Emergence, matter, mind, and consciousness

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What follows is an outline of my current thinking regarding emergence, mind, and consciousness.

I believe that intellectual progress parallels biological evolution: there is a creative, expansive phase in which variety of hypothetical possibility is generated, and a evaluative, contractive phase in which the possibilities are exhaustively criticized and subjected to sober, rigorous test. I think we should strive to simultaneously keep our imaginations as open as possible and our evaluative faculties as sharp as possible. Although I have strong opinions on problems of "emergence" and of "consciousness", I think it is important to be as inclusive and open-minded as possible when weighing the possible utility of differing perspectives. Nobody has a monopoly on the "correct" formulation of either concept. I do believe, however, that we need to be clear about what we mean, such that others can use our definition to reliably make the same distinctions and to arrive at the same conclusions.

I have written about different varieties of emergence–computational emergence, thermodynamic emergence, functional emergence, emergence-relative-to-a-model – that encompass the emergence of new physical, chemical, biological, mental, and social structures and functions. Of these, I find problems of the emergence of life, mind, and consciousness to be by far the most interesting.

The problem of conscious awareness

I take both the existence of the phenomenal world of our mortal, time-delimited conscious awareness and the existence of an external material world as givens. I am impatient with questions of ultimate existence (e.g. Chalmer's "Hard Problem" of why conscious awareness exists, or why matter or gravity exist, or Possible Worlds interpretations of quantum mechanics) because these questions never seem to go anywhere – they don't generate predictions about the world, phenomenal or material, that could ever be tested. Philosophical questions are too important to be left only to philosophers. I believe that many of the problems of the material, neuronal requisites of conscious awareness and the correlates of the contents of that awareness are quite tractable once they are posed properly.

Matter-organization hylomorphism. I take Aristotle's "causes" as complementary modes of explanation that invoke different aspects of a given material system – form (formal cause), structural properties and internal dynamics (material cause), external forces (efficient cause), and functional organization (final cause). These constitute different aspects of a material system that are bound up with that system (hylomorphism, see Graham's *Aristotle's Two Systems*, or D. Modrak's *Aristotle: The Power of Perception*). Formal explanations form the core questions of mathematics, material causes the

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fundamental problems of physics, chemisty and molecular biology. For theoretical biology, neuroscience, and psychology, I would argue, functional organization, and not the behavior of particular parts, is most fundamental because it is the distinctive functional organization of organisms and nervous systems/minds that define them as such. In matters of life and mind, we seek to go beyond a listing of parts and their mechanics to understand principles of operation and organization that teach us new strategies for design.

Life arises when autopoietic networks are formed that can regenerate their parts, and life persists when reliable memory mechanisms (e.g. genetic codes) arise that constrain rate-dependent self-production dynamics by means of rate-independent processes (Pattee's a-temporal, inheritable symbols that reset boundary constraints). Signals and "informational" processes arise when behaviors of systems can be described in terms of switchings between distinguishable alternatives contingent on pattern recognitions.

Mind as informational organization. Mind is the functional organization of the informational processes of nervous systems. I believe that conscious awareness is an ontological concomitant of a particular organization of informational processes – the capacity to regenerate coherent patterns of activity and to switch between alternative patterns. According to this view, the structure of conscious awareness reflects the structure of this regenerative process with the contents of awareness being isomorphic to the structure of the regenerated (neuronal) signals. We do not yet understand the nature of the central neural code(s) that bear the informational patterns that subserve the contents of our awareness. *The neural coding problem is the single greatest barrier to understanding the details of how the brain works as an informational system.* It is like trying to understand biology without The Central Dogma, that DNA is the vehicle of genetic inheritance. If you don't understand the nature of the signals in a system, it is very difficult to understand how it works, what are its operant functional principles, In the case of the nervous system, it is difficult to determine what is and is not meaningfully correlated with phenomenal experience. What is the essential difference in neuronal activity that makes a difference phenomenally? The current mainstream view is that neural codes involve constellations of particular neurons firing either more frequently or in synchrony. An alternative, minority view is that neural codes could involve characteristic temporal-patterns of spikes, synchronously or asynchronously generated, irrespective of which particular neurons are involved. I believe that this alternative hypothesis about neural coding makes sense both from considerations of how the various kinds of information might be integrated into a coherent whole and from the failure of large scale connectionist models of brain function. Whether coded in terms of temporal patterns or combinations of active neurons, neuronal signals are regenerated through recurrent circuits (re-entrant, feedback loops a la Cajal, Lorente, Kubie, McCulloch, Lashley, Hebb, John, Edelman, Llinas, et al) that support reverberation of neuronal signals. This is essentially a cybernetic functionalist view of mind that utilizes feedback loops and analog pattern-resonances (in contrast to a computational functionalist view that holds that the essential organizational requisite of mind is a symbolic computation).

The structure of experience. Arguably, general anesthetics disrupt the coherence of signal regeneration, and with it conscious awareness. Those regenerating patterns that are generated from outside the loop network, i.e. contingent on inputs from sense organs, are experienced as sensations. Those sequences generated from within the loop network are experienced as thoughts and emotions. Desires and purposes are embedded in the limbic and frontal circuits that evaluate and anticipate the consequences of behavioral alternatives. These hypotheses are empirically testable in the near future, especially once more is known about neural coding, by correlating neuronal activity patterns with states of consciousness (either introspectively experienced or inferred from external observation). In the case of general anesthetics, what aspects of the organization of neuronal activity change at the concentrations at which loss of consciousness ensues? This theory depends on network interactions of neuronal cellular and molecular elements capable of receiving and sending pulse-coded signals; no exotic quantum mechanical processes are required.

Consciousness and physical causality. According to this general perspective, conscious awareness, being a concomitant aspect of the organization of neuronal activity, plays no causal role per se. It doesn't need to because it is an integral aspect of the same substrate, not a separate substance.[2] Awareness has no adaptive value or "function" in and of itself, apart from the action of the informational processes which it reflects. As a consequence, I don't think talk of either zombies or evolutionary adaptationist just-so stories for conscious awareness itself is helpful. Likewise, goal states (purposiveness) are part of the functional organization of neural circuits that steer behavior. We experience our desires and purposes because they are a part of the regenerated informational order, but our awareness of them does not have a causal effect in the sense that the awareness itself alters the physico-neural processes that ensue.

Determinism, autonomy, and free will. Free will is important for moral and political reasoning. Even if our conscious awareness and volition per se cannot causally alter our physico-neural processes, this does not mean that our brain states are necessarily predetermined in any rigorous or verifiable sense. The arguments about whether the universe is inherently deterministic or indeterministic on some micro-scale look to me to be completely untestable in practice; even if we believed that physical laws are deterministic, knowledge of them alone would not give us all the initial conditions needed to make predictions of the molecular state of a single simple organism – a host of measurements is needed. Claims of ontological micro-determinism are even more difficult to make in light of (most interpretations of) quantum mechanics. However, I think macro-determinism bears much greater practical relevance to the problem of free will – how independent are our brains and minds from external influences and coercions. Here self-control and self-direction determines the degree of autonomy relative to one's

[2] Ervin Lazlo makes similar arguments for hylomorphic panpsychism and connects this view with that of Leibnitz, Spinoza, Teilhard, and Whitehead (*Zygon* 41(3): 533-541; 2006). However, it is not clear to me whether *all* material entities must have corresponding phenomenal aspects (Liebnitzian monads) or whether these are associated with only appropriately-organized material assemblages such that there is some organizational threshold or memory-closure that must be achieved before a persistent phenomenal perspective can be realized.

surrounds. The realm of volitional freedom is amplified when actors attain a degree of psychological autonomy (they know what they want) coupled with enabling conditions for action (ability to act effectively to realize goals; relative absence of external coercive barriers). I believe that there are degrees and kinds of free will that distinguish reactive organisms from self-directed ones and slaves from those who are free (a political prisoner in a gulag may have more psychological freedom but less physical freedom than a well-to-do celebrity who is addicted to drugs). I think the central goal of a free society should be to maximize freedom by facilitating the growth of psychological and physical self-determination in its members.

The problem of emergence

The problem of emergence involves the processes by which novel structures, functions, behaviors, organizations and properties come into being. It has two major thrusts, philosophical-scientific discourse that is directed at explaining how novelty is possible in the world and practical, design-oriented investigation that is directed at understanding what principles are involved in building creative, open-ended systems with emergent properties. Thus emergence is intimately related to problems of the relations between matter, mind, consciousness, creativity, and free will.

The philosophical-scientific discourse bears on questions of the origins and evolution of conscious awareness and free will. If mental properties and conscious awareness depend on particular organizations of matter that have come into being over time, then these properties are emergent in the temporal sense. If these emergent properties cannot be entirely reduced to or accounted for in terms of the action of physical laws, then these properties are inherently emergent because they are in a deep sense complementary to or incommensurable with physical laws. In my experience, many ontologically-oriented discourses on emergence founder because they neglect to provide operational definitions for recognizing the properties involved and clearly, reliably making the essential distinctions. Clear definitions are absolutely critical if these discourses are to maintain coherence. One alternative to wrangling over ontological issues is to examine different kinds of concrete descriptions of systems to determine whether (or under what conditions) one kind of description can be reduced to (or explained in terms of) another. For example, a given physical digital electronic computer can be described (in principle) in terms of deterministic, time-dependent differential equations that embody the laws of classical physics, in terms of the mass-statistics of microscopically-indeterminate quantum mechanical states that yield reliably-determinate macro-state transitions, or in terms of a rule-governed symbol system that can be put in a 1:1 correspondence with a finite-state automaton. All three are valid, useful descriptions of the computer, but they are not fully interchangeable or automatically deducible from one another. It takes extra "bridge" concepts (e.g. notion of a stable attractor, ability to delineate attractors) to go from the micro-physical descriptions to the macro-functional, symbolic descriptions. The three descriptions illuminate different aspects of the same material process that involve different sets (and types) of observables and predictive formalisms.

Towards a physics of organization. Rather than (or in addition to) stoking ontological debates over quantum mechanics and the ultimate nature of the world, deterministic or not, I think we need a physics of organization and information that addresses the fundamental problems of biology and psychology. We need physical descriptions of special constraints, functional organizations, symbols, memory, information, measurement operations, and computations, a la Howard Pattee and Robert Rosen, and a theory of the observer-actor that can span biological organisms, nervous systems, information processing devices, and semiotics. Further articulation of such a physics would provide a bridge between material processes, the organizational closures that characterize life, the informational processes that characterize minds and observers, and (arguably) the informational closures that support consciousness.

Design and construction of emergent systems. The engineering approach to emergence involves learning by doing; to understand the process by using it to conceive, design and build emergent systems. This is where I place myself, at the intersection between theoretical biology, theoretical neuroscience, and cybernetics. The important questions for this approach involve understanding the functional principles that underlie life, mind, and consciousness. What kinds of parts and functional organizations do we need to evolve living organizations, neuronal information-processing systems, and potentially conscious entities? How should a biological, neuronal, or even social system be organized so as to be capable of self-directed, open-ended creative innovation? Here computer simulations of organisms and of neural networks are useful as investigations into the organizational requisites for the regeneration of material components (life) and informational patterns (mind). Building robots is useful for understanding the basic functional requisites for perception, coordination, and goal-directed action. Although the basic outlines seem clear, the details of biological self-production (autopoiesis) and the effective organization of informational processes require more investigation. I believe that the most useful contribution that I can make at this point is to show how informational processes in brains could be coherently organized via temporal pattern pulse codes, recurrent transmission networks, broadcast of signals, and mass-statistical processing of temporal spike train patterns, and how such a signaling system could self-organize to create entirely new types of signals.

History and sociology of science. I should say that I often feel like one of the last surviving members of several soon-to-be-extinct intellectual species. These include: the cybernetics and bionics of McCulloch, Ashby, Pask, Walter, Wiener and Sommerhoff; the theoretical biology of Pattee, Rosen, Waddington and Weiss; the neurophysiology of neural coding; the perceptual psychology of the Gestaltists; and those theoretical neuroscientists such as Lashley, Pribram, John, Abeles, Freeman, and the Gibsonians who have envisioned alternatives to purely connectionist theories of brain function. It always seemed to me that cybernetics, theoretical biology, psychology, and neuroscience could form a natural, integrated approach to fundamental problems of life, brain, mind, and consciousness. This never transpired, I think partly because of the dominance of symbolic AI and the computer metaphor in the cognitive sciences and philosophy of mind. On the biological and neuroscientific side, the extremely distorting effects of the NIH's disease-oriented funding approach, which has no stable guiding compass, has created and nurtured scientific cultures that are averse and sometimes downright hostile to unifying theories. The migration of physicists into neuroscience has been very positive in this respect because they come from a scientific culture that values fundamental problems and unifying theories, but on the other hand, many physicists tend to be blind to the cybernetic and psychological dimensions of mind-brain problems. Dynamical systems, statistical mechanics, and Bayesian inference models of brains are not so interesting in and of themselves; they need to be applied to realizing concrete neural information processing mechanisms directed at the explanation of the structure of specific psychological functions. It is such a pity that many of the older intellectual lineages have not been able to regenerate their numbers by channeling durable sources of funding, and that as a consequence, their ideas are all but systematically omitted from both the histories and current formulations of these problems. In my lifetime, I have seen profound, even indispensable intellectual traditions sidetracked by tribal dynamics, funding bandwagons, and current academic fashion. I know that these largely abandoned traditions hold insights that are of high relevance to the problems we are again addressing. In many cases, the quality of thinking in these traditions was considerably higher than what is on the current scene – the additional empirical data that we have before us helps little if we do not have coherent conceptual frameworks available for making sense of it all. For this reason, I think it is important to take a longer-range view that values scholarly efforts to understand and apply the ideas of past traditions as much as it does those ideas that happen to be popular at the moment.

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