceptually complex machines spontaneously formed in inanimate nature? The supposedly simplest archaea or eubacteria contains hundreds of thousands of nanocomputers, operating systems, softwares, biochemical pathways and cycles leading to exquisite organization and the relentless pursuit of the goal of staying alive. Inanimate physicodynamics can achieve none of the above. It can't even perceive function, let alone pursue the goal of and program a potential computational function that doesn't even exist yet.

7. Physicodynamic Determinism vs. Programming Determinism

We are accustomed to using the term "determinism" to refer to inanimate physicodynamic cause-and-effect chains. Physicodynamic determinism is the source of the term "necessity." Events are necessary because they are invariantly caused by the orderliness of fixed relationships in physical inanimate nature. But in reality, two kinds of determinism exist—1) physicodynamic and 2) cybernetic:

7.1 Physicodynamic determinism

The forced exerted on an object is equal to its mass times its acceleration (F = ma). This mathematical relationship that we call a "law" is fixed—invariant in classical physics.

Physicodynamic determinism arises out of cause-and-effect chains. Physicodynamic interactions are governed by the orderly relationships described by mathematical constants and laws. Except for the effects of seemingly random heat agitation, complex causation interactions, and mild statistical bell curves of variation, the orderliness of macroscopic physical interactions is largely fixed. Contingency, including both chance contingency and especially choice contingency, is precluded. No freedom exists in these fixed physicodynamic relationships that would permit selection of some paths and rejection of other paths. Thus, we refer to such largely inescapable cause-and-effect chains as "necessity.' To try to extract any type of programming freedom at decision nodes, logic gates, or configurable switch settings from "necessity" is ludicrous. No yet-to-be discovered "law of self-organization" could logically exist. Laws describe incontrovertible regularity, not selectable bifurcation points. For a configurable switch to serve as a logic gate requires that this switch be specifically designed to provide a unique purpose. The setting of the switch must be independent from the physicodynamics of the switch itself. The switch setting must be "physicodynamically inert" or "physicodynamically indeterminate." Although a physical device, it can only be set by nonphysical choice contingency. None of the four fundamental forces of nature determine *how* the switch is set—which direction the binary switch knob is pushed.

Why do we call physicodynamic relationships "natural?" We define these relationships and predict with them using nonphysical mathematical formulae and equations. All mathematics is formal. Mathematics is abstract, conceptual, choice-based, and requires use of a representational symbol system. Mathematics requires rules, not laws, to govern the voluntary behavior of mathematicians. Mathematicians are free to err. Their calculations are not forced by deterministic laws. But if they expect to derive utility from their mathematical manipulations, they had better obey the purely formal rules of mathematical deduction. If they want their scientific conclusions to be valid, they had better obey the rules (not laws) of logical inference. And they must make wise choices at every decision node. Yet there is no opportunity for choice within physicodynamic determinism.

In addition, all mathematics in physics flows from unproven mental pre-assumptions called axioms. There is nothing about axioms that is physical or "natural" in a physicodynamic sense. The same is true of the rules of equation manipulation.

Most of physics consists of manipulating these mathematical expressions and predicting based on their formal calculations. We can know what the physical outcome will be before anything physical happens. There is nothing "natural" about such purely mathematical prediction fulfillments. To try to call physics and the subject of physics "natural" in the sense of insisting both are derived from a mass/energy explosion is laughable. Einstein rightly pointed out the impossibility of ridding science of metaphysics. He tried his best to minimize metaphysics, with poor success.

7.2 Cybernetic (programming) determinism

Cybernetics is the study of control. Cybernetic determinism programs PI (see Chapter 1, section 4). PI either instructs or indirectly produces (e.g., via already-programmed computational robots) formal function and organization. Cybernetic determinism arises only out of choice contingency. Purposeful choices have to be made at bona fide decision nodes, logic gates, and configurable switch settings. Programming choices, a form of control, determine computational outcomes and the pragmatic value of operating systems and softwares.

Choice contingency and its effect can be a lot more dramatically determinative than the fixed and boring orderliness of nature. Choices matter. Programming and computational capabilities are endless. The utility that can be generated by cybernetic determinism is mind-boggling. Cybernetic determinism alone integrates elements into a holistic cooperative scheme. Bona fide organization is always the result of cybernetic determinism, not mindless inexorable physicodynamic regularity.

The determinism of choice contingency is realized only after the choice is made. At that point, cybernetic determinism becomes theoretically formally absolute with a probability of 1.0. At the moment a binary switch is *re*set, however, the probability returns for an instant to 0.5 with one bit of Shannon uncertainty. Once reset, it immediately returns to p = 1.0. Cybernetic determinism, being formal rather than physical, is by far more definitive and absolute than the so-called "necessity" of physicodynamic causal chains. Because of heat agitation, quantum and other stochastic factors, the so-called necessity of physicodynamics must be described with a certain bell-curve relativism. Once absolute cybernetic determinism is instantiated into a physical medium, however, then the physical medium's relative "necessity" takes over (e.g., a physical configurable switch could malfunction in accord with the 2nd Law).

Physical tokens can also be arbitrarily, yet purposefully, selected from an alphabet of tokens within a material symbol system. Deliberate selections for potential meaning or function are made from an alphabet of symbols and a lexicon of word-like short symbol sequences. The same is true of nucleotide selections and amino acid selections during biopolymer formation. For nucleic acid and sRNAs to wind up functional, their sequencing must be proper before they prescribe or fold. The rigid covalent bonds between monomers provides cybernetic determinism of potential formal function at the level of molecular and genetic construction. Only later is it realized that the sequencing is cybernetically determinative of a certain folding, three-dimensional shape, highly sophisticated biofunction and contribution to system integration.

Choices acting into the physical world don't violate physical laws. But such control choices can temporarily circumvent or make use of physical laws to achieve formal function.

Although statistical differences and patterns distinguish one linear digital prescriptive string from another, no PI exists because of probabilistic combinatorialism [59]. PI only exists at the moment a particular choice for potential function is made [8]. When a nucleotide is rigidly (covalently) bound to the single-stranded string, the four-way configurable switch knob is figuratively pushed in one of four possible directions. At that moment all Shannon uncertainty is replaced with *formal CCC (Choice-Contingent Causation)—cybernetic determinism*. The vector of the four-way switch knob is determined by choice, not by physicodynamics or chance. It is only when one of the four options is actually selected so as to prescribe potential function that PI comes into existence. It is only when that choice initiates movement of the physical switch knob in one of the four directions that formalism is instantiated into physicality."

8. Conclusion: Prescription, regulation and control require Choice Contingency

Constraints should never be confused with controls. Constraints refer to the cause-and-effect deterministic orderliness of nature, to local initial conditions, and to the stochastic combinatorial boundaries that limit possible outcomes. Bits, bifurcation points and nodes represent "choice opportunities," not choices. Controls require uncoerced purposeful selections from among real options. Controls alone steer events toward formal pragmatic ends. Inanimacy is blind to and does not pursue utility. Constraints produce no integrative or organizational effects. Only the purposeful choice of constraints, not the constraints themselves, can generate bona fide controls. Configurable switch settings allow the instantiation of formal choice contingency into physicality. While configurable switches are themselves physical, the setting of these switches to achieve formal function is nonphysical and physicodynamically indeterminate—decoupled from and incoherent with physicodynamic causation [31, 32]. The mental choice of tokens (physical symbol vehicles) in a material symbol system (MSS) also instantiates nonphysical formal PI into physicality. The essence of any formalism is the exercise of purposeful choice contingency.

In a formal process, bifurcation points become true decision nodes when choice with intent determines the selected path. Anticipation and planning are involved prior to the commitment. Deliberate choice of path makes possible unlimited design and engineering successes. Nontrivial function is only achieved through selection *for potential function*. When purpose, goal, and intent are removed from the equation, "choice" becomes the equivalent of random number generation.

Three pressing questions are of immediate interest to ProtoBioCybernetics:

> 1) What are the necessary and sufficient conditions for turning physicodynamics into controls, regulation, organization, engineering, and computational feats?
>
> 2) How did inanimate nature give rise to a formally-directed, linear, digital, semiotic and cybernetic life?
>
> 3) How does nonphysical volition arise out of physicality to then establish control over that physicality?

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