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Freedom, Determination, and Causality

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Despite centuries of analysis, problems of "determinism," issues surrounding agency, the freedom of agency, personal causation and responsibility of individuals for their choices, still abound. Up to the minute literature is based upon analyses from 18th century figures such as Kant (Onof, 2024). The situation seems to be similar to Talmudic or Shakespearean scholarship: literature often devolves into discussion of how a given scholar's interpretation of another scholar is incorrect (and theirs better), continually moving farther and farther from fundamentals. Often lost in "determinism versus free will" is any sense of perspective on what advances in knowledge from other fields (and newer ones) have on major issues; such as age-old problems of how advances in science (and technology) ramify back through philosophical issues. New data change the battleground, eliminating issues and possibilities without ending legitimate discussion (Weimer, 1976). Classic problems have been solved by more recent analysis, creating in turn new problems in their stead. Advances in physics, psychology, complexity, biosemiosis, and origin of life studies paint a new picture of the problems of determination, and supply a new canvas for them to be painted upon. One fundamental new distinction is between the physical and the functional domains. Another is the difference between rate dependent theories and phenomena in the physical domain, and the rate independent systems of the functional realm. Such distinctions reorient issues away from traditional problems (no matter how "up to the minute") to new formulations. Realization that the functional domain (of semiosis, intentionality, knowledge, etc.) is fundamentally different from, and can and does harness (to use Polanyi's formulation) the law-governed physical domain by employing a system of higher-order constraints, allows us to see there is no incompatibility between agency freedom as higher-order constraint and physical inexorable lawful control. We need accounts in both domains, physical and functional, to complement each other (Pattee, 2012), because either alone is incapable of explaining the complex realms of freedom and determination.

Keywords: determinism, physical vs. functional, free will and agency

"The mind is free in its action — exactly as our common sense knows it to be free. The mind harnesses neurophysiological mechanisms; though it depends on them, it is determined by them."

Michael Polanyi
Knowing and Being, 1969

Dedicated to Raymond Chester Russ, in appreciation for forty five years of stewardship of this Journal.
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> "(E)very event in the world is connected to every other event. But you cannot carry on science on the supposition that you are going to be able to connect every event with every other event.… It is, therefore, an essential part of the methodology of science to divide the world for any experiment into what we regard as relevant and what we regard, for purposes of that experiment, as irrelevant.
>
> We make a cut. We put the experiment, if you like, into a box. Now the moment we do that,we do violence to the connections in the world. We may have the best cause in the world.… To put a fence around the law, to put a fence around the law of nature that we are trying to tease out. And we have to say, 'For purposes of this experiment everything outside here is regarded as irrelevant, and everything inside here is regarded as relevant.'"
>
> Jacob Bronowski
> *The Origins of Knowledge and Imagination,* 1978

The epigraph from Bronowski represented the original Copenhagen interpretation (now the "operational interpretation") of quantum theory, which replaced billiard ball determinism with statistical probabilism. And yet, Bronowski still had to take the opposed view, held by Einstein, that there must be an underlying level of "deterministic" reality beneath the statistical or probabilistic quantum results. Why? Can these opposed views both be correct? How do we reconcile overwhelming experimental support for quantum entanglement (Einstein's "spooky action at a distance"), with extreme *apparent* determinism, with both quantum realm probabilism and with the choice contingency of the mental/semiotic domain of life? With respect to traditional philosophical questions, how can agents (animal or human) be free to determine their own actions if the laws of nature are inexorable every-where, every-when statements, showing only clockwork physical mechanisms? In short, how, if at all, does physical theory relate to semiotic control and genuine novelty in the universe? Polanyi pointed the way to the answer in "Life's Irreducible Structure" (in Polanyi, 1969). His account, and that of biosemiotic theorists influenced by him (and by Peirce) is far more adequate than better known indeterministic ones of Copenhagen physicists and philosophers who opposed that view, such as Karl Popper (1972, 1982). To see why we must delve into some history.

Basic issues. What happens when events follow events? What principles of order specify the relationships that, once we have classified events into like kinds and classes, can be said to obtain between them? As complex creatures in uncertain environments we have had to evolve to respond to *relatively* invariant aspects of external (and our own internal) environments to have gotten to the point where we can ask such questions. Then problems of knowledge and its acquisition, of what scientific inquiry is and can disclose, and the nature of human conduct immediately arise.

Traditionally such problems are found in philosophy, centering around free will and/or determinism, "chance" and/or necessity, and personal responsibility versus coercion (for individual conduct). The classic problems have all been resolved, and no longer appear except in introductory philosophy or psychology classes as examples for beginners to discuss. The classic problem of "free will" was decisively resolved decades ago by Dickinson S. Miller (under the pseudonym of R. E. Hobart), in a paper whose title alone ends the original issue: "Free will as involving determination and inconceivable without it" (Hobart, 1934). Miller pointed out that one cannot possibly have agency, or have what we call freedom of choice (or "will"), unless one's *own actions* "determine" our choices.

This simultaneously solves the problem of free will and moral responsibility for *voluntary* action. For now, note the crucial point: the "Hobart" paper specifies *determination*. In earlier centuries "hard" science (for example, on the usual interpretation of 19th century physics) "determination" would have construed this as "billiard ball" causality or as strict *determinism and necessity*. In psychology, Freud's plumbing of depth psychological causation of overt issues would have been and remains so interpreted. Indeed mid-20th century behaviorism proposed to dispense with freedom and dignity and provide a "scientific" account in terms of deterministic contingencies of reinforcement alone (Skinner, 1976). In billiard ball interactions of atoms in the void nothing is left to "chance" (except the description of individual ball draws from absolutely uniform urns according to rigid statistical "laws" of probability). Everything is causal necessity (and chance "probability") determined by strict principles called laws of nature, which is what "billiard ball" determinism consists of. The "will" (choice contingency) seemed to be absent from discussion except for a few old-fashioned philosophers.

But what if *determination* is not exhausted by determinism? What if laws of nature do *not* cover everything? What if the universe as a whole is *indeterministic* instead? What if our agency *is* "free to choose" what we do instead of being physically determined? How can we account for obvious "constant" regularities in nature and agent (principally human) behavior if determinism does *not* hold, billiard ball causality is *not* the necessary connection between events, and prediction and control are *not* indispensable to science? In point of fact, all these "not" claims are true statements.

Understanding this requires we explore problems of novelty (emergence) in the physical and functional domains (clearly distinguishing physicality from functionality), and how emergence can be explained in spontaneously organized complex phenomena. Here, while determinate, nature is nondeterministic and non-necessitarian. Although hinted at in antiquity, this has come to be adequately understood only since the beginning of the 20th century with problems posed by the "new" or quantum physics, the dynamic picture of economic activity from the "Austrian" school of economics research into the market order and culture in the 1920s and 1930s, the rise of the transformational approach to the complexity of language in the 1950s, and developments in logic and computation theory from Gödel and Von Neumann from the 1930s to the 1950s. More recently has come the field of biosemiotics, returning to the study of semiosis (meaning and agency) as the definitive characteristic of the functional domain, while semiosis is totally absent from the physical realm. Developments in such fields have shown the inadequacy of explanatory ideals and presuppositions of inquiry that held sway until the quantum revolution (and remain current in many areas).

We begin by exploring the classic deterministic account at its strongest. Brand Blanshard presented a clear and coherent account of the deterministic, and therefore necessitarian, position.

Blanshard on determinism and necessity. Completing his training in the 1920s, Blanshard was familiar with the "new" physics of the quantum, and the equally new and brash philosophy of logical positivism. More sympathetic to Russell, he took Russell's critical analysis of realism (that eventually led Russell [1948] into structural realism) to be a refutation of realism rather than a refinement, opting instead for idealism. His guiding principle was the doctrine of internal relations (or as he preferred, internal relevance). This metaphysical view holds that human understanding consists in grasping the necessity of relations between things. To explain something is to see it as necessitated within a system of relations, a definitive context of constraint, within which it *must* then occur as it in fact does occur. Reality is not just a consistent whole, but rather a positively coherent and unified one, united by necessity, and thus operating totally deterministically. Given sufficient information (which he admits it is never possible to actually possess) it would be possible for Laplace's demon to "predict" the entire fate of the universe from a complete knowledge of its initial conditions. His working hypothesis for philosophic and scientific inquiry was that if the correct relations of internal necessity could be found we would know everything that could be known. Notice at the outset that this position says *nothing* about reality (ontology), as it is only an epistemic (knowledge) doctrine.

Discussing indeterminism and "free will," Blanshard put it this way:

> He [the indeterminist] is not saying that there is any event to which some nameable antecedents are not necessary; he is saying that there are some events whose antecedents do not make them necessary. He is not denying that all consequents have necessary antecedents; he is denying that all antecedents have necessary consequents. He is saying that the state of things just before he decided to tell the truth might have been exactly what it was and yet he might have decided to lie. (1961, pp. 19–20)

Against this Blanshard defined determinism this way: "by determinism, then, I mean the view that every event A is so connected with a later event B that, given A, B must occur" (ibid., p. 20). Echoing Hobart on free will he states: "the real issue, so far as the will is concerned, is not whether we can do what we choose to do, but whether we can choose our own choice, whether the choice itself issues in accordance with law from some antecedent" (ibid., p. 21).

One should note the change from the event A necessitating B to *choice* following from law (from ontology to epistemology), an uncharacteristic lapse for a clear thinker. Unfortunately, we will see this confusion of epistemology and ontology plagues most writers on determinism. No doubt this occurred in Blanshard because he held the principle of internal relevance to apply equally to events and to laws about those events, even though this is a category mistake as Ryle (1950) used the term. But let us accept the Hobart formulation as to conduct (as far as it goes) at this point. Then the issue is whether *determination* is restricted to *determinism*. Must our choices (in conduct, theory construction, knowledge acquisition, or whatever) be restricted to necessary consequences by strict determinism? Are there, allowing Blanshard's definition, events whose antecedents do *not* make them necessary? At that time physics was coming to exactly that conclusion. Blanshard dismissed the conclusion.

Addressing that indeterminism in physics, Blanshard countered "Physicists now tell us that descriptive statements about the behavior of bodies are really statistical statements.… Hence to speak any longer of nature as governed ultimately by causal laws — i.e., statements of precise connection between antecedent and consequent — is simply out of the question" (ibid., p. 23). His conclusion is that such reasoning amounts to an argument from ignorance. Historically, "When things happened whose causes were unknown, it was assumed that they had causes nevertheless. To assume that a frustration of present knowledge, even one that looks permanent, is a sign of chance in nature is both practically uncourageous and theoretically a *non sequitur*" (ibid. p. 29).

Even if the indeterminist argument in physics is accepted, Blanshard held it must be irrelevant to human behavior. We are not single particles. Thus:

> The question of importance… is whether, if acts of choice are dependent on physical processes at all, they depend on the behavior of particles singly or on that of masses of particles. To this there can be but one answer. They depend on mass behavior.… So, even if the physicists are right about the unstable behavior of single particles, there is no reason whatever for translating this theory into a doctrine of indeterminism for human choice. (ibid. p. 25)

Note that the "assumption" Blanshard relies upon cannot ever be tested empirically — it is what Popper and his students (e.g., Watkins, 1958) called a "haunted universe" metaphysical doctrine. Such positions (like the doctrine of atomism and the idea of a plenum universe) have been fruitful in physics as suggestive sources of testable theories, even though they themselves (as metaphysical conjectures) can never be refuted, and thus are not scientific.

Things have changed since Blanshard's metaphysical commitment to determinism seemed reasonable. Determination in relation to physical necessity has given way to the problem of agency control. The necessitarian view can no longer be accepted — choice in agency can and does *supervene* over physical determinism when agents are involved. Functionality constrains physicality. And the laws of nature are not themselves "physical" phenomena, but rather functional (i.e., mental or theoretical constructs) *approximations* of physical phenomena existing in our conception. Never confuse issues in ontology with epistemology. To see this we first detour through what happened in physical theory.

Schrödinger's cat and the death of classical determinism. An enormous literature defends the "new" normal science paradigm shift to indeterminism. Two main features of that shift are, first, realization that what had been regarded as rigidly deterministic "laws" had been based upon the tacit assumption of an infinite number of observations (measurements) supporting definite results when in fact all empirical results that are ever available are finite, by definition *incomplete* representations, statistical in character, and subject to error; and second, all the taken-for-granted every day marvels of 21st-century life (e.g., genetic engineering, microwave ovens, computers, and thousands more) would not exist were it not for acceptance of quantum results that depend upon indeterminacy at that realm ramifying into the phenomenal one of molar behavior in the manifest image of day to day life (Gribbin, 1984). So the quantum theory "cookbook" makes marvelous meals every day, and the recipes it utilizes are inherently statistical and quantal rather than deterministic.

Writing in 1931, Schrödinger summarized the situation:

> 50 years ago it was simply a matter of taste or philosophic prejudice whether the preference was given to determinism or indeterminism. The former was favored by ancient custom, or possibly by an a priori belief. In favor of the latter it could be urged that the ancient habit demonstrably rested on the actual laws which we observe functioning in our surroundings. As soon, however, as the great majority or possibly all of these laws are seen to be of a statistical nature, they ceased to provide a rational argument for the retention of determinism. (1935, p. 67)

In contrast, Blanshard held determinism as a metaphysical a priori *belief* and simply disregarded empirical results that had overwhelmingly accrued prior to his defenses of the doctrine of internal necessity. But what of this metaphysical notion of internal necessity? Can it be reformulated in terms of the connection between observed results and observers in a hopelessly intertwined quantum experimental situation? That is the import of the emphasis upon the inseparability of the observer from both the results of experiments and the *entire* experimental situation in which both observations and results occur. Consider first Schrödinger's and Wigner's (1961, 1964) interpretations of the role of the observer in knowledge.

Preliminary excursus: State vectors and discontinuity. According to the classic phenomenalistic or Copenhagen interpretation, the *information* (whatever that is remains ill defined, and that fact is likely responsible for many physicists failing to distinguish ontology from epistemology) available about the possible states of the quantum system can be characterized in quantum accounts by state vectors that can change in *only* two ways. Due to temporal succession, they change continuously, according to Schrödinger's (1956) time-dependent equation (equations of motion). The state vector also changes *discontinuously*, in probabilistic fashion, *as a result of measurement operations* performed on the system. The problem of measurement *on the object* leads inevitably to the problem of observation *on the measuring apparatus*. This latter step is the epistemically problematic one (where the ontological quest is stymied in epistemic limitations) and concerns what, for Bohr and Copenhagen followers, is known variously as "the reduction of the wave packet or function" or "the collapse of the state vector." (Note particularly that the probabilistic aspect of the theory is located quite far from what "ordinary experience" would expect: one would assume probability laws to govern the change of the system over time, such that interactions of particles would be statistical. But the uncertainty of the system does not increase over time if it is undisturbed by measurement — in such a case change in the state vector is "causal." So-called chance or probability enters with epistemology (with the problem of knowledge *about nature*) in the move from physical to functional, when one *observes* the system in order to judge if it changed in the manner predicted by the equation of motion. Note also that this slip from epistemology to ontology is what later enabled DeWitt's (1970) interpretation of Everett's (1957) dissertation to be an ontological speculation (about "many worlds"). It is the *functional role* of that consciousness (or even purely physical measuring apparatus), *not* anything physical, that gives the meaning of the result obtained. There is no possible purely physical theory specification of function — of semantic information or meaning. Quantum *measures are always semantic* rather than syntactic, and thus fundamentally ambiguous until interpreted in the context of relevant theory and fact.

The cat "paradox." Another way to show the ambiguity in quantum measurement is to recast the situation as Schrödinger did, as a hypothetical experiment in which a single photon passes through a half-silvered mirror. This photon will either be reflected or transmitted through the mirror. If it is reflected, nothing happens. If it is transmitted, it activates a photocell that poisons a cat that has been placed in a small sealed and isolated box. After this "experiment" is over, *but before anyone has looked*, the wave function that represents all the information that quantum mechanics can specify for the combined system is a linear combination of functions representing a dead cat and functions representing a live cat. Indeed, given all the information that is available to quantum mechanics which, remember, is nondeterministic, it is impossible even to say that the cat is either dead or alive! When, however, an observer looks inside the box she will see that the cat is alive or that the cat is dead — which seems to "adjust" the "epistemic" wave function to an ontological reality accordingly. The point is that functional cognitive (actually epistemic) intervention on the part of an *agent* capable of making choices — in the form of the choice of ultimate *interpretation of the meaning* of the system — is necessary to remove an intolerable ambiguity about the cat's existential status.

This ambiguity exists until meaning is provided, which then interprets the result. It is not consciousness that is indispensable, as Wigner suggested, but the requirement that meaning assign definite interpretation to an inherently ambiguous "experimental" ensemble of events. J. A. Wheeler later extended this type of result into the quantum entanglement paradigm, with the empirical outcome that it is the presence (or absence) of meaning that "determines" the result.

Opponents of the Copenhagen interpretation utilize situations such as the cat paradox to argue for the incompleteness of quantum mechanics as a full description of reality. David Bohm (1957/1971a, 1971c, 1976), exponent of a hidden variable approach, suggested that in addition to the wave function, there must be specified further parameters that tell what the actual state of the system is after interaction but before "looking." Such information can only come from a "sub" quantal level of analysis that would explain the observed effects "up" at the quantum level. Bohm's arguments led to what came to be known as the Bohm quantum potential underlying the quantum level of analysis. If his approach were successful, it would show that quantum theory is not a complete description of reality while also leaving it an apparently complete description *at its own level* of analysis. Even if successful, this or any other hidden variable approach (such as Wheeler's quantum "foam," whether as "local" hidden effects or otherwise) must still explain why ascription of meaning has the effect that it does (Endnote 1).

Excursus: *Entanglement and non-locality*, *and determination.* Consider the sort of mutual entrainment that occurs at the quantum level when two (or more) potentially separate entities are put together or paired. Quantum entanglement occurs when pairs (or groups) are generated together or are made to interact so that the quantum state of each constituent cannot be determined or described independently of the other constituent(s), even when they are separated by great distances. Entanglement occurs when the quantum state must be described for the system *as a whole*. For the purpose of analysis, it becomes necessary to regard such pairs or groups as a single entity despite spatial separation of the components.

Non-locality is different from entanglement (despite the separation of parts of pairs implying "instantaneous" transmission of information from one location to the other). Entanglement has been seen as a basic "fact" of quantum life since experiments begun by Alain Aspect (beginning in 1982) indicated that faster than light correlation between entangled entities does indeed occur. The domain of quantum computation could not exist as it does today unless the fact of entanglement were presupposed. Entanglement is necessary but not sufficient for a two-party state to be nonlocal. Non-locality is a more generalized notion of quantum theoretical formulations dealing with the general question of Einstein's "spooky action at a distance." Regardless of these differences, one can ask if either concept restores determinism.

The answer is "No." Entangled pairs as singular conceptual entities still run into the uncertainty principle and statistical determination sooner or later. In the case of non-locality as a conceptual issue, it is not clear what determinism could possibly mean. In an entangled account the classical billiard balls were *never* separated singularities, so one could not ever "cause" another to do anything in any deterministic sense. In a Bohmian enfolded universe there is only a constant movement process which folds and re-folds. While the rate independent (timeless theoretical) factors such as the conservation laws would likely apply the same way as in classical systems, it is not clear how theories of the rate dependent (physical) processes would be deterministic in any usual sense.

Bohm discussed this, well before his enfolded universe views were developed:

> There is no case where those laws (of nature) are completely satisfied — there will always be some discrepancy between the predictions of an underlying determinate law and any set of laws of probability. This discrepancy, I think, is an advantage rather than a disadvantage. First of all we do not know that any set of laws of probability is absolutely and universally true — we only know that it is true in some approximation and in some domain. From the point of view which I am proposing this is hardly surprising as single events are always dependent on an enormous number of factors which fluctuate in a very complicated way.… There has been a general tendency to stress the fact that laws of probability contain causal laws as a limiting case, but it goes the other way as well. If you take a causal law as a limiting case of a law of probability it will not be a perfect causal law but only an approximate case; and if you take a law of probability as a limiting case of a causal law it will also be only an approximate law probability. So if you suppose the infinity of nature then — no matter how far you carry the laws — there will always be something outside, something that gives rise to fluctuations. Hence no causal law can be perfectly exact. On the other hand, however, every fluctuation comes from some causes and therefore no law of probability can be perfectly exact.… So in reality events are related by causal laws and by laws of probability as well as by still other kinds of laws which have not yet been developed. (Bohm, 1957/1971a, p. 84)

Those other kinds of laws "not yet developed" were what he attempted to specify in the determinate regularities of his later enfolded universe view. Whatever they may be, they will be formulated in the totally deterministic timeless or rate independent domain as general statements of determination. Whatever occurs in the indeterministic rate dependent or dynamical existence of the universe will only be linked to such laws by identification or postulation (see Körner, 1966), and thus the only conceptual necessity will remain in our rate independent theories and can never be known to actually exist in the dynamics of the real world events. We continually forget that that presumed linkage is our conceptual creation, and not anything more (Endnote 2).

Bell and the postulate of "superdeterminism." As an intellectual exercise John Stewart Bell (2004) proposed that one could "explain" entanglement phenomena by postulating a superdeterminism, in which chance and accident did not ever exist, and the entire history of the universe had been fixed or known *in advance* of its actual existence (perhaps by Laplace's demon God who existed independently of the universe as a whole). This would "solve" the problem of faster than light entanglement because the universe would already "know" what the separated but entangled particles were going to do, and thus their behavior would be "determined." Is such a metaphysical postulation of any benefit?

Of course not. First of all, superdeterminism is just plain old metaphysical determinism. All determinism is "super," or "specified in advance." As such, it is a Popperian haunted universe metaphysical doctrine (Watkins, 1958), completely untestable and utterly uninformative as to the nature of reality, since no matter what happens (or doesn't happen) it is "compatible" with this postulate. Useful metaphysical doctrines (such as atomism) suggest theories and research that are testable (i.e., have empirical content, which is to say, specify consequences which are *forbidden to occur* if the theory is correct). Bell's "super" postulation does not do this, and cannot be repaired in any manner to make it testable — it (by definition) simply has no empirical content at all. Thus this exercise does not "explain" the phenomena of entanglement or, indeed, anything else.

Complex Phenomena and Determinism at the Functional Level of Existence

Prediction and the novel growth of knowledge and language. Since the 1950s another line of attack has been made against metaphysical determinism at the functional (not physical) macro level of the growth of knowledge and the genesis of novelty. This argument is fatal to strict determinism and predictability without going "down" to the level of sub atomic physics. It is based upon the existence of genuine novelty (that is, completely unpredictable occurrences) in the growth of human knowledge and in the genesis of behavior. When properly understood, it becomes obvious that our behavior is the result of abstract rules of determination, constraints that redefine what we mean by causality, forcing a reformulation of what constitutes scientific understanding in functional realms of complex spontaneous orders such as language and market processes. Although they arose independently, two arguments have been developed that are two sides of the same coin. First in impact was the transformational revolution in linguistics, emphasizing the productivity or creativity of human language, and thus the inadequacy of deterministic models of language (and hence, all cognition around language). Second was the impact of Popperian arguments (based upon Karl Bühler's account of language) emphasizing unpredictability in the growth of knowledge, and thus the impossibility of a linear surface structure or billiard ball account of language in the acquisition of knowledge. Consider them in turn.

Import of the transformational revolution. Until Chomsky's publication of *Syntactic Structures* in 1957, attempts to explain language concentrated upon relating and exhaustively categorizing surface structures. All grammars were phrase structure grammars, attempting to show how the surface components are put together to form sentences. The transformational "revolution" forced the realization that one cannot understand language by more refined attempts to sharpen the "blurred edges" of the statistical picture of the *surface* form of language. We can only account for creativity in language (the generation of novel but appropriate utterances) by coming to grips with the deep structural rules of determination that are manifested in indefinitely extended domains of possible surface particularity.

Transformational approaches explain linguistic surface phenomena by deriving them from abstract rules of determination specifying how deep structural entities (such as S, intuitively understood as sentence, or NP as noun phrase) are constrained to appear in their eventual surface realization. Explanation traces the derivational history of an utterance by listing the successive rewrite rules that change S into the realized surface form. Such explanations manifest how an infinite number of sentences can arise from finite syntactic constraints in conjunction with the finite number of surface words (terminal vocabulary elements) in any natural language. Creativity or productivity, the ability to make (and comprehend) novel but "appropriate" (Brown, 1958) sentences, is a matter of constraint by recursive syntactic structures resulting from rules of varying generating power.

While we now understand how an infinite variety of sentences (where a sentence is a completed meaningful output, a functional rather than physical specification) can be generated from deep conceptual structures, no one can predict either what surface word or sentence a speaker will next utter, nor make any inference from linguistic theory as to the functional cause of any utterance. That is beyond the bounds of understanding in complex domains. Analogous to Boltzmann's impact on thermodynamics in which there is no knowledge possible of the motion of any particular molecule, one result of Chomsky's transformational revolution was the virtual disappearance of attempts to provide causal and predictive accounts of linguistic particulars after the mid 1960s.

Linguistic freedom (another term for creativity) always presupposes rules of order, a context of constraint, in order for it to operate. It consists in the production (to use Brown's felicitous phrase) of "novel but appropriate" utterances. Novelty results in new meanings expressed as sentences through the generative capacity of rules that form syntactic structures. Transformational grammars defined creativity as the result of rules of varying degrees of generating capacity operating on symbols (strings of symbols for rules of transformational power) that produce new strings of symbols. The theory of Post languages (from E. L. Post, 1943, 1965) is the mathematico–logical framework in which grammars, consisting of rules of determination for production of terminal vocabulary items from abstract and non-terminal items, are studied. Even though there is a finite number of rules and terminal and non-terminal vocabulary items, the number of *meaningful* sentences that can result is infinite. All realms of creativity make infinite use of finite means to generate novelty. There is thus an essential complementarity between creativity and constraint. Creativity is dynamically (rate dependently) realized by constraints. No one has seen this more clearly than Howard Pattee (especially 2012). Referring to linguistic creativity as *symbolic* freedom he said: "we now must state the complementary aspect of symbolic freedom, and that is simply the universal requirement of symbol systems that they must have grammatical constraints if they are to have any meaning" (1981, p. 125). Freedom is a problem of meaning no matter where it is manifested, and it results from functional rules of determination rather than from physical laws and determinism.

Rate independent regularity — the products of human conceptualization and theory — is (because it exists only cut off from dynamical reality) frozen for once and for all. As such, it is as "deterministic" as the consequences of a mathematical operation, or a logical deduction (which are our most familiar instances of rate independent regularity). Even though the outcomes are novel and not predictable in advance, they are in a very important sense still "determined" by the iterative conceptual rules which generated those outcomes. They are not due to chance or happenstance or similar notions that have arisen from looking at physical phenomena. They are determinate but not deterministic.

We still need to see how higher-order functional constraints can direct lower-order physical processes that are, in themselves, subject to control by the laws of nature (in conjunction with local boundary constraints). How do we combine (functional) freedom with (physical) control?

Plastic control: Of clocks and clouds. A famous argument by Popper called for indeterminism in physics and, by extension, in the mental realm. He formulated that problem this way: "how can it be that such things as states of mind — volitions, feelings, expectations — influence or control the physical movements of our limbs" (1972, p. 231)? In psychology this became J. C. Eccles' problem of how can it be that physical states of the organism influence its mental states and vice versa (Eccles, 1970, 1976)? Attempts to answer are deterministic whether they emphasize it or not — they are all centralized control point (Popper called them "master-switch") models of control, as for example in Meehl's (1989) resuscitation of the "command neuron" hypothesis. In such cases the body is conceived as a machine (as in Eccles et al.'s [1967/2013] "the cerebellum as a neuronal machine") that is regulated from one or more control centers (as Descartes' pineal gland was supposed to as the "seat" of the soul).

What if such Cartesian approaches put "de cart before de horse"? What if the central problem is elsewhere, in the issue of *how do we combine freedom and control*? Popper felt this latter formulation was fundamental, and identified it as a problem posed by physicist A. H. Compton: What is the influence of meaning upon human behavior?

> There are such things as letters accepting a proposal to lecture, and public announcements of intentions; publicly declared aims and purposes; general moral rules. Each of these documents or pronouncements or rules has a certain content,

> or meaning, which remains invariant if we translate it, or reformulate it. Thus *this content or meaning is something quite abstract*. Yet it can control — perhaps by way of a short cryptic entry in an engagement calendar — the physical movements of a man in such a way as to steer him back from Italy to Connecticut. How can that be? (Popper, 1972, p. 230)

This led Popper to search for *plastic controls* — controls with feedback and hierarchical structure that could learn from their experience. This becomes an evolutionary approach incorporating feedback systems: "My theory… consists of a certain view of evolution as a growing hierarchical system of plastic controls, and of a certain view of organisms as incorporating — or in the case of man, evolving exosomatically — this growing hierarchical system of plastic controls" (ibid., p. 242) Organisms, regarded as a hierarchical system of plastic controls, become systems of clouds that are controlled by other clouds. The "physical" organism is actually an open system instead of a closed and deterministic one. Agency makes "clouds" rather than 19th century deterministic clocks. But Popper had no idea how this could happen (Endnote 3).

This change of formulation — from physical determination to functional control systems — was made without understanding or acknowledgment of the fundamental difference between physical systems and the functional domain of existence in which physical signs become functional symbols and, as higher-order control constraints, select the occurrence of physical events. That understanding came *outside* philosophy, from the origin of life studies, and the physics of symbol systems research.

The causal theory of mind and the issue of dual control. While Popper did little to address causal efficacy in consciousness and the nondeterministic nature of the genesis of language, others clarified what is involved. Polanyi and Pattee (both readily available when Popper was elaborating his [unfortunately contradictory] doctrines of indeterminism in quantum theory and determinism in conscious language) provide the direction in which an answer lies. One can defend both the thesis that language (thus cognition, thought, theory, etc.) is not necessitarian or "determined" and also the causal theory of mind. To do this we must note how certain kinds of purely physical boundary and initial conditions harness deterministic laws of nature, and how "accidents" that are "frozen in time" occur in both physical and functional domains.

The problem is how to beat the second law of thermodynamics without running afoul of the every-where and every-when laws of nature. We must have available sufficient physical degrees of freedom, thus providing a lack of deterministic constraint, to allow agents to be able to choose. Polanyi *solved* this by noting that agency harnesses inexorability. Functionality must constrain physicality rather than being inexorably determined by it. It must provide a *higher-order* form of constraint. There must be dual levels of control, one exercised by the functional mental, and also the physical realm. The use of symbols in the functional mental realm must be free in the sense that they are *under*determined by the laws of nature (and the local boundary conditions). This requires energy degeneracy to avoid thermodynamic limits and inexorable control: The cost of energy expended in symbolizing (thinking in the human case) cannot be large (as is indeed the case with the very low energy "cost" of neural activity), and there cannot be appreciable differences in energy expended for any given symbols (it can't be "harder" or more costly to think or say one word or sentence as opposed to any other). This allows an indefinite number of "thoughts" (neural firings–sentences–words–intuitions–feelings–whatever) to come into existence without being constrained by or in violation of physical laws. This enables a system of *dual control*: as Polanyi (1969) said,

> The mind is free in its actions — exactly as our common sense knows it to be free. The mind harnesses neurophysiological mechanisms; though it depends on them, it is not determined by them.
>
> Moreover, the mind itself includes an ascending sequence of principles. Its appetitive and intellectual workings are transcended by principles of responsibility. Thus the growth of man to his highest levels is seen to take place along the sequence of rising principles. And we see this evolutionary hierarchy built as a sequence of boundaries, each aiming at higher achievements by harnessing the strata below them, to which they themselves are not reducible. (p. 238)

This dual control or hierarchical structuring of differing levels of function allows freedom *within each level* to occur so long as the constraints of the lower level are not violated. Life cannot violate physico–chemical laws of nature, and thought cannot violate the constraints applying to living systems. But due to the downward causation of constraint from higher over lower levels (Campbell, 1974), the "mind" can control our behavior, which in turn can control physical phenomena (that in turn are controlled by the laws of inanimate nature). Earlier Popperian arguments fail to understand this hierarchical *dual* control, and thus cannot begin to address the obvious causal determination of the higher mental processes when it occurs. Looked at from below, each level leaves open and thus indeterminate (*under*determined) the function of the next higher level. Looked at from above, each level imposes (nondeterministic) constraints and controls or "causes" upon lower ones.

Complex functional phenomena and the nature of determination. Physics is not alone in having replaced determinism as strict necessity with determination. In domains of very high complexity, such as the organization of the CNS or the market orders of society, we find it is necessary to abandon the attempt to explain or predict particular events, or (to use Blanshard's terminology) to specify precisely delimited antecedents as causes. All that we can achieve in such domains are "in principle" accounts based upon general rules of order which allow *classes* of events (such as any given particular instantiates) as (energy degenerate) *possibilities,* while prohibiting (if the account is correct) other classes from occurring. Our accounts can address "plastic control" of highly evolved structures by specifying the context of functional constraint that is "causal" (i.e., theoretically well motivated) without being deterministic. These accounts are of *rate independent* (purely formal) specifications of a context of constraint that prohibits the occurrence of particular classes of events in rate dependent (actual empirical) processes. There is no possibility of accounting for complex phenomena by specifying infinite numbers of particulars that must occur or that must be achieved.

Spontaneously organized complex phenomena are biological, social, and (only recently studied) physical phenomena that evolve without conscious or explicit planning (or deliberately imposed "external" controls) according to *internal* regulative principles. They are characterized by decentralized or "coalitional" (as opposed to linear or chaining, or top–down hierarchical) control, unpredictability of particulars, and immense complexity compared with simple systems (Weimer, 1987). They are understandable only in terms of what Hayek (1967) was the first to call *explanation of the principle* rather than the particular. These principles of regulation are rules of interactive constraint rather than deterministic laws. Constrained orders are determinate — regulated by abstract rules or principles — but not deterministic and/or predictable. They are, as Bronowski (1978) and Popper (1972, 1982) emphasized, cloud-like systems that look like clockwork mechanisms. Cloud-like systems, when looked at from the right scale, are clocks.

A precise but unspecifiable definition of complexity. What is "complex" as opposed to "simple?" Spontaneous complexity presents a qualitatively different class of problems from those encountered in "simple" sciences (Weimer, 1987, 2022, 2023). Qualitative differences emerge from quantitative changes in the subject matter: they emerge from simple physical phenomena. They are emergent at a precise but unspecifiable point: *where the least complex rigorous model of a phenomenon is as complex as the phenomenon itself*. For relatively simple phenomena we can, as von Neumann noted, build (physically or mentally) a model of how something works that is less complex than the thing itself: such a model simplifies and economizes to enable us to comprehend the phenomenon. For high complexity the reverse occurs: models are either more complex than the phenomenon, or equally complex, and thus do not enable us to simplify in the attempt to understand. For high complexity we are limited to understanding abstract regulative principles of order rather than ever being able to exhaustively model the particulars (either deterministically, or in the rate independent mode, deductively).

This way of specifying (high) complexity can be called *Von Neumann's conjecture*, stemming from his pioneering work in the theory of self-reproducing automata and the organization of the nervous system. As von Neumann (1966) put it: "It is characteristic of objects of low complexity that it is easier to talk about the object than produce it and easier to predict its properties than to build it. But in the complicated parts of formal logic it is always one order of magnitude harder to tell what an object can do than to produce the object" (p. 51).

Trying to understand the central nervous system led von Neumann to this conjecture. Earlier (1951) he discussed the issues in relation to modeling the visual system: “In this domain a real object might… constitute the simplest description of itself, that is, any attempt to describe it in the usual literary or formal–logical method may lead to something less manageable and more involved” (p 24).

Thus explanation of all particulars by covering laws in complex domains is in the realm of utopian fantasy. Von Neumann’s specification of high complexity (reached when the simplest adequate model of the system is as complex as the system itself) provides a criterion with which to draw the distinction between two very different types of scientific understanding. It delimits areas in which pattern prediction, explanation of the principle, abstract regulation by a (largely negative) context of constraint (Weimer, 2020), etc., are all that human understanding can hope to achieve, from “simple” realms in which we are able to provide explanation of particular events, prediction, “laws,” and so on.

Limits of explanation: *Complexity and explanation of the principle*. Von Neumann’s conjecture leads to this constraint on explanation: it is beyond the capacity of systems to explain (or model) phenomena that are as or more complex than themselves. This limit is reached at self-explanation. The system can only *be* itself, it can never explain itself. An explaining system must be more complexly organized than the thing modeled or explained. No system, such as the human brain, could ever fully explain its own operations (as emphasized by Hayek, 1952/1999). This logical limitation relates back to explanation of the principle — all understanding can hope to achieve in complex orders is explanation of the abstract principles according to which the system is constrained to function. We can never model such systems completely (deduce or predict their particular states), nor corroborate the adequacy of our models in all particulars. Their productivity or creativity — their capacity to make infinite use of finite means — ensures we can never comprehend such systems except in terms of general, abstract rules or principles that generate domains (classes) infinitely rich in particulars.

This limitation must not be confused with the claim that there are:

> Particular rules which no such system could ever state. All the former contention means is that there will always be some rules governing a mind which that mind in its then prevailing state cannot communicate, and that, if it ever were to acquire the capacity of communicating these rules, this would presuppose that it had acquired further higher rules which made the communication of the former possible but which themselves will still be incommunicable. (Hayek, 1967, p. 62)

But what sort of understanding does explanation of the principle provide? *Only* information about the compatibility of classifications or kinds of properties that could be exhibited by the complex phenomenon. Our knowledge of a model’s adequacy, like the evolutionary survival of a species, will be based solely upon falsification (extinction of a species), in that we can learn only that a particular model we construct is incorrect (when it fails to adequately describe the data). A successful model is always a tentative conjecture — it is never "proven" or "true." A good model is one that has thus far survived serious attempts to refute it. A tenable model generates classes of properties that are the same as classes of properties of the complex order, but we can never know that the model is instantiating exactly the same principles that regulate the complex phenomenon. We can conjecture about the abstract principles and test them against empirical particulars, but our knowledge will always be limited to classes of phenomena compatible with given particulars. Explanation is a specification of a possible context of constraint regulating a complex order, it can never be the deduction of particulars in the order.

Rules versus laws. The character of the complex sciences is quite different from that of the sciences of the relatively simple. More obviously metaphysical, they are less directly testable, and incapable of prediction and control of particular events (except in artificially or deliberately restricted and constrained cases). Thus while they are empirical, they are *not* experimental in the sense in which ratio scaled physical research is. The objects of study cannot be separated from complex contexts and complicated boundary conditions like "simple" physical experiments can. Nor can research disclose "laws of nature" such as those occurring in "simple" science. There can be no time independent deterministic relationships such as Newton's famous F = MA. There can be no "every-where, every-when" inexorable laws in the physical theory sense. All we can expect are *pattern predictions* that result from postulating abstract rules underlying the indefinitely large number of surface particulars. Being finite creatures, we could never comprehend the welter of particulars *at all* except in terms of their relationships to general rules of determination. Prediction of particulars, their "exact" quantification, and deterministic laws are utterly meaningless except in realms of low complexity, with finite domains of reference completely specifiable in advance (Weimer, 2023).

Understanding complex phenomena makes use of abstract rules of determination rather than deterministic laws of prediction. Explanation provides classes of possibilities (equiprobable outcomes) held in check by negative or prohibitory rules of determination. These rules forbid the occurrence of particulars of certain classes without restricting us to the specification of any "positive" particulars (individual events that must occur). They address the potentially infinite welters of particularity in complex orders without restricting them to finite systems of simple phenomena.

Control structures and the nature of determination. I have noted four potential control structures or systems that have been proposed for complex phenomena (Weimer, 2023). These are: (1) linear or causal chain theories of the linkage of events; (2) hierarchical or branching "multiple control" theories that require a terminal versus non-terminal vocabulary distinction for the theoretical and surface empirical terms involved; (3) polycentric (Polanyi) or distributed information accounts that require an increase in the proportion of non-terminal vocabulary items to characterize what relationships exist in that system; and, (4) coalitional (von Foerster) control models that generalize polycentric control to n-dimensional systems that are far more abstract and complex than polycentric orders. Note that only the first two classes of theoretical models can be called deterministic. The other two exhibit increasingly more abstract relationships with particulars which can only involve rules of determination rather than laws or determinism. The classic concept of causality becomes divorced more and more from determinism as we move through those other two types of control.

Consider differences in the explanatory capability of these control structures on a complex order that we all possess: the CNS. Is the CNS functionally equivalent to any of them? One way to answer this question is to consider the effect of disruption on possible control models. In a chain, breaking a link terminates ongoing performance at that point: no control is passed over the disruption, and behavior is stopped at that point. Results with cerebral lesions summarized by Lashley (1929) killed chaining models a century ago.

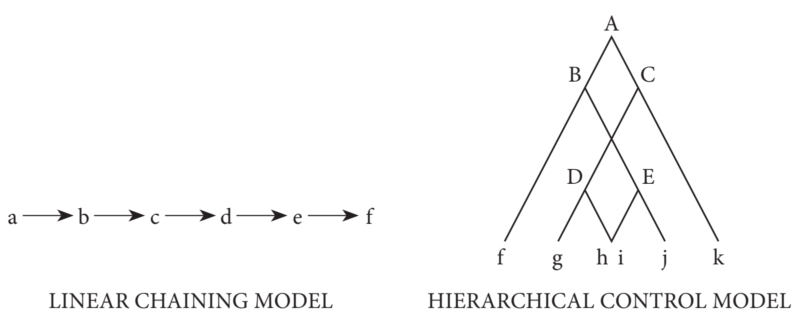

Figure A: Surface structure linear control versus hierarchical (surface distinguished from deep) centralized control. In the hierarchical diagram the control structures are capitalized and the overt surface behavior is represented by lower case letters.

Consider the more powerful hierarchical structure in Figure A. A hierarchical structure is indefinitely more powerful — since the control relations are from top to bottom rather than between terminal elements, this model not only recognizes *deep* structural control of surface particulars, but can survive even the removal (as by Lashley's cortical lesions) of a higher node. But a hierarchy, even with other hierarchies under it as nodes, is still logically a *centralized* control structure with one final initial node functioning as the chief executive (a proverbial homunculus in the head, or a command neuron, or whatever). Do we really have one "upstairs?" No. While our waking consciousness is pleased to be regarded as a *single* self, there is never any evidence to support that hypothesis.

Two lines of evidence from psychology make this point. First is the tacit dimension of all skilled performance. Not only can we routinely recall a difficult problem, but we can do so while carrying on polite conversation as part of our tennis game, or while driving a car (during either of which we are simultaneously breathing, digesting, and carrying on a myriad of other bodily functions). All such performances interact, to be sure, but they are too independent to be controlled by any one hierarchy. One can hold one's breath without disrupting the other activities (except speaking — but one could write the problem down). There is a constant interaction (better: mutual coordination) between highly complicated activities that *in isolation* look like they are hierarchically controlled, but upon examination one can never find a single final locus of control for them all at once.

A second line of evidence stems from Sperry's (1969, 1976) pioneering studies of corpus callosum sectioning. Here we find a plurality of "selves" that are largely independent when commisurotomy or selective anesthesia removes the usual link between our hemispheres. Similar evidence for independence greater than that permitted by hierarchical control has *long* been available, with classic sources such as Teuber's (1960) work with traumatic cerebral insult, and Penfield's (1975; Penfield and Roberts, 1959) studies of direct cortical stimulation. Similar results have corroborated these accounts for decades.

One can see the same problem for hierarchical control in more "basic" biological processes such as the growth transformation of the face and head during aging (Enlow, 1958). The head dynamically remodels entirely — there is no single locus of control directing the remodeling of the face as an individual ages. What we find is a *mutual coordination* of factors that constrain one another, but no determinism and no single ultimate control center (and one should contrast this with extant computer modeling systems).

Examples such as facial remodeling exemplify what Polanyi called polycentric orders. Later von Foerster (1962) and Shaw (Shaw and McIntyre, 1974/2024) proposed a modification of polycentric ordering they called *coalitional control*. The CNS as a whole is not a monocentric system like a chain or a hierarchy: it seems to be a coalition of many (perhaps) hierarchical structures, somehow allied together, but with no single locus of ultimate control. Decentralization of control is one definitive property of coalitions. The second is the lack of determinate specifiable boundaries between the coordinated systems. Clearly perception is not memory or locomotion, but one cannot sharply separate any of the three. The boundaries of a coalition both as a whole and within itself are intrinsically "fuzzy." A third crucial property is that coalitional structures are super-additive: the whole is more than the additive sum of the parts. Emergence is a fact of coalitional life. What a coalition can "do" is vastly greater than the sum of its individually added parts. Graphic illustration may help clarify this.

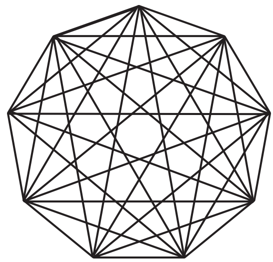

Figure B: Polanyi's polycentric (decentralized) control.

Begin with the simpler models in Figure A. Compare the control relations represented by a chaining model and the hierarchy in Figure A. If we disrupt the chain at the occurrence of surface structure event c, for example, the chain is broken and nothing else occurs beyond it. Removal of hierarchical node D would disrupt surface events at h, but the remainder of the sequence would be intact. Now consider the circular polycentric order in Figure B. The complexity of relatedness here increases as the number of nodes is increased, and the consequence of disruption of any single surface point is minimal in comparison with the hierarchical model. Clearly Polanyi's conception is more adequate (less linearly deterministic) to explaining how the nervous system works than the hierarchical model. It could possibly represent a "simple" system such as the ANS regulation of respiration.

Still more adequate representation of the CNS is found in a coalitional structure, or what Hayek in the 1970s (referring to the social orders) called a *cosmos*. A cosmic structure such as the brain would require a three dimensional sphere with connections through the interior (thus effectively completely filling in the polycentric two-dimensional model and creating a sphere). When one considers the possible interconnections of 100 billion neurons and a trillion glial cells, the sphere is effectively solid: anything is connected with everything, and anything can, as part of a large pattern of activity, "control" anything else. Thus we can "see" why coalitions have fuzzy boundaries and super-additive capacity compared to linear models. We can better appreciate von Neumann's remark that "the order of complexity is out of all proportion to anything we have ever known" (1951, p. 24). Classical simple accounts, such as strict determinism, simply have no place here. "Control" is in the patterns of activity, not their anatomical location.

Research on cortical structural and functional organization has long since made it obvious that the brain functions as a distributed information processing system that is effectively coalitional. Mountecastle (1978) noted three findings in this regard. First, the neocortex is constructed by cloning identical multicellular units or modules. The module is a vertically organized or columnar group whose functioning is similar throughout. Second, the extrinsic connectivity of larger entities is much greater than earlier research recognized. Third, the modules of large entities are themselves fractionated into subsets, linked to similar submodules in other entities. The effect of all this is to corroborate a picture of distributed systems linked in echeloned serial and parallel connections. As Mountecastle noted, "information flow through such a system may follow a number of different pathways, and the dominance of one path or another is a dynamic and changing property of the system" (p. 40).

This *dynamic* coalitional capacity, allowing a flow of constantly changing "control" points to act as though they were the "command neuron" or deterministic cause of subsequent events, is what provides determin*ate* but not billiard ball deterministic "control" in the nervous system. It is what separates humanity from all known "deterministic" machines, including conceptual devices such as Turing machines, so long as they are assumed to compute in discrete steps.

Co-occurrent enablement. Even so, one could assume these differences in control models simply increase the complexity of the billiard ball control structure and make it harder to trace out. Are there cases in which things "just happen" without, to return to Blanshard's criterion, having "antecedents which do not inevitably have necessary consequents?" What happens when a coalitional "control" framework is so amorphous that it is just a loose conjunction of constraints? Can there be antecedent events or situations which do not necessitate consequent events or situations? An example of coalitional structuring that fits this specification in emergent evolutionary domains is Kauffman's (2019) conception of enabled rather than caused emergence. Here there are antecedents (often many) that do not have any necessary causal connection to the emergent novelty that is their consequent.

Consider Kauffman's example of a Darwinian preadaptation (exaptation): the swim bladder. Some fish have a bladder that holds air, and by accident of the fish living in water, some water enters. Some fish have subsequently evolved swim bladders from this accidental conjunction.

Paleontologists think swim bladders evolved from the lungs of lungfish. Water got into some lungs, which now had a mixture of air and water and were poised to evolve into a swim bladder:

> With the swim bladder's emergence, a new function came to exist in the biosphere: neutral buoyancy in the water column.… Might a worm or bacterium evolve to live only in swim bladders? Yes, of course. So the swim bladder, by existing, opens a new crack in the floor of nature, to borrow from Darwin, and a worm can live in that new crack.
>
> And there is still more: does the bladder *cause* the worm to evolve to live in the swim bladder? No. The bladder enables the worm to evolve to live in the swim bladder — a subtle but crucial difference.… The mutation in the worm that is part of the evolution of the capacity to live in swim bladders is itself a random quantum event. Much of the becoming of the biosphere has to do with *making possible*.…

> Natural selection played a role in "fashioning" a working swim bladder. But did natural selection fashion the swim bladder such that it constituted an adjacent possible empty niche in which a worm could evolve to live? NO! But that means that without selection accomplishing it, evolution creates its own possibilities of future evolution! Evolution, without selection achieving it, evolves its own future pathways of becoming! (Kauffman, 2019, pp. 116–117)

Functions cannot be "predicted" or prestated from physical events. Consider the uses of a screwdriver: there is literally an indefinite number of them, and in the future there will be an indefinitely new number of them that just "emerge." No physical theory can ever explain or predict the emergence of a new use for a screwdriver. Physical determination can occur only in a phase space in which an equation of motion can be specified for the variable(s) in question — to trace its motion through the phase space. The problem with a screwdriver is that it is a functional utility that can never be specified in a *single* phase space. The novelty — the emergence — comes into existence because physically specified situations "enable" the emergence of new phase spaces of functionality for the screwdriver. The problem for determinism here is not simply that it is just unbelievably complicated, it is that it is impossibly so. The impossibility is found in the fact that an infinitely complete specified physical situation can never account for or predict that a function will (or will not) emerge. Functionality is always deep structurally ambiguous with respect to any physical specification. The antecedents have no "necessary" consequents whatever.

Back to brains, clocks, and clouds. Determinism requires that everything be a clockwork: regular, orderly, and (to omniscient intelligence) completely predictable because antecedents necessitate consequents. As a metaphysical research program it directs us to interpret everything as a clock, and to postulate that prima facie exceptions, such as clouds, should be analyzed into smaller deterministic clock works. But there is a definite similarity, constantly being empirically explored, between the active brain and the cloud. As Edelman said, the model of the CNS as coalitional and coordinate is not deterministic: "It would be a mistake to conclude… that a system of group-degenerate selection with re-entry of signals operates in clockwork fashion…. Selection can occur from cell groups participating in the states without "telling molecules what to do" (Edelman and Mountcastle, 1978, p. 86). The lack of determinate predictability is equally obvious in molar behavior — especially so in our creative use of language — which is quite cloudlike. As Bronowski said decades ago of word associations, "These responses must have this statistical character: you feed in a perfectly definite piece of information, you get out a perfectly definite answer, but what goes on inside is not at all a computer-like process. It must be much more like the process which we imagine goes on in a cloud of gas" (1978, p. 105). Rule governed creativity in the rate independent realm, as instantiated in a computer or written in an explicit grammar, is one thing; the way in which rate dependent reality operates, such as the dynamical brain, is quite another.

A cryptic remark of von Neumann (1958) in this regard is relevant:

> What matters are not the precise positions of definite markers, digits, but the statistical characteristics of their occurrence, i.e., frequencies of periodic or nearly periodic pulse-trains, etc.
>
> Thus the nervous system appears to be using a radically different system of notation from the ones we are familiar with in ordinary arithmetics and mathematics: instead of the precise systems of markers where the position — and the presence or absence — of every marker counts decisively in determining the meaning of the message, we have here a system of notations in which the meaning is conveyed by the *statistical* properties of the message. (p. 79)

The statistical (patterned) as opposed to purely mathematical character of the CNS becomes clearer with the realization that the all-or-none spike potential is only one type of event in the functioning system. In addition there is the fuzzy, or cloudlike, *graded* wave potential activity that has been emphasized as the mechanism for wavefront interference phenomena in the CNS. Pribram's (1971) holographic model takes advantage of the clouds of pre-and post-synaptic dendritic slow potentials to provide a plausible interpretation of the distributed information processing and retrieval characteristics of the CNS, particularly in "imaging."

Following Wundt and other 19th century theorists, Pribram (1971, 1991, 2013) proposed that the CNS uses both a digital code and an "analog" or wave-like one. Instead of leaving us in indeterminism as Popper does, he argued (as did Edelman) that the two process model provides exactly the sort of plastic control that evolution requires, but on an *abstract* (and indetermin*ate*) rather than and indeterministic basis. "The uncertainty of occurrence of events is only superficial and is the result of holographic "blurring" which reflects underlying symmetries… and not just haphazard occurrences" (Pribram, 1977, p. 98).

In the regulation of complexity we see most clearly the essential tension between clocks and clouds, between (level) determinism and (level) indeterminism, and the emergence of determinate order as an outcome of the interaction of different levels. Spontaneous complex orders will have both characteristics, and their relative prominence will vary over time. We must never identify spontaneous complex orders such as the CNS (or the even more powerful tacit market order of human interaction) with any extant rigorous control model.

Chaos, catastrophe, complexity, and determination. We have focused in physics upon the *in*determinacy of initial conditions and the inevitable statistical nature of so-called deterministic laws in the molar realm, and upon fundamental uncertainty in the quantum realm. But the second half of the 20th century saw new views arise concerning the predictability of events in complex dynamical systems that seem to account for unpredictability in terms of deterministic laws — random or chaotic results from the iterative application of determinate laws to classes of initial conditions that include attractors to pull a dynamical system into (usually long-term) cycles of sequences of states, rather than coming directly to rest. Unlike the case in Brownian motion, relatively small systems without unseen or quantum effects (molecules or atoms are not visible, only their effects in the Brownian situation) can, when in these states, show the randomness now called chaos (stemming from Lorenz, 1963). Simple "deterministic" systems of only a few elements can generate random, totally unpredictable behavior from fixed rules. There is order underlying the creation of this surface chaos. This theory has added deterministic models, strict sensitivity to initial conditions, strange attractors, fractal dimensions and more terminology to our burgeoning vocabulary. Later Thom (1983) introduced catastrophe theory, which studies how seemingly continuous actions can wind up producing discontinuous results — how catastrophic results come from deterministic laws continuously or recursively applied.

There is no need to explore these theories in detail to examine whether they constitute the reinstatement of determinism. They do not. What they provide is examples of what Hayek (well before them) called explanations of the principle rather than the particular. These theories actually build upon the earlier work of Boltzmann and Poincaré. As Poincaré said in 1908:

> A very small cause which escapes our notice determines a considerable effect that we cannot fail to see, and then we say that the effect is due to chance. If we knew exactly the laws of nature and the situation of the universe at the initial moment we could predict exactly the situation of that same universe at a succeeding moment. But even if it were the case that the natural laws had no longer any secret for us, we could still only know the initial situation *approximately*. If that enabled us to predict the succeeding situation with *the same approximation*, that is all we require, and we should say that the phenomenon has been predicted, that it is governed by laws. But it is not always so; it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible, and we have the fortuitous phenomenon. (1908/2007, pp. 67–68)

Recall that the rate dependent "laws of nature" are not what kills determinism: it is the infinity of complexity of initial conditions in conjunction with the inevitably statistical nature of the laws we have (we have never examined any infinite population to see if they in fact hold). Chaos and catastrophe theories are studies of initial physical conditions, showing that the repeated application of "rigid" (thus deterministic in the rate independent realm) procedures leads to fuzzy results that cannot be predicted in advance. As such, their impact on science is through epistemology and then (inevitably) in the methodology of research.

Crutchfield et al. (1986) put this point well in physics:

> The existence of chaos affects the scientific method itself. The classic approach to verifying a theory is to make predictions and test them against experimental data. If the phenomena are chaotic, however, long-term predictions are intrinsically impossible. This has to be taken into account in judging the merits of the theory. The process of verifying a theory thus becomes a much more delicate operation, relying on statistical and geometric properties rather than on detailed prediction.
>
> Chaos brings a new challenge to the reductionist view that a system can be understood by breaking it down and studying each piece. This view has been prevalent in science in part because there are so many systems for which the behavior of the whole is indeed the sum of its parts. Chaos demonstrates, however, that a system can have complicated behavior that emerges as a consequence of simple, nonlinear interaction of only a few components. (p. 56)

Thus, methodologically, studies of chaos (and catastrophe, despite Thom's dislike of "chance") [Endnote 4] show limits upon the possibility of prediction of particular outcomes in complex phenomena (and, indeed, in some seemingly "simple" situations). Our hope of "scientific" understanding in these domains lies in constructing theories of the rules or principles involved rather than ever being able to enumerate or explain particulars by natural laws. These principles will have a determinate form in our theoretical formulations in the rate independent realm. But that cannot reinstate classical determinism for the rate dependent realm of actual physical phenomena.

Functional Agency, Enablement, and Novelty in a Physical Framework

In physics, freedom is meaningful only with reference to "degrees of freedom," areas in which the laws of nature in combination with the boundary conditions present do not constrain events into a defined path of motion in a phase space. Explanation in physics is finding an equation of the motion of an event or entity in a phase space defined by physical parameters on the axes of the space. It is the areas with a lack of totally defined constraint which allow for the physically "novel" to occur if energy degeneracy is present. Nonlinear interactions in chaos and catastrophe are examples. Crucially, the functional domain can come into existence only because physical systems allow, through energy degeneracy, for its emergence. The closest thing to randomness or pure "chance" is when these degenerate situations (such as life) eventuate into what agents would consider to be "choices" between physically equally possible alternatives. While their basis is in physical systems, agents transcend that physicality because they can choose between alternative equiprobable physical paths. This is Polanyi's "harnessing" physicality through Campbell's downward causation over distance and time. Life and agency are emergent from "purely" physical interactions when, as Pattee put it, signs become symbols. Symbols harness the physical: signs are just physical objects. When the semiotic domain arises, physics has been superseded by functionality. Symbols are now control structures. Life is a matter of meaningful interactions, occurring in functional phase spaces rather than physical ones. This enables agency, the domain of the "will," and its freedom lies entirely in functionality, not physicality.

Determination and personal causation. Self-help or personal motivation books or articles are commonly on how an individual can take charge of their life and escape from the rigid "external" force-determined "physical" domain by utilization of their own "personal" powers of causation. Such accounts intend to help the individual "take charge" of their own lives, and in so doing, stop being a "mere" billiard ball being knocked about solely by external forces beyond their own control (as Skinner, 1976, proposed we must inevitably be). These accounts usually propose that the future is an ever diverging (opening) cone (somewhat analogous to the light cone in a Minkowski diagram) of opening possibilities, and that "well-adjusted" or "fully self-actualized" (or whatever) individuals are those who pick and choose what they want from that range of ever increasing possibilities that are all equally possible. Thus those who are the "self-actualized" "take charge" of their own lives and "make it happen."

Does this account square with what physics allows and scientific understanding actually provides? Not quite. When one takes into account necessary distinctions between rate independent and rate dependent laws, initial and boundary conditions versus lawful dynamics, and the inevitable statistical nature (to say nothing of the thermodynamics) of reality, then a different picture emerges.

What kills determinism in physics is not the lawful dynamics that science attempts to discern. What is covered by the "laws of nature" is postulated to be determinate in all cases and deterministic in those artificially simplistic "experimental" situations in which, *by convention*, we disregard all the inexplicable "slop in the system" and *choose* to regard the relationship between thus isolated phenomena as billiard ball causal. But, and one can hardly emphasize this strongly enough, *the amount of lawful regularity in the universe is tiny* in comparison to the infinitely vast domain of initial conditions that are *merely frozen accidents* and thus *never appear in the lawful dynamics* at all (Endnote 5).

The human existential predicament is described by the second law of thermodynamics: for the brief span of our lives we "beat the universal odds" and stave off otherwise inevitable heat death, thus contributing to a local area *increase* in order and complexity. As such "local entities," we violate the second law up until our individual deaths. But during our lives we can and do bring not only order but fundamental novelty and unpredictability into existence. Life violates thermodynamics in the isolated regions and times when it occurs. Living systems are in the business of violating entropy and creating novelty. In that regard "free will" is, as an exhibition of agency, one of their defining characteristics. Life, dependent upon semiosis, allows us to be free to choose, and choice creates novel outcomes when we exercise the choice contingency inherent in agency.

Our novelty does not come from the unknown future. That future, when unfolded into actual history, is as lawfully determinate as our now frozen-in-history past. Both the past and the future eras (histories) are *lawfully* dynamic (up to the limits imposed by our inherently statistical universe and the existence of error because of our incomplete finite sampling). Then where is the openness? Where can choices exist? The answer is obvious: in the ever increasing welter of present boundary and initial conditions which we as active agents ceaselessly freeze into frozen *accidents* with the passage of time. The relativistic light cone model is essentially backwards: we freeze the future into determined possibilities by assimilating it into the frozen past by our present "initial condition" behavior. The realm of physical undetermined contingency, the area in which we can exercise our free choice, is in the specious present. Recall Poincaré: it *may happen* that small differences in the initial conditions produce very great ones in the final phenomena. Our indeterminately long specious present is the bottom or open end (actually the beginning) of the cone — *we narrow the future* into determinate regularity (and sometimes lawfulness) by continually freezing our initial conditions. Choice contingency freezes out those initial conditions and forces the open bottom end of the light cone to taper together to constrict the future. The light "cone" analogy or model *actually* shows three separate and distinct shapes (none of which are cones), as shown in the three types of diagram in Figure C at right.

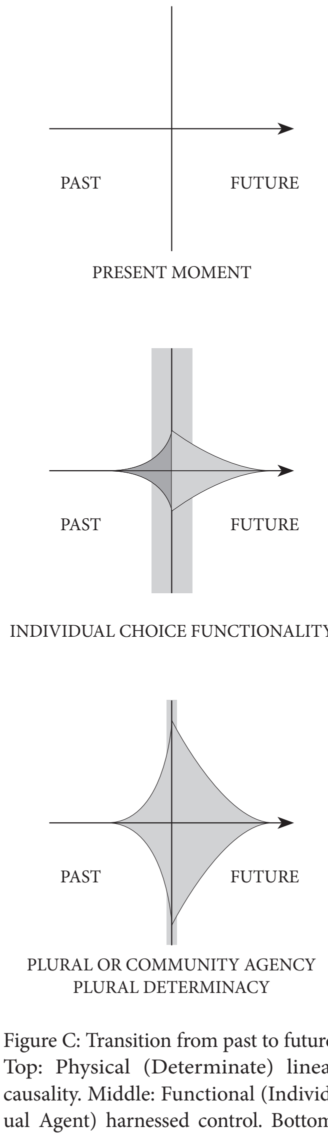

Figure C: Transition from past to future. Top: Physical (Determinate) linear causality. Middle: Functional (Individual Agent) harnessed control. Bottom: Social or Plural harnessed control.

First is the "no cone at all" diagram of billiard ball determinism, with the transition from past to future being a thin straight line to the future (we can ignore the actual probabilism and indeterministic statistical nature of reality, which would simply smear and blur the *width* of the straight line, but not change its direction). Next to consider is the case of a single agent with choice control in the "specious present," who shows a small widening of the (actually probabilistically blurred) straight "line" immediately coming in to the specious present moment, which then closes into a "determined" line in the future *as a result* of choices made in the rate independent realm during that (and each succeeding) specious present(s). In actual fact the line representing the specious present, the experienced now, should be smeared because we do not know in terms of any "clock time" how long it lasts (subjectively it has no time marker at all). Thus we cannot specify exactly how many choices and alternatives actually occur or can co-occur within it. Last to consider is the fact that we are members of *groups* of individuals *all of whom have the power* of taking charge of their own directions in a physical phase space, through choice contingency within their respective specious present moments. The increased degrees of freedom provided by the remaining members of our groups during any (clock time determined) specious present for all of us widens the straight line into a curved flat surface coming from the past to the present instant, and also widens the range of indeterminacy and shape of the curve closing in to a determinate future for any given individual, and eventually also for all of humanity. Obviously one cannot put any numbers or specific designations for the amount of choices that are involved, but in general the relative shapes of the "cones" of the future are specified in these diagrams. If we could not choose for ourselves what we can do in that specious present moment there would be no point to the therapeutic directive to "take charge" of our lives — we would then be stuck in Blanshard's or Skinner's necessaritian nightmare universe in which actual knowledge, free will, and personal causation were illusions because we did not yet "know" the "straight line" deterministic causes of our behavior.

So the usual Einsteinian light cone analogy is false, indeed misleading. We do not proceed from the narrow bottom of a cone to the wider opening of possibilities in the future. We proceed from a highly ordered and frozen (because it is *already* determined by the passage of time) past into a lawfully dynamic future that is, *in between*, continually being constrained and hence altered when our open present choices result in determinate freezing out of ever new initial conditions, which in turn affect that future lawful dynamic by changing its course.

Free will has become a scientific problem. The classic "Hobart" paper resolved the issues of its day by noting that free will requires that we as agents do in fact determine our actions. Subsequently, physics contributed little beyond making it absolutely clear that we must, on epistemic and ontological grounds, make a cut (Pattee's epistemic cut), and a distinction between the inexorable and hence "determined" laws of nature, and the infinite welter of boundary conditions and initial conditions that must be specified in order for us to make sense of, and to utilize (attach to reality), those laws. Then Polanyi (on the margins of physics, psychology, and the biology of life) pointed out that functional life *harnesses* physical inexorability. Living systems, while constrained at the lower level(s) by the conceptually inexorable laws of nature, transcend those laws through their own internal semiotic constraint systems operating as controls. When life came into existence, control by higher order constraints — choice contingency — also arose. It is now up to biology and psychology to specify how that control comes into existence and how it manages to constrain physicality. We can easily understand the physics of binary choice switches (to use the example of David Abel, 2010, 2011), but we now require a biology of agency, to show how such functional switches could have arisen in the physical universe, and a psychology of how they function in life when organisms flip them in one or the other direction. Biologists influenced by Longo and Kauffman have taken important initial steps here. But we need to supply (as Donald Campbell continually emphasized) *all* the intermediate steps from the level of basic physical theory through the biology of life, and then into the psychology of inference and expectation. All that (and no doubt more) will be necessary to understand human action in the complex spontaneous social order that it enables and creates (Endnote 6).

A Summary of "Determinism"

Determinism is the thesis that events are connected (or better, bound) to antecedent and then consequent events by direct "causal" chains following inexorable (every-where, every-when) physical laws. It is a metaphysical research program (not a scientific theory) that guided science until the beginning of the 20th century. It is an incorrect account of the nature of processes in both "simple" sciences in which building a model of the phenomenon that aids and simplifies our understanding is possible, and equally in the realms of complexity in which explanation is a matter of rules which can only specify general principles of outcome rather than particular events. Blanshard was wrong: there is no principle of internal necessity or internal relation *intrinsic to nature*. Any such postulation is found *only* in the rate independent realm of conception, in agency, in our theoretical accounts of nature. As thermodynamics illustrates, prediction of particular events is not an indispensable characteristic of science; in all cases our accounts deal only with principles and not particulars, and when we seem to find particulars being predicted it is because of a simplified description of the "experimental" isolated situation which artificially constrains and sufficiently delimits what we study.

Our theories of inanimate nature were historically the source of hope for the metaphysical research program of determinism. Subsequent research has shown that that hope cannot be sustained. The "laws of nature" that classical science found are in empirical fact actually statistical generalizations rather than deterministic, certain outcomes. This became painfully clear in the physics of the very small, where quantum phenomena become "facts of life" that cannot be explained by deterministic principles.

Summary of Functional Determination

Even at the classical molar level the phenomenon of life refutes determinism, because genuine novelty comes into the universe with the creativity or productivity of behavior and the growth of knowledge. Life, as Polanyi was the first to note, harnesses the inexorability of physical laws with *higher-order* functional constraints. This is how the "mental" can change the "physical," as when plans for a building cause terraforming of the surface of the planet. The character of theories that are necessary to account for novel but appropriate language creativity, and the spontaneous ordering of behavior in the abstract and impersonal realm of the market order, cannot be deterministic even though they depend upon rate independent application of recursive processes according to rules. When we move to the level of abstract and deep structural rules of determination we supplant "laws" of nature by rules of behavior, and automatically transcend prediction of particular events and determination of particular outcomes.

If determinism doesn't work for either simple or complex domains it doesn't work *anywhere*. The "demon" of Laplace was always a convenient fiction — if determinism were true the demon would have been "determined" and thus perfectly predicted. Instead it (and unbelievably naively, our cognition of it) was always proposed to somehow stand *outside* the natural order of events as an infallible epistemic agent, in order to judge that order by observing it — and it would have had to be *un*determined in order to render a correct judgment. All that is available to human understanding is determinate theories that cannot disregard the impossibility of strict determinism. The sooner we give up determinism as a desideratum or necessity for science, the sooner we can go about our business of trying to explain reality.

What does the death of Laplace's demon open up for us? The answer is obvious: everything we are actually interested in. If Laplace's strict physical determinism held sway we could never use it to understand anything about ourselves or our universe. Indeed, without the epistemic cut to separate us from that purely physical determinism there could be no knowledge whatever. Our existential status and its predicaments would remain forever beyond the realm of explanation, because strict determinism cannot countenance knowledge but also probability, error, novelty, emergence, agency, or choice. When you lose determinism you're not losing anything that is indispensable (or indeed anything of great importance), even though it requires always being stuck with ambiguity and the possibility of error. Does this sound too good to be true? It is not.

The Laplacean ideal conceived universal knowledge as a completely formalized, hence completely syntactical or mathematical, representation of reality. But we could *use* these mathematical formulae to explain something only after we had already, by non-formal and extra-mathematical means, come to the point of asking questions about it, and had somehow found (or postulated) a relationship between the questions asked of nature and the mathematical formulae. Mathematical reasoning about experience must inevitably include and depend on *non*mathematical reasoning and hence is literally self-contradictory. Polanyi (1969) noted this:

> Mathematical reasoning about experience must include, besides the antecedent non-mathematical finding and shaping of experience, the equally non-mathematical relating of mathematics to such experience and the eventual, also non-mathematical, understanding of experience elucidated by mathematical theory. It must also include ourselves, carrying out and committing ourselves to these non-mathematical acts of knowing. Hence a mathematical theory of the universe claiming to include its own bearing on experience would be self contradictory in the same sense as the conception of a tool would be if the tool were described as including its own user and the things to which it was to be applied. (p. 179)

Our "interesting" questions involve a level of meaning and pragmatic context that is emergent from, and thus conceptually far above, any account at the smallest "physical" levels. The particulars of entities always lack the characteristics and qualities that the entities themselves possess.

> When we focus our attention on the ultimate particulars of the universe we are facing things which have the least possible meaning. A Laplacean mind that would compute from the present virtually meaningless atomic topography of the world its future similarly meaningless topography would not materially advance our knowledge of the world, let alone represent a universal knowledge of it. (ibid., p. 178)

Each level of reality has its own functional properties, and they cannot be "reduced to" or explained by only the regularities of their particular parts. Our universe is one of downward causation (Campbell, 1974) and, as such, inevitable higher-order control constraint.

The same conclusion applies to probability and error. Thermodynamics, in the form of the second law, is fundamentally statistical in character, and as such requires that we introduce the concept of probability (and thus the concept of error due to inevitable incompleteness) into physical theory and measurement. Where we have probability we must have uncertainty. Where there is uncertainty the possibility of error is also introduced. Polanyi (ibid.) put it well:

> The law of irreversibly increasing entropy governs the fundamental processes of equilibration in nature. But the entropy of the system cannot be computed from the knowledge of its atomic configuration, for it is measured by the extent to which this configuration is uncertain. This argument can be made more definite by assuming quantization. The entropy of a precisely known atomic con-

> figuration is, then, zero and remains zero throughout the future; equilibration by increasing entropy does not take place. We can have equilibration only if we introduce conceptions of probability, by assuming that the configuration of atoms is to a considerable extent uncertain. (p. 174)

Summary

Having begun with Blanshard, let us end with him. From *Reason and Analysis* (1962):

> That the universe is not a mere heap of things and events thrown together in hit-or-miss fashion, that it contains at the lowest estimate many extensive sub-systems, we have argued in some detail. But is it a single system? Granted that some things are related through a necessity linking their qualities, and that some events are related through the necessity implicit in causation, is there any good ground for holding that *all* things and events are inter-related necessarily? (p. 472)

We can now answer this. There are *not* good grounds for holding that all physical things and events are necessarily interrelated. The boundary conditions and the initial conditions of physics cannot be subsumed under the inexorable laws of nature. This leaves the vast majority of the universe — including its apparent regularity — as a matter of accidents that have been frozen into place by no "cause" other than co-occurrence, and the passage of time at that region in the universe's evolutionary history. Those happenings could never have been predicted on the basis of even perfect knowledge of all the laws of nature. As living beings we, as choosing subjects, create *all* initial conditions. Initial conditions exist in the functional domain and not the physical, subject only to constraints imposed by the "lower-level" laws of thermodynamics and the obvious requirement that they must be compatible with (i.e., cannot violate) all natural laws. The *rules* of behavior are not *laws* of nature. This leaves an immense realm for life, in which it is not possible to assert that given physical events must have particular specified consequents (or for that matter, particular specified antecedents). There is genuine novelty, genuine unpredictability, creativity or productivity, in the universe as a result of the behavior of agents (and, of course, frozen accidents). That behavior in turn can and does alter the future history of the physicality of the universe. Functionality constrains and alters physicality. That is the sense in which life harnesses inexorability. We are, as Milton and Rose Friedman (1980) so loved to say, *free to choose*. Living things are constrained by physicality, but are not determined by it. The key to the functional domain is in enablement co-occurrences, not deterministic causality. There is an insurmountable gulf between "constrained to be compatible with" and "determined by." Without that gulf we could have no knowledge at all, and could never even ask questions about the limits of determinism and the nature of free will or choice contingency.

Endnotes

Note 1. *Consciousness is not the problem*. The physics problem need not be framed in terms of the collapse of the state vector or wave function. The problem is that a subject of conceptual activity is required to provide meaningful interpretation. The measurement situation may be looked at as an instance of either surface or deep structural ambiguity, and the various proposals for "disambiguation" treated accordingly. Bohr's reasoning (see Saunders, 2004), leading to his version of the principle of complementarity, was that the only possible language for the unambiguous communication of the results of an experiment was that of "ordinary" or pre-quantum physics (now called "classical," but really implying intuitively "reasonable to common sense"). In discussion of measurement in such classical terms, any results permit inferences about an observed object that exists separately and independently, since it can be said to "have" those properties whether it interacts with anything else (the observer or the experimental apparatus) or not. This makes the situation one of surface structure ambiguity: one and the same entity is *described, and therefore interpreted*, differently depending upon the context of inquiry. In other words, observers disambiguate the ambiguous meaning of the experimental operation(s) by supplying a context that "parses" it in one manner or the other. This proposal led to a dilemma: Is physics about reality or about the observer? Dirac argued that, by convention we study a choice upon the part of nature; Bohr and Heisenberg argued that, by convention, we study a "choice" upon the part of the observer constructing the instruments and reading them (see Bohr, 1949, p. 223). Wigner's and Schrödinger's arguments are powerful initial support for Heisenberg's choice in this dilemma, and it was in terms of those arguments that we discussed the measurement problem.

But examination of the quantum nature of the *total apparatus* (indeed the entire situation of observer plus apparatus) forces a *deep-structural* interpretation of the ambiguity. Experimental conditions cannot be considered just a separate link in the chain of inferences; they remain an indissoluble part of the description of what is called the "observed" object. Arguing against Einstein's realism, Bohr (1934) himself saw that the quantum context forces a new kind of description which does not attempt a sharp separation of observer and observed object. As Bohm (1971c) argued, "A centrally relevant change in descriptive order required in the quantum theory is thus the dropping of the notion of analysis of the world into relatively autonomous parts, separately existent but in interaction. Rather, the primary emphasis is now on *individual wholeness*, in which the observing instrument is not separable from what is observed" (p. 377). This step has not been acknowledged by many, likely because they are reluctant to admit what it does to our conception of scientific analysis. This makes the problem of understanding one of deep structural ambiguity, in which one "object" (a system that is literally one whole) is to functionality actually two systems, in the same way that one

Necker cube is *two* objects when viewed (interpreted) from different perspectives. According to Bohm (1971b):

> In the quantum situation, terms like "observed object," "observing instrument," "experimental conditions" and "experimental results" are just aspects of a single overall "pattern" that are, in effect, abstracted and "pointed out" or "made relevant" by our mode of discourse. Thus it has no meaning to say, for example, that there is an "observed object" that interacts with the "observing instrument." (p. 38)

Instead, reality is an undivided totality of events and their relationships, which is referentially unitary but intensionally deep structurally ambiguous. This underlies the wave–particle duality separating classical from quantum accounts. At issue is whether "the same" phenomenon, which can alternatively be construed as a particle or as a wave, is either a particle or a wave, or whatever (such as some kind of quantum or prequantum field) could underlie both.

Bohr's proposal said that when it is "in" the apparatus, the wave must be treated as a particle. Consistent applications of quantum mechanical description often yield only waves. The so-called completeness of quantum mechanics (as in von Neumann's "proof") arguments say that no analysis of quantum phenomena can disclose other than this (mainly because they build this into the premises). Hidden variable theorists, from Einstein up, searched for a deep structure underlying both relativity and quantum frameworks. If such a framework could be found it could unify both domains.

Note 2. *Hidden variables and determination*. Theorists following Einstein's distaste for quantum indeterminacy are portrayed as searching for factors that, underlying or in addition to the quantum cookbook, would explain quantum results as arising from deterministic variables at a different level. Such variables are presumably "hidden" from view in the results but would render them explicable in traditionally deterministic (but not classical) terms. Bohm, Einstein's most direct intellectual descendant, is portrayed in popularizations and technical articles as proposing a deterministic theory underlying quantum results. Alternatives to Copenhagen, such as the Wheeler–Everett–DeWitt "many worlds" hypothesis now in vogue, proposed instantly branching "universes" that come into existence (i.e., are then somehow "real") with any seeming quantum indeterminacy realization. For example, Schrödinger's cat branches into one world in which it is alive and another in which it is dead, without ever having been (as Copenhagen said) both dead and alive or neither dead nor alive. In each branching structure determinism of outcomes is thus presumed to be preserved. The data relevant to Einstein's "spooky action at a distance" provided by the Aspect et al. experiments having shown non-locality to be a fact of quantum life, the "hidden" views now take for granted (on faith) that some such account or other deterministic underpinnings will be found.

Can such theories reinstate classical determinism in which every event has a necessary immediate and proximal antecedent event? Not at all. Experimental results (by Aspect et al., 1982, and then many others) ruled out "local" hidden variable theories (ones that would have provided the close proximity "fill in the chain" causal account) as incapable of accounting for the data. The quantum cookbook still works, and leaves non-locality as a more global phenomenon requiring explanation in terms of rules of determination rather than strict determinism.

And contrary to superficial interpretation, Bohm's account did *not* involve determinism at all. This is initially surprising, since he is seen as defending Einstein's quest for determinism. But if one understands Bohm it is clear that his starting point, the *undivided* whole of the universe, renders talk of isolated particulars that can be defined and analyzed *as such* to be meaningless. Billiard ball determinism depends upon the possibility (actual existence) of independently and discretely specified basic entities. There can be no linear causality in a framework that is intrinsically continuously relational. As Bohm put it:

> (W)e and our active observation are like that which we observe; i.e. relatively constant patterns abstracted from the universal field movement, and thus merging ultimately with all other patterns that can be abstracted from this movement.… *What is* is a whole movement, in which each aspect flows into and merges with all other aspects. Atoms, electrons, protons, tables, chairs, human beings, planets, galaxies, etc. are then to be regarded as abstractions from the whole movement and are to be described in terms of order, structure, and form in the movement. The notion of a separate substance or entity is dropped, or at most, retained as part of the earlier world view, which is now seen to fit the totality of our experience only in certain limited ways. (1976, pp. 38–39)

Thus for Bohmian mechanics, determinism is a now meaningless, "earlier" concept.

Everett's interpretation of J. A. Wheeler's view of an "undivided" plenum universe is that it is *not*: the overlapping wave functions of the whole universe *never* collapse. They divide the universe into infinitely variegated possibilities of existence. All are equally real (thus divided: the basis of the "many worlds" view), if not actually *realized*. They each "exist" in their own dimensions in some *purely conceptual* "super space–super time." When we in our world make an observation at the quantum level that process forces us to select one such alternative. That selected alternative becomes our "real" world, and the alternatives then are all entirely cut off from the real world, to somehow float away separately into that conceptual super space–time. Each such alternative would contain its own observer who, slightly different from us, making the *same* observation in that world, has gotten a different quantum answer and thus thinks he or she alone "collapses the wave function."

This haunted universe doctrine has no apparent predicted results different from others, like the operational quantum "theory" (the neo-Copenhagen one), but it seems to preserve the term "causal" in some fashion. Does it preserve determinism? Is it deterministic in the classic or linear chain sense? It is so only in the *retrodiction*, never in prediction of how the observer is going to "see" the next quantum level choice. Few theories say we cannot look backward in time and find out how things evolved to the state they presently occupy (indeed Bohm implies that we could in principle "un" or "re" fold our enfolded universe and thus go back "there" in time–space to some specified locale). It is quite another thing to look forward and "predict" the next quantum level choice the ensemble of observer cum apparatus cum measurement will disclose. So the many worlds view implies that reality is *deep structurally ambiguous*, and that it is rendered into one surface form or another by agency — a cognizing subject who is an observer who "sees" the Necker cube from one configuration or the other, or the duck–rabbit as *either* a duck *or* a rabbit. Resolution of deep structural ambiguity can never be deterministic in the rate dependent universe. It can be resolved only in the rate independent realm of conception, by specifying the abstract conceptual structures that allow alternative interpretations of the same surface string of entities — in this case, perceptual structures — to be "seen" or come into existence. This requires *rules* of determination that generate indefinitely extended classes of potentials rather than deterministic or lawful specification of definite particulars.

Note 3. Note the identification (by both Popper and his critics) of meaning with language (specifically the argumentative mode in theories and explicit conjectures or directives), and the use of hierarchical control structures as noncausal (in the classical determinism sense) in our behavior. Both notions are incorrect — other solutions are required for adequately modeling mind and meaning. Consider first an unresolved ambiguity in consciousness and language with respect to causality in Popper's account.

Popper argued that consciousness is causally productive of behavior:

> Conscious states, or sequences of conscious states, may function as systems of control.… Consciousness appears as just one of many interacting kinds of control.… Consciousness can hardly be said to be the highest control system in the hierarchy. For it is to a considerable extent controlled by these exosomatic linguistic systems — even though they may be said to be produced by physical states; yet it controls them to a considerable extent. Just as a legal or social system is produced by us, yet controls us, and is in no reasonable sense "identical" to or "parallel" with us, but interacts with us, so states of consciousness (the "mind") control the body, and interact with it. (1972, p. 257)

While that statement is correct, one should ask how consciousness is to be causal if it is hierarchical and linguistic, when Popper argued for the noncausal nature of language in these argumentative modes of behavior precisely because of that hierarchical nature (he identified hierarchical systems as "noncausal"). He proposed no account of this noncausality, nor resolution of this problem, and Popperians have slipped from beating materialists with the noncausal nature of language and/or consciousness into clearly causal accounts of "plastic control" in other contexts. Studying control structures in complex phenomena indicates ways in which centralized top–down (hierarchical) control structures (what Hayek called *taxis* structures) interact with decentralized or *cosmic* structures in the economic order (Hayek 1979, 1983), in epistemology in general (Weimer, 2023), in language (from the "transformational" revolution), and the origin of life and semiosis (Abel, Barbieri, Pattee, Polanyi, Weimer).

Note 4. The concept of "chance" has little utility in science. As Poincaré noted, we call things chance occurrences only because we are unaware of the underlying regularities. As knowledge increases, there is less utility in employing the concept of chance. Chance is a term for our ignorance, not knowledge. It is not an explanatory concept. In the past, some theorists used the term chance as a substitute for the effects of the indefinitely extended welter of boundary conditions when they interact with an observer's freezing out of initial conditions (C. S. Peirce and Poincaré seem to have done this). Much better that we simply acknowledge our ignorance of all the relevant aspects and not use the term chance at all. No one is apt to confuse ignorance as an explanation for a scientific problem, whereas chance suggests a possible causal entity with a theoretical explanation.

Note 5. This has been obvious for decades. Pattee was the clearest in presenting the essentials:

> The basic distinction that must be made is between *laws* of nature and *rules* of constraints. One cannot usefully apply the concept of control to laws nor to all types of constraints. The same is true for information. Informational and control constraints must be describable in terms of alternative states that are not dynamically related. That is, they must change in time but not change as a function of rates, as do the laws of nature. Such constraints are nonintegrable or nonholonomic, and their behaviors can be said to execute a control rule.… Laws are *inexorable, incorporeal, and universal*; rules are *arbitrary, structure-dependent, and local*.… We cannot alter or evade laws of nature, whereas we can redesign or eliminate a rule; laws do not need a device or structure to execute them, whereas rules can only be executed by specific physical structures that we call control constraints; and finally, laws hold at all times and all places in the universe, whereas rules hold only where and when there is a physical structure to execute them. (Pattee, 2024, p. 23)

When applied to the issues of biological agency and cognition, this results in a fundamental incompatibility that must be acknowledged:

> The incompatibility I am speaking about would occur when describing intentional control policy and how this interacts with the deterministic dynamical activity of what is controlled.... The informational content of an ignition key is incommensurable with the degrees of freedom of the automobile which it starts. This is

> because the informational content in the key is determined by the number of people you do not wish to use your automobile (i.e., an intentional policy) and has virtually nothing to do with the complexities of the deterministic mechanisms of automobiles.… It is obvious that an ignition key cannot be explained as nothing but a slotted brass object with bumps on its edge, no matter how detailed the structural description may be. Nor can the key be explained as nothing but an informational representation of a potential population of car thieves. (ibid., p. 25)

This is the fundamental incompatibility between the physical and the functional, and when coupled with the distinction between the limited domain of the laws of nature and the ubiquity of the frozen accidents of local boundary conditions, taken in conjunction with the control of agency through rules, it becomes obvious that the areas in which "determinism" could hold sway are far smaller and more restricted than had once been thought.

Note 6. What sort of control structure is agency, and how does it "determine" choices and outcomes? All "control" structures in cognition (and other aspects of living systems) are effected by functional constraints. Agency is, tautologically, self-directed or iterative (recursive) constraint control. How can a control constraint manage to constrain itself? By having constraint operation (closure) initiate another constraint operation which ends (in its closure) by initiating the first or initial constraint operation over again. This is how organisms act on their own behalf. Self constraint means that the circular organization of a constraint process specifies its own defining dynamics. The effects of that activity specify and establish the maintenance of the conditions of its own existence. As Mossio and Bich (2017) put it, biological systems *are* what they *do*. As they say, biological systems are specified by:

> [T]he fact that the thermodynamic flow is channeled and harnessed by a *set* of constraints in such a way as to realize mutual dependence between these constraints....The organization of constraints *can be said to achieve self-determination as self-constraint*, since the conditions of existence of the constituents of constraints are, because of closure, mutually determined within and by the organization itself. (2017, pp. 1103–1104)

Agency constraints are sets, as these authors make obvious, patterns of patterns. We are processes. And processes of processes. Semiosis is patterns. Life is patterns. And patterns of patterns.

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