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Freedom as a Natural Phenomenon

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Abstract "Freedom" is a phenomenon in the natural world. This phenomenon—and indirectly the question of free will—is explored using a variety of systems-theoretic ideas. It is argued that freedom can emerge only in systems that are partially determined and partially random, and that freedom is a matter of degree. The paper considers types of freedom and their conditions of possibility in simple living systems and in complex living systems that have modeling (cognitive) subsystems. In simple living systems, types of freedom include independence from fixed materiality, internal rather than external determination, activeness that is unblocked and holistic, and the capacity to choose or alter environmental constraint. In complex living systems, there is freedom in satisfaction of lower level needs that allows higher potentials to be realized. Several types of freedom also manifest in the modeling subsystems of these complex systems: in the transcending of automatism in subjective experience, in reason as instrument for passion yet also in reason ruling over passion, in independence from informational colonization by the environment, and in mobility of attention. Considering the wide range of freedoms in simple and complex living systems allows a panoramic view of this diverse and important natural phenomenon.

Keywords Freedom · Free will · Determinism · Agency · Autonomy · Autopoiesis · Automatism · Sensitivity · Consciousness

1 Introduction

The systems theorist Stuart Kauffman (1998) once posed the question: "what is required of a system for us to say that it 'acts on its own behalf'?" This paper poses a related question: "what is required of a system for us to say that it exhibits 'freedom'?" This question is

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addressed by an abstract systems-theoretic look at various *types* of freedom occurring in living systems. These types of freedom include but go beyond phenomena often given the labels of "autonomy" and "agency." The subject of freedom as a natural phenomenon also offers a broad context for discussions of free will.

The paper first argues that a condition of possibility for freedom is that the dynamics of a system are partially deterministic *and* partially random, or deterministic but at "the edge of chaos." It advocates conceptualizing freedom as a matter of degree rather than as simply present or absent. Freedom first appears in the biological realm, and the paper considers conditions of possibility and different types of freedom in simple living systems and in complex living systems having modeling (cognitive) subsystems. These types of freedom are not derived from a single principle, but are approached with a systems perspective based in graph theory, dynamical systems theory, information theory, decision and game theory, thermodynamics, and other sources in science and philosophy. The aim is to gain a panoramic view, a "crude look at the whole" (Gell-Mann 1994), of freedom as a diverse and important natural phenomenon.

2 Determinism and Randomness; Freedom a Matter of Degree

Denial of free will is often based on the view that the world is governed by deterministic laws. If it is, actions are not free. Denying determinism doesn't solve the problem. If the world is random, actions are also not free, but in a different way. However, while determinism and randomness each, at its extreme, makes freedom impossible, each also remedies an impossibility implied by the other. Randomness allows for a variety of actions needed for freedom, a variety precluded by complete determinism; determinism causally links decision to action and action to its effects, linkages precluded by complete randomness (Dennett 2003). However, a system that is partially determined and partially random can have properties absent in one that is wholly determined or wholly random. Freedom is possible by virtue of *interaction* between partial determinism and partial randomness.

A similar effect can occur even in a fully deterministic system. Such a system can have chaotic attractors, where the dynamics appear random but are not. Between dynamics that rapidly converge on fixed points or limit cycles and dynamics that are chaotic—these being analogous, respectively, to extremes of determinism and randomness—there is an intermediate regime called "the edge of chaos," where dynamics both differ from and resemble both extremes. Langton (1991), Kauffman and Johnsen (1991), and others argue that all interesting dynamic phenomena, such as computation, occur in this regime. Altogether aside from this idea of the edge of chaos, dynamic systems can also have singularities at which the future is not merely unpredictable, but actually undetermined. None of this invokes quantum mechanics, which will not be taken up here, except to note that in some interpretations quantum theory also harbors a mixture of determinism (in the time evolution of the wave function) and non-determinism (in the mixtures of states produced by measurement).

Just as freedom is impossible at either extreme of determinism or randomness, freedom itself is not all-or-nothing, but a matter of degree. In set theoretic terminology, the set of free actions and the set of unfree actions are not "crisp," where the question is whether the first set is or is not empty. Instead, these sets are "fuzzy" (Zadeh 1965), where the degree of membership in a set is not necessarily either 0 or 1, but can take on any value in between. An action can have membership in the set of free actions of 0.1 or 0.5 or 0.9. What is important in this fuzzy set perspective is not any precise membership value, but the idea that freedom lies on a continuum and that some actions or conditions for action are freer than others, depending on the system and the type of freedom under discussion.

3 Simple Living Systems

3.1 Independence from Fixed Materiality; Internal Determination

Some systems construct and maintain themselves, exhibiting “autopoiesis” (self-making) (Maturana and Varela 1980). They do so by informational control over a matter-energy flux through the system. Control operates (a) via a boundary that allows only some forms of matter-energy into the system; and (b) via a metabolism that continually reconstructs the system and, in complex systems, reproduces it. In autopoiesis, identity is not material but informational, so although the system must be materially instantiated, it is free from dependence upon *specific* and *fixed* materiality. Jonas (1966) saw metabolism as the first appearance of freedom in the natural world. This freedom is an autonomy, not from the environment that embeds the system, but from the materiality that instantiates it. This autonomy, however, is bought at the steep price of vulnerability: the system is completely dependent upon the matter-energy flux through it.

Metabolism provides the matter and energy for self-making. The use of energy is governed by internal information, distributed in the network of autopoietic interactions or, in living systems, concentrated in genomic information. (For Maturana and Varela, however, autopoiesis suffices to define life.) This information guides the operational furthering of the system’s “interests,” summarized in the decision- and game-theoretic notion of “utility” (von Neumann and Morgenstern 1944). Freedom thus requires particular relationships between matter (the physical instantiation of the system), energy (the capacity to transform matter), information (the governing of this capacity), and utility (the goals that implicitly or explicitly guide such governance). In Aristotelian terms, matter is material cause, energy is efficient cause, information is formal cause, and utility is final cause. Independence from fixed materiality and other freedoms require harmony among these four causes.

There are two views of what a system is: an open systems view in which a system *is* a nexus of internal structure and external function, and a closed systems view in which structure is what the system *is* and function is what it *does*. For complex systems, internal factors are more constitutive than external factors, so the latter view is more appropriate. For a system to be free, determination must be internal rather than external. Freedom, in this sense, means being *causa sui*, the cause of oneself. While there is no escape from environmental constraint, disturbance, and dependence, freedom is self-determination, not other-determination; autonomy, not heteronomy. However, since complete immunity from external determination is impossible, freedom is a matter of degree: the more internal factors prevail over external factors, the freer in this sense the system is.

This is the deep significance of autopoiesis. In so far as the system is determined by internal information, it is “closed under causal entailment” (Rosen 1991). It is the main cause of itself—or at least of its core identity. This idea was conceptualized in early cybernetics: “Cybernetics might…be defined as the study of systems that are open to energy but closed to information and control—systems that are ‘information tight’”

(Ashby 1956). To be more precise: such systems *can* have informational inputs, but these inputs do not determine the material organization of the system.

One aspect of internal determination is regulation by the boundary of the degree to which the system is open or closed. Closedness can shield the system from external disorder (entropy) that threatens its internal order and from external order (constraint) that diminishes its autonomy. Openness can protect the system from internal disorder and from internal order that reduces necessary variety. Everything depends on when, to what degree, and towards what is the system open or closed. Freedom—and viability—require internal control of closedness and openness.

3.2 Available Energy; Unblocked Activeness

Autopoietic metabolism provides a condition of possibility for another type of freedom. The flux through the system used for self-construction also gives the living system an internal reservoir of energy. Bateson (1979) refers to this as "collateral energy," and gives the example that a kicked dog jumps not from the force of the kick, but from its own energy sources. The dog's jump in this case is triggered by the external disturbance, but the point is that the dog has internal energy usable for activity.

Energy makes activeness possible, but activeness can be blocked. At the human level, freedom is often conceived of as implying the absence of obstacles to the fulfillment of desire. Desire and what opposes it are generalized in Bennett's (1966) "systematics" in the abstract ideas of active and passive forces. In Newtonian terms, these forces could be called action and reaction; in Hegelian (actually Fichtean) terms, thesis and antithesis; in Peirce (1991) terms, firstness and secondness. Activeness facing no opposition at all (no reaction, no antithesis, no secondness) might be considered freedom, but since activeness is rarely unopposed, for freedom to be possible, some means must exist to neutralize the opposition that is normally encountered.

Neutralization can be accomplished by a third factor added to the active–passive dyad. Systematics conceptualizes "the triad" as consisting of active (affirming), passive (opposing or receptive), and neutralizing (reconciling, mediating) forces, labeled 1, 2, and 3, respectively. Bennett considers the six permutations, {123, 132, 213, 231, 312, 321}, and gives to each a different meaning. He interprets the 321 triad as "freedom" in the following sense: a reconciling force (3) neutralizes the opposing force (2) in advance, removing it as an obstacle, leaving the active force (1) to manifest freely. 321 thus represents freedom as activeness that is unblocked.

In the external interaction of system and environment, system as agent is active, and the environment, when it is resistant to system action, opposes. The system must bring its own neutralizing factor to the interaction or else depend upon fortuitously enabling conditions. In a sense, biological phenotype, which mediates between genotype and environment, might be considered to be such a neutralizing factor. Adaptation to environmental constraint may also have this 321 structure: freedom may inhere in satisfying constraints before they drastically limit possibilities of action. For example, a horse tied to a moving cart can gain freedom by running with the cart. Running neutralizes the constraint of being tethered or, worse, dragged, allowing the horse some free motion.

The 321 triad also manifests internally. 1, 2, and 3 can be correlated with energy, matter, and information, respectively, and 321 exemplified by catabolism, in which information (enzymes or genomic information that codes for enzymes) acts on matter (molecules of food) to release energy (ATP) available for action. A simpler example of 321 is any spring-loaded mechanism that can be triggered: the trigger removes that which temporarily blocks action, allowing the release and utilization of stored energy.

3.3 Wholeness

To be maximally free, action must arise from the *whole* of the system. If action arises from only part of the system, the rest of the system is passively subject to consequences of the action and is unfree. At a human level, this is relevant to the question of free will because there are reasons to deny that the psyche has enduring unity. If parts act as if they were the whole, each part, governed by its own utility, causes negative externalities to other parts. If the system is united, however, multiple utilities are aggregated into a unitary utility, or an order of priority is established, or one utility is selected as the objective function with the other utilities only providing constraints on the optimization. Under these conditions, agency is freer because it is more whole. No system is a totally integrated whole, however, so what is needed is that the degree of integration is adequate or that some core aspect of the system is unitary.

System action or its basis in utility is thus free in this sense to the extent that it is non-decomposable. In the terminology of graph theory and information theory (Krippendorff 1986), a system's degree of holism is measured by how much order (information) is lost when it is decomposed into parts. For example, if ABC is a set-theoretic relation or a probability distribution, the first decomposition yields the structure consisting of all three dyadic relations, written as AB:AC:BC. Further decomposition yields two dyadic relations, e.g., AB:BC, and so on. If *all* order in ABC is lost in the first decomposition, that is, if the triadic system has no dyadic order, it is maximally holistic. It is free in so far as it acts as a unity.

It would be incorrect, however, to conclude that multiplicity, the opposite of unity, is always adverse to freedom. Multiple options for action are in fact a prerequisite for successful adaptation. Ashby's Law of Requisite Variety (1956) formulates this principle as a necessary condition for successful regulation against external disturbances. The law states that a regulator needs a variety of options from which it can select a response that assures viability. In the LRV, selection is most effective when it is deterministic, but in other contexts optimal regulation may require randomness. In zero-sum games without saddle points, optimal action is a mixed maximin strategy in which actions are selected randomly (though selections are governed by fixed probabilities). Randomness is also central to Ashby's "hunt and stick" (trial and error) regulation. Partial determinism and partial randomness are thus both needed to counter external disturbance.

3.4 Agency: Choosing or Altering the Environment

There is no possibility of escaping environmental constraint altogether, but some environments impose more constraints or more benign constraints than others. There is a type of freedom in having an influence on *which* constraints the system will come under. Some systems can select their environments; for example, locomotion allows animals some choice of location. Locomotion is a freedom in space, and is a major evolutionary advance. Beyond choice of environment, or accommodation to it via regulation, there is the possibility also of modifying the environment to suit the system. This form of agency requires collateral energy (mentioned above) and usually at least some minimal capabilities of cognition (discussed below).

Agency is the subject of decision theory and game theory, which describe "rational action" by a system as the maximizing of utility. Rationality here does not imply intentionality or consciousness; in its simplest form, it requires only the ability of a system to act in a way that benefits itself. Natural selection results in utility-driven behavior even in systems whose cognitive capacities are minimal. Bacteria can be rational in optimizing fitness (a form of utility); they can even be afflicted by the prisoner's dilemma (Schultz et al. 2009). Agency, defined as rational action in this sense, is a type of freedom.

This type of freedom may appear teleological, and thus not scientifically acceptable. Being driven by final causes might seem to differ sharply from the efficient cause explanations that are normative for physics, reflected in its extensive use of differential equations. But game theory can also employ differential equations in which action depends on utility differences, so rational action can also be given an efficient cause formulation. Also, differential equations themselves implicitly include final causes, namely the attractors that the dynamics lead to (that's why they're called attractors). Although utility has no physical units and is not a category for physics, where causes are given in terms of matter-energy, utility is an emergent that can be expressed in the language of physics. Freedom, in the sense of agency, is compatible with causality.

4 Complex Living Systems

4.1 Hierarchy

Some types of freedom have a hierarchical character, in which the existence of a higher level connotes a degree of freedom from the levels beneath it. Complex living systems have hierarchies of needs, viewed as hierarchies of constraint or of qualitatively different types of utility. Lower constraints or types of utility address fundamental requirements of viability, while higher constraints or types of utility are relatively optional. For human beings, an example is Maslow's (1943) hierarchy, which ascends from physiological and safety needs, to needs for love and esteem, up to a need for self-actualization. Finer discriminations of these basic and intermediate levels are obviously possible, and a modified version of this scheme might be generalizable to other organisms. Although the pursuit of higher level needs does not necessarily indicate the prior satisfaction of lower level needs (beyond the requirements of viability), such pursuit does indicate some freedom from lower level constraint.

The gaining of higher level utilities depends heavily on the environment, which may support the system by providing more than its matter-energy requirements (physiological needs in Maslow's scheme). The environment may offer a field of realization. Freedom to develop and actualize potential may require—even presume—that the system is situated in an environment that not only sustains and nurtures, but also provides opportunities and challenges.

4.2 The Modeling Subsystem

In complex adaptive systems, more particularly higher organisms, the informational domain includes a "modeling subsystem" (the nervous system; perhaps the endocrine and immune systems should also be included) that regulates the system and its interaction with the environment, and—reflexively—even regulates itself. Modeling of the near and far augments the freedom in space gained in locomotion; modeling of past and future adds a kind of freedom in time. Representation allows the system to explore possibilities of action virtually while remaining free from the dangers of exploring them in actuality. Since the modeling subsystem is central to the system, the question of the system's freedom becomes the question of the modeling subsystem's freedom. An absence of freedom is suggested by the automatism of many of the functions of this subsystem. To the extent that the modeling subsystem is on auto-pilot and reactions triggered in it are automatic and involuntary, this subsystem is unfree in its determinism. To the extent that its reactions do not reflect permanent core principles, but are contingent on variable internal factors, it is unfree in its randomness. However, if this subsystem is partially determined and partially random, it has at least the possibility of freedom.

Mental activity rises above automatism when it generates subjective experience, i.e., sensations, emotions, or thoughts, here called "sensitivity." This level of mental function is unavailable to robots or zombies, and—if one accepts an emergence and not a pan-psychic theory of subjective experience—is plausibly considered absent in (sufficiently) "lower" organisms. Sensitivity brings partial freedom from automatism by enabling informational processes to be experienced, leading to responses by other parts of the subsystem. Sensitivity is transcended in turn in "consciousness," in which experience becomes associated with a seemingly unified "self," able to direct attention. This tripartite view of the modeling subsystem, which posits automatic, sensitive, and conscious levels of informational activity, is derived from Bennett (1961).

In Kahneman's (2011) distinction between types of thinking, fast thinking, which is associative, occurs mainly at the level of automatism; slow thinking, capable of being logically ordered, occurs at the level of sensitivity. Sensitivity encompasses not only thought but also feeling, as well as experience of sensory-motor and instinctive function. From the perspective of freedom, the relative priority that exists between thought and feeling (or instinct) can be viewed in two opposing ways. Hume's (1739) view, that "reason is and ought only to be the slave of the passions," exemplifies the relation between utility and information that is mentioned above: passions express the imperatives of utility, and reason is their informational slave. Here reason instrumentally empowers agency, but does not determine its goals. Such internally determined and utility-driven action is a type of freedom, yet in the possibility of the *opposite* priority between thought and feeling, in which the former—in its slow thinking mode—is dominant, there is a freedom of a different type: the modeling subsystem, and the system as a whole, is free when, by the rule of reason, it is not a slave to passion. To the idea of freedom as unimpeded desire, one might oppose the different idea of freedom as desire governed by reason. One might even entertain the more radical idea in which freedom becomes available via the relinquishing of desire.

Consciousness expands sensitivity by lowering the threshold between it and the hidden automatism beneath it; this increases freedom by allowing impulses to be vetoed, by opening up additional choices of action, and by enabling deliberation. It may be that consciousness reflects a higher degree of neurological holism than exists at lower levels of mental function (Tononi 2008). Consciousness and sensitivity can be partially independent, analogous to axles in a transmission that are disengaged by a clutch. If this independence is sufficient, the contents of sensitivity can be perceived as not completely equivalent to self. Separation is then possible to some extent from the reactions that impressions normally engender. If the energy of sensitivity is not too strong, habitual action or the completion of action already incipient need not occur. The system is freer. If conscious attention is fast enough, impulses towards action that are usually discharged immediately can even be diverted into other channels, augmenting available energy. But such alchemy is rare;

normally sensitivity and consciousness are stuck tightly together. To prevent total capture of attention by external or internal impressions, consciousness must to some extent be pried apart from sensitivity (a prying apart which, in a sense, is a partial relinquishing of desire). A condition of possibility of freedom for the modeling subsystem in human beings is thus mobility of attention. From another point of view, mobility of attention *is* freedom, the freedom of consciousness not fused with sensitivity.

Thought and feeling are subject to indirect environmental control. The environment (other systems in it or the environment as a supra-system) colonizes the modeling subsystem by establishing beachheads within it. This is not as constraining as external compulsion directly exercised on the system, since informational intrusions can in principle come under internal influence, but foreign implants often escape detection by becoming established within the automatism of the subsystem and by hijacking the synthesis of self. In its benign effects, the environment simply causes the system to adapt or co-determines its character without undermining its core identity. It even, as noted above, may offer the system a field of realization in which the potentials of the system might become actualized. But in its less benign impacts, the word "colonization" is apt: the system is alienated from its own nature and acts on behalf of the environment rather than itself. There is thus a hierarchy of possible freedoms: first from direct external control; then from external colonization that exploits; and then from compromise with environmental codetermination that marginalizes what is unique and innate to the system. Even the system's core identity might be transcended, in liberation from determination that is solely system-centric.

4.3 Self-Reference

The modeling subsystem not only models the system's interaction with the environment and the rest of the system, but also itself. Self-reference is not only central to autopoiesis, but occurs also in the modeling subsystem, where it offers another type of freedom: in the fuller perception of the energies operating within it, this subsystem, and the system as a whole, is freer. Such perception is the role of consciousness; at the level of sensitivity, self-knowledge, coupled to rationality, is a complementary dimension of freedom.

Self-reference generates paradox and, more significantly, undecidability. Langton (1991) has suggested that systems at the edge of chaos are mathematically undecidable, i.e., have states that cannot be reached deterministically. In Gödel's theorem, self-reference allows the existence of a well-formed formula that is meaningful but undecidable; moreover this formula, despite being undecidable, is true. As a consequence of this theorem, many other well-formed formulae are also undecidable. If decidability in formal systems is taken to correspond to causal determinism in physical systems, truth then corresponds to actual occurrence (Zwick 1978). What occurs but is not determined to occur can only be self-caused. It is conceivable that self-reference allows the operation of the mind to be *causa sui* (Zwick 2007)—in some sense and to some degree. This is the highest form of freedom conceived of in this paper.

5 Summary

Freedom is a natural phenomenon, indeed many similar phenomena, made possible by various enabling properties of simple and complex living systems. These phenomena bear to one another a kind of "family resemblance" (Wittgenstein 1953). The words "autonomy" and "agency" adequately label some of these phenomena but the word "freedom" encompasses a wider range. This paper is an attempt to bring the diversity of these phenomena into view, using systems theoretic ideas about the system/environment relation, dynamics, categories of matter, energy, information, and utility, hierarchies of structure and function, and other related notions. For simple living systems, phenomena of interest include freedom from fixed materiality; internal as opposed to external determination; freedom in having available energy whose use is unblocked and holistic; and locomotion and agency, by which a system selects or alters its environment. For complex living systems, phenomena of interest also include freedom from lower level constraints; the transcending of the modeling subsystem's automatism in sensitivity (subjective experience) and the transcending of sensitivity in consciousness; the paradoxical freedom implicit in self-reference. In action guided by rationality, there is even a possibility of freedom from (narrowly defined) self-interest.

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