Ulanowicz, R.E. 2000. Ontic closure and the hierarchy of scale. pp. 266-271. **In:** Chandler, J.L.R. and Van de Vijver, G. *Closure: Emergent Organizations and Their Dynamics.* Annals of the New York Academy of Sciences. Vol. 901.

Ontic Closure and the Hierarchy of Scale

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ABSTRACT: The Newtonian, universalist world view is incompatible with the notion of ontological indeterminacy. A hierarchical, or granular perspective, however, reveals how the consequences of pure chance, at scales far removed from those at which the event occurs, can be mitigated.

INTRODUCTION

The cornerstone of the *modern synthesis* was laid soon after Newton's publication of *Principia.* It was embodied in a growing consensus that all natural phenomena were the immediate result of only two types of causes—material and mechanical. Explanations cast in any other terms were effectively proscribed from scientific dialogue.

During the eighteenth century there was much logic to the expedient of ontic closure, and science blossomed profusely throughout most of the following century as a result. By the advent of the twentieth century, however, discoveries in relativity theory and especially in quantum phenomena, led physicists to begin to question the validity of ontic closure. In contrast, biology, perhaps of necessity a more conservative endeavor, hewed steadfastly to Newtonian precepts. In fact, the biologist's faith has been reinforced by several notable achievements during the past several decades, such as the *grand synthesis* and the discovery of the structure and workings of DNA, both of which have been intentionally cast in mechanical terms. As a result, the prevailing neo-Darwinan framework of biology today remains largely Newtonian in scope.

Most challenges to biology–as–machinery have come from those outside the discipline, notably from philosophers such as Charles Saunders Pierce, Alfred North Whitehead, and Karl R. Popper, who see ontic closure as inaccurate and/or misleading. Popper, for example, suggests that, until we revise our most fundamental notions of causality, we will be unable to attain a full "evolutionary theory of knowledge."[1] Furthermore, doubts about *natura cum machina* are not confined to those who invoke the results of quantum physics. Popper sees an entire world that is "open"—at the level of society, as well as at the microscale of the quark.[2]

CONTRADICTION AND PARADOX

Of course, the idea of *de novo* causation at macroscopic scales conflicts fatally with the reductionist world view. By conventional wisdom, allowing for causes to appear along all scales of the hierarchy would result in nature simply self-destructing. Such a conclusion is ordained by the newtonian postulate that all laws are universal in nature; that is, they apply everywhere and at all scales. If an anomaly were to appear anywhere, the universal laws would propagate its effects everywhere else. Rampant disorder would ensue.

Paradoxically, the reason that anomalies wreak less havoc in a causally open world has to do with the decoupling of scales that are far removed from one another. Under the hierarchical perspective, now popular in some schools of ecology, laws are formulated at particular levels of space, time, and complexity. As one proceeds farther from those levels at which a law was cast, the explanatory capability of the precept is thought to wane—sometimes drastically.[3] The resulting view of the world becomes "granular" in nature.[4] Each law remains robust only within a limited sphere of the spatio–temporal hierarchy. There is some overlap among these domains, to be sure, but no universal interpenetration, as previously assumed. Hence, the effects of any anomaly with its own characteristic lengths and times can potentially be mitigated or damped at scales far above or well below the scale of the anomaly. Somewhat ironically, the situation is akin to Ronald Fisher's observation that "the reliability of the physical material was found to flow, not necessarily from the reliability of its ultimate components, but simply from the fact that these components are very numerous and largely independent."[5] In a world that is not rigidly coupled, the domain of any effect is necessarily circumscribed.

Saying that true accidents can have only limited effects falls short, however, of accounting for what many perceive as a cohesion or rough order to the realm of living, evolving systems. In some instances, conventional mechanisms appear to function within hierarchical boundaries, but in an ontically open world universal mechanisms alone cannot forestall untold chaos. Enter Karl Popper, who avoids rampant stochasticity by postulating the existence of what he calls "propensities"—generalizations of Newtonian-like forces (mechanisms).[1]

ORDER GENERATING PROPENSITIES

In brief, a propensity is the tendency that a certain event might occur within a particular context. Popper relates (but does not equate) propensities to conditional probabilities; for example, the probability that B will occur, given that A has happened. If A and B are related in mechanistic (force-like) fashion, then every time that A occurs, B is sure to happen. (The conditional probability of B given A is one.) With propensities, A is less rigidly coupled to B. Most of the time that A occurs, B happens, but occasionally C or D might result. The occurrence of C or D Popper would term an "interference". Popper allows for the context of a propensity to include other propensities, so that propensities may arise at any level due to interferences with other propensities at that level.

Other than vaguely relating propensities to conditional probabilities, Popper stops well short of formulating how one may quantify a propensity—how the concept might be made operational. Furthermore, beyond the mention that propensities may arise out of interferences, Popper pays scant attention to how propensities, once in existence, might evolve. I have attempted to address these lacunae in Popper's narrative by the application of information theory to networks of interacting processes.[6] Very briefly, I have concentrated on situations wherein propensities interact with each other in ways that give rise to positive feedback. Mutual reinforcement of propensities has the *extensive* effect of strengthening the magnitudes of the interacting processes, whereas its *intensive* result is to amplify the participating processes at the expense of other nonparticipating phenomena. That is, nonparticipating processes are effectively pruned away (or at least relegated to the background), as the growing aggregate activity becomes progressively constrained to the linkages among the members participating in autocatalytic feedback.

QUANTIFYING PROPENSITIES

Information theory is the ideal tool for quantifying and separating the complexity inherent in a nexus of interacting processes into distinct organized (constrained) and disordered (free) components. Left to their own devices (i.e., without significant novel disturbances from below or blocking constraints from above), groups of self-reinforcing propensities will tend to aggrandize themselves, both by becoming stronger in magnitude and more mechanical in nature. (Hoffmeyer's "habits of nature" become ever-deeper.) The system's *internal* constraints grow stronger, and this facet is captured most conveniently by the index, *average mutual information* from information theory.[7] (The average mutual information is composed in part from conditional probabilities.)

The performance of living systems, whenever they are isolated from major disturbances, can be portrayed in terms of the products of the growing magnitudes of the processes themselves, each multiplied by the increasing intensities of their associated propensities to occur.[8] The aggregate of such products for any system is called its *ascendency*. That is, a system's ascendency is the process-weighted aggregate of its component propensities.[9] All other things being equal, increases in system ascendency are abetted by more species, more specific predation, greater internalization, and increased cycling. Taken individually, these are attributes of what Eugene Odum termed "more mature" ecosystems.[10] In other words, ecosystems (and possibly other living organizations) appear to have an inherent propensity to increase in ascendency.

CAVEAT

As an important caveat, we note that real ecosystems are continually beset by disturbances, some of them major. Ecosystems cannot rush unimpeded towards ever-higher levels of performance. Neither is the disordered complexity (the degree of freedom and stochasticity) always an encumbrance to the system (despite the chosen moniker, "system overhead"). Whenever the system is confronted by some novel perturbation, it is only from this pool of disorganized complexity that the community can draw elements with which to create for itself an effective reconfiguration to meet the challenge. Overhead is essential to a system's reliability, long term survival, and continued evolution. Any system that is *healthy* or possesses *integrity* must maintain a tradeoff between the mutually exclusive system attributes of ascendency (representing performance or efficiency) and overhead (reliability).[11,12] In some respects this creative tension resembles a dialectic.

ECHOES OF NEWTON

In considering the hypothesis that living systems possess an inherent propensity to increase in ascendency, we note that the ascendency itself is a weighted propensity. Whence, the prescription reads like a second order dynamic—the propensity of a propensity. In this regard it resembles Newton's second law (which describes the rate of change of a rate of change). Actually, this formal analogy should come as no big surprise. Popper intended the concept of propensity to generalize the notion of mechanical force. It follows then that any principle built upon propensity should bear at least vague resemblance to Newton's law of force. We see, then, how the principle of increasing ascendency proceeds from Newtonian law in much the same way that Schroedinger's wave equation for quantum physics grew out of formal analogy with Newton's second principle.[9]

If shadows of Newton's laws survive in the principle of increasing ascendency, the same cannot be said of the enlightenment metaphysic that evolved in the wake of Newton's *Principia*. The (relatively) minimalist character of that work led followers of Hobbes, Descartes, and Newton to conceive of the natural world as ontically closed, determinate, universal, dynamically reversible, and atomistically decomposable. One by one the latter four assumptions have been challenged by our increased awareness of the complexity inherent in natural phenomena. Finally, ontic closure itself, the lynchpin of the modern synthesis, is brought into question.

AN ECOLOGICAL METAPHYSIC

Just as Popper conceived of mechanical forces as degenerate forms of more general entities, the classical physical world begins to resemble only a remote caricature of the ecological world that immediately surrounds us. We are prompted, therefore, to formulate a new ecological metaphysic to accompany the new dynamics. Accordingly, I have proposed the following metaphysic to replace each of the Newtonian axioms in its turn:[9]

1. Ecosystems are ontically *open.* Indeterminacies, or *genetic events* can arise anytime, at any scale. Mechanical, or efficient causes usually originate at scales inferior to that of observation and propagate upwards; formal agencies (*sensu* Aristotle) appear at the focal level; and final causes arise at higher levels and propagate downward.[3,13]

2. Ecosystems are *contingent* in nature. Biotic actions resemble propensities more than they resemble mechanical forces.

3. The realm of ecological phenomena is *granular* in the hierarchical sense of the word: An event at any one scale can affect matters at other scales only with a magnitude that diminishes as the scale of the effect becomes farther removed from that of the eliciting event. It follows that genetic events at lower levels do not propagate unimpeded up the hierarchical levels, because they become subject to constraint and selection by formal and final agencies extant at higher levels.

4. Ecosystems are *historical* entities: Genetic events constitute discontinuities in the behaviors of systems in which they occur. As such, they engender irreversibility and degrade predictability. The effects of genetic events are retained in the material

and kinetic forms that result from adaptation. The interactions of propensities in organic systems create a more likely direction or telos in which the system develops.

5. Ecosystems are *organic*: A genetic event is likely to appear simultaneously at several levels. Propensities never exist in isolation from their context, which includes other propensities. Propensities in communication grow progressively more interdependent (increasing ascendency), so that the observation of any part in isolation (if possible) reveals ever less about its behavior when acting within the ensemble.

A CONSTRUCTIVIST POSTMODERNISM

In the light that the ecological vision sheds upon nature, attempts to retrieve the modern synthesis seem counterproductive.[14] For, it is not as the revanchists would have us believe—that the only alternative to ontic closure is the unbridled deconstruction of postmodernism. Rather, with some imagination, it becomes possible to achieve a postmodern construct[15]—a new lens on a world full of true wonders.

ACKNOWLEDGMENTS

The author wishes to acknowledge support from the Multiscale Experimental Ecosystem Research Center (MEERC), and Contract R19640 from the US Environmental Protection Agency.

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