Articles

EMERGENCE, NATURALLY!

by Robert E. Ulanowicz

Abstract. The prevailing common assumptions about how nature behaves have their origins in the early Enlightenment. The notion of emergence does not sit comfortably within this framework. Emergence appears virtually impossible within a world determined by ineluctable and unwavering natural laws. But the variety and combinations inherent in living systems render physical laws indeterminate. The study of ecological dynamics suggests that processes rather than laws are what accounts for most order seen in the living realm. As a consequence, there are aspects of ecological dynamics that violate each of the Newtonian postulates. The dynamics of ecosystems suggest a smaller set of rational assumptions through which to view nature—an "ecological metaphysic." Emergence appears as a rare but wholly natural phenomenon within the new rational platform. In addition, several apparent conflicts between science and theism that arose under the Newtonian framework simply vanish under the new perspective.

Keywords: causality; chance; Darwinism; determinism; dialectic; ecology; emergence; evolution; free will; indeterminacy; materialism; metaphysics; naturalism; Newtonianism

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If you look at the world through rose-coloured spectacles, you cannot tell which parts of it really are rosy and which parts just look rosy.

—Oliver Penrose (2005, **000**) au: give page no. of quote

The title of this essay may strike some readers as peculiar, simply because emergence seems anything *but* natural under the prevailing scheme of things.

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How indeed can one fit the concept of emergence into a world that is assumed to be driven by ineluctable and unswerving laws? As is the case in other realms of complex behavior, the picture of ecosystem dynamics seems to diverge from one in which laws determine all that transpires. Such departure from common wisdom is not something entirely new, however. Gregory Bateson (1972), for example, staunchly maintained that ecology provides a very different perspective on how living systems evolve. More radically, Bateson implied that the fundamental assumptions commonly used to view the world—the very same assumptions that have fueled so much accomplishment over the past 300 years—are *categorically wrong*.

Bateson further cautioned that, should society hold to its current course, it inevitably will come to a bad end. The only way out, he warned, is to adopt an ecological vision to replace the Enlightenment principles. There is no mistaking that by focusing on ecology Bateson was not simply advocating environmentalism. Rather, he was declaring that the lens that society uses to view the world is falsely colored and in need of correction according to how matters transpire in the realm of ecology.

Contemporary Metaphysics

Bateson's challenge is decidedly radical. In order to gain some perspective on just how radical, it is necessary to outline the fundamentals that currently guide the scientific enterprise. First, it is not scientific methodology that is being questioned. With few exceptions, the scientific method remains robust and highly effective, as a legion of books would assure the reader. Rather, at issue here are the fundamental, usually tacit postulates that virtually every scientist accepts about how the world operates. The subject at issue is the ontology of nature, or what science assumes as its metaphysics.

au: impossible?

The difficulty with any discussion of personal assumptions is the impossible variety of beliefs that the multitude of scientists hold. In an effort to achieve a tractable description, the stratagem here is to return to a time (the early nineteenth century) when a reasonable consensus did exist concerning basic assumptions about nature. It happens that virtually all shades and combinations of current opinions can be traced back to this formulation, which originated in the wake of Newton's *Principia* and captures the essence of Enlightenment views on nature.

David Depew and Bruce Weber in their tome *Darwinism Evolving* (1995) enumerated those assumptions (Ulanowicz 1999a):

1. Newtonian systems are causally *closed*. That is, only mechanical or material causes are legitimate, and they always co-occur. Other forms of action are proscribed, especially any reference to Aristotle's "final," or top-down, causality.

2. Newtonian systems are *atomistic*. They are strongly decomposable into stable least units, which can be built up and taken apart again. Atom-

ism combined with closure gives rise to the notion of causal reductionism, whereby only those agencies at the smallest scales are of any importance. Whence, Carl Sagan, in summarizing his television show on biological evolution that featured magnificent images of dinosaurs feasting and struggling with one another, saw no inconsistency whatsoever in his declaration, "These are some of the things that *molecules* do!"

3. Newtonian systems are *reversible*. Laws governing behavior work the same in both temporal directions. This is a consequence of the symmetry of time in all Newtonian laws.

4. Newtonian systems are *deterministic*. Given precise initial conditions, the future (and past) states of a system can be specified with arbitrary precision.

5. Physical laws are *universal*. They apply everywhere, at all times and all scales. The key adverb here is "everywhere." In combination with determinism, universality says that nothing occurs except that it be elicited by a fundamental physical law. In the words of Stephen Hawking (1988) and Sagan, there is nothing left for a creator to do.

The reader might justifiably object that no one today fully believes in the validity of all five tenets. For example, soon after Pierre LaPlace ([1814] 1951) had exulted in the absolute power of Newtonian laws, Sadi Carnot ([1824] 1943) initiated the science of thermodynamics with his demonstration of the irreversible nature of physical processes. Later, Charles Darwin (1859) would include history (irreversibility and indeterminism) in his scientific narrative. Perhaps the final blows to the ascendancy of Newtonianism were struck at the beginning of the twentieth century when relativity and quantum theories surfaced to throw universality and determinism gravely into doubt.

It is no exaggeration to say that after nearly two centuries of erosion, the fabric of the classical assumptions lies fully in tatters. Such circumstance notwithstanding, almost every scientist continues to cling to at least one or more of its dangling threads. Thus it is that closure is strictly enforced in the neo-Darwinian scenario of evolution. Richard Dawkins (1976) and Daniel Dennett (1995), for example, are scrupulous in making reference to only material and mechanical causes. Atomism (reductionism) continues to dominate biology—witness the prevalence of molecular biology today. Almost daily one reads or hears about the discovery of some gene that *directs* a particular trait—echoes of Sagan's paean to the many wondrous things that molecules do. As for determinism, most appear to continue to deny the reality of chance in the world, contending instead that probability theory simply papers over an underlying determinacy.

Problems with Biology

Reasons why so many cling to this disheveled basis for rationality are discussed more fully later. Suffice it for now to note that in at least one field of endeavor phenomena appear to violate all five of the Newtonian precepts. As Bateson suggested, that field is ecosystem behavior, which seems to provide an appropriate theater in which to search for clues helpful in formulating new rational foundations for science.

Ecosystems are so notoriously messy to deal with that the idea that their behaviors are not fully determined by laws should not sound all that strange. Herewith I argue that ecological dynamics are fixed not by scientific laws but by *processes* (Whitehead 1929; Barbour 1997). Of course, this perspective is hardly new. Darwin portrayed evolution as a process, not as a law, but that distinction is rarely emphasized in today's milieu. Support for the insufficiency of law has been provided by physicist Walter Elsasser (1981), who maintained that all attempts to seek "laws" akin to those used in physics to explain biological phenomena are patently illogical.

Elsasser's argument centers around the obvious heterogeneity in biological systems. That biological entities all differ from each other in at least minor ways limits the kinds of interactions that can occur between groupings. Elsasser makes the distinction that physics deals with a continuum, whereas in biology the dominant concept is that of a class (as in taxonomy.) Philosophers Alfred North Whitehead and Bertrand Russell (1913) demonstrated that the way in which physics deals with a continuum can be reduced in logical terms to operations between perfectly homogeneous sets, that is, groupings of entities that are indistinguishable from each other. Examples of perfectly homogeneous classes are collections of electrons or hydrogen atoms. An investigator has no means available to label one electron as different from another.

A recapitulation of Whitehead and Russell's logic is not appropriate here, but one can get an inkling of it via two very elementary examples. The first consists of homogeneous sets of integers. The first homogeneous set consists of five identical tokens of the integer 1; the second contains five tokens of the integer 2; the third contains 3s, and so on. Now the set of 2s is allowed to interact with the set of 4s according to some fixed operation (Figure 1). For example, each of the tokens in the first set might be multiplied by any corresponding member of the second. The result is another homogeneous set of five 8s. The determinate result is a single homogeneous set.

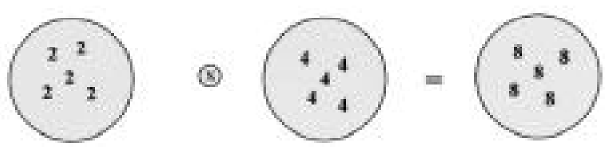

Fig. 1. A fixed operation upon two homogeneous sets. The result is a single homogeneous set.

In biology one is forced to work with heterogeneous groupings. To represent this circumstance one might consider sets of integers grouped by fives according to magnitude. That is, the first set contains the integers 1 through 5, the second 6 through 10, the third 11 through 15, and so forth. If the first set now operates on itself according to the same scheme as used in the first example, one possible outcome would be the integers 4, 5, 6, 8, and 15. These integers are scattered across three separate sets (Figure 2.) Other combinations would yield similar "indeterminate" results in the sense that they would be scattered over several groupings.

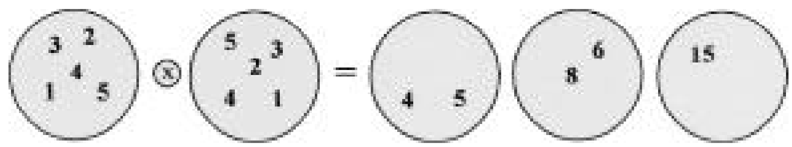

Fig. 2. The same operation as in Figure 1 carried out on a heterogeneous grouping of integers yields results in several different groups.

Elsasser concluded that determinism among heterogeneous groupings is nonsensical. No laws akin to those proper to physics can ever arise in biology (see also Lewontin 2000). As Karl Popper (1982; 1990) opined, indeterminacy and interference force one to generalize concepts if they are to become applicable to complex systems.

Of course, indeterminacy is exactly what keeps statisticians employed in biology. And despite ubiquitous aleatoric influence, one does observe statistical regularities throughout the living realm. Is one to infer that the genie of chance is now under control—that science, as Hawking and Sagan have suggested, essentially has all the answers? "Hardly!" Elsasser would reply, because he also was able to demonstrate that probability theory *cannot* be applied to most chance phenomena.

Conventional approaches to chance events almost always make the tacit assumptions that all chance is simple, generic, and repeatable. Elsasser (1969), however, demonstrated that the overwhelming majority of stochastic events in biology are totally unique, never again to be repeated. At first such an assertion sounds absurd, given the enormity and age of the universe, but further reflection reveals it to be surprisingly easy to defend. Elsasser did so by defining a threshold to what he called "enormous" numbers. An enormous number of possibilities is one so large that it must be excluded from physical consideration, because it greatly exceeds the number of physical events that conceivably could have occurred since the Big Bang. As an estimate of this threshold, Elsasser multiplied the appropriate number of fundamental particles in the entire known universe (about 10^{85}—1 followed by 85 zeroes) by the number of nanoseconds[1] that have transpired since the Big Bang (about 10^{25}). Any number of possibilities much larger than this product (10^{110}) simply transcends physical reality.

Those familiar with combinatorics immediately will recognize that it does not take a large variety of distinct elements or processes before the number of possible configurations among them becomes enormous. It does not require billions of separate entities to pose a number of possible combinations that exceeds Elsasser's limit on physical reality. A system with eighty or so identifiable components will suffice. Any event randomly comprising more than eighty separate elements is almost certain never to have occurred earlier in the history of the universe. It follows, then, that in ecosystems, which are composed of hundreds or thousands of distinguishable organisms, one must reckon not just with an occasional unique event but with legions of them. Unique, singular events are occurring all the time, everywhere! Now, a necessary precondition for applying probability theory to chance events is that the event in question occur at least several times, so that a legitimate frequency can be estimated. Singular events, however, occur only once, never to be repeated. Legitimate probabilities simply cannot be assigned to them.

It is important to note that singular events constitute actual holes or gaps in the causal fabric. Akin to Heisenberg uncertainties, they constitute a necessary part of nature, not some epistemological lacuna awaiting later theoretical elaboration. In the face of this situation, the assertion that determinism is a universal characteristic of nature appears absurd. Of course, a price must be paid for eschewing determinism and acknowledging that the universe is open: One must relinquish the hope of ultimate control over nature. There is, however, no alternative.

Both threads in Elsasser's thinking can be summarized in a few words: "Variety and combinatorics overwhelm law." It is not that any known law is ever violated. Rather, in complex systems so many combinations become possible that a multiplicity of configurations is always available to satisfy any set of parameters in the applicable laws. Laws continue to constrain what can happen, but they become insufficient to *determine* which configurations eventually prevail. That task must fall to some other type of agency.

From Laws to Processes

First Elsasser dispenses with the possibility of dynamical laws, and then he reveals the inadequacies of probability theory. Up to this point the discussion has been depressingly deconstructivist, and the reader would be justified in objecting that lots of biological phenomena patently *do* recur with significant regularity. If not laws, what might account for such regularities? As suggested earlier, all indications point toward processes.

For purposes of this discussion a *process* may be defined as the interaction of random events upon a configuration of constraints that results in a nonrandom but indeterminate outcome. A useful example of a simple artificial process is Polya's Urn (Cohen 1976). This exercise begins with a collection of many red and blue balls and an urn that initially contains one red ball and one blue ball. The urn is shaken and a ball is drawn blindly from it. If the ball is the blue one, it is returned to the urn along with another blue ball from the reserve collection. The urn is shaken and another draw is made. If a red ball drawn, it and another red ball are likewise returned to the urn, etc. A first question arising is whether, after a long sequence of such draws and additions, the ratio of red to blue balls would converge to a precise limit. It is rather easy to demonstrate that after many draws, the ratio does converge to a constant, say 0.46967135. A further question would be what would happen if the urn were emptied and the starting configuration were recreated. Would a subsequent series of draws converge to the same limit as the first? It is easy to demonstrate that it will not. The second time it might converge to 0.81427465. After continued repetitions of the process, one eventually discovers that the ratio of balls is progressively constrained by the series of draws that have already occurred. It likewise becomes clear that the limiting ratio for any series of draws and replacements can be *any* fraction between zero and one.

Before going on, it is very useful to note three features possessed by even the artificial and simplistic Polya process:

1. It involves chance.
2. It involves self-reference.
3. The history of draws is crucial to any particular series.

As an aside, it also is helpful to point out that a mechanical law is a limiting form of a process. That is, if a process converges to a mechanical-like behavior (as the Polya process does on those occasions when it approaches a limit near the extremes zero or one), its behavior becomes indistinguishable from the action of a law. Generally speaking, however, processes remain indeterminate in their outcomes. Popper (1990) likewise suggested that physical forces could be considered limiting forms of more general interactions, which he called "propensities." In his lexicon, a *propensity* was the tendency for a certain event to occur in a particular context. With a law, every time A happens, B is "forced" to follow. More generally, however, when A happens, B usually follows, but not each and every time.

Polya's Urn is but a hypothetical process, and its constraints are imposed from without. Bateson (1972), however, provided a clue to where natural processes might of their own impart order to affairs. He noted that the outcome of random noise acting upon a feedback circuit is generally nonrandom. Such bias is especially characteristic of one particular form of feedback—autocatalysis (Ulanowicz 1986; 1997; Kauffman 1995). By *autocatalysis* here is meant any instance of positive feedback wherein the direct effect of every link on its downstream neighbor is positive.

Without loss of generality, one may take as an example the serial, circular conjunction of three processes A, B, and C (Figure 3). Any increase in A has a *propensity* to induce a corresponding increase in B, which in turn could elicit an increase in C, and whence back to A.

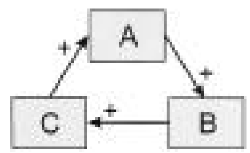

Fig. 3. A simple example of autocatalysis.

A didactic example of autocatalysis in ecology is the community that forms around the aquatic macrophyte *Utricularia* (Ulanowicz 1995). All members of the genus *Utricularia* are carnivorous plants. Small bladders, called utricles, are scattered along its featherlike stems and leaves (Figure 4a). Each utricle has a few hairlike triggers at its terminal end, which, when touched by a feeding zooplankter, opens the end of the bladder, and the animal is sucked into the utricle by a negative osmotic pressure maintained inside the bladder. In nature the surface of *Utricularia* plants is always host to a film of algal growth known as periphyton. This periphyton serves in turn as food for any number of species of small zooplankton. The autocatalytic cycle is closed when the *Utricularia* captures and absorbs many of the zooplankton (Figure 4b).

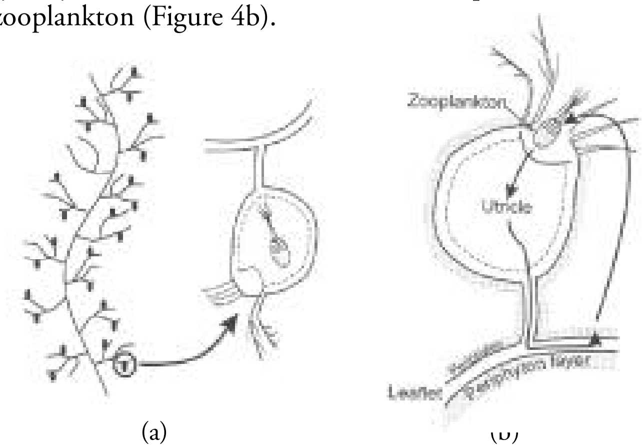

Fig. 4. (a) *Utricularia*, a carnivorous plant. (b) The cycle of rewards in the *Utricularia* system.

In chemistry, where reactants are simple and fixed, autocatalysis may be regarded as simply another mechanism. As soon as one or a few participants are able to undergo small, incremental alterations in response to stochastic events, the picture can change dramatically. In such case, a number of decidedly nonmechanical behaviors can arise (Ulanowicz 1997), but space allows for discussion of only a few:

Of notable importance, autocatalysis is capable of exerting *selection* pressure upon its ever-changing, malleable constituents. Consider, for example, a small spontaneous change in process B. If that change makes B either more sensitive to A or a more effective catalyst of C, the transition will receive enhanced stimulus from A. Conversely, if the change in B makes it either less sensitive to the effects of A or a weaker catalyst of C, that perturbation will likely receive diminished support from A. That is to say, there is a preferred direction inherent in autocatalysis—that of increasing autocatalytic participation. Such asymmetric action violates the assumption of ***reversibility***. Furthermore, as components are drawn further into autocatalysis, or mutually adapt to the cycle, they may lose the capability of acting on their own. Should they become separated from the cycle and still survive, they would behave radically differently from how they acted as part of the autocatalytic scheme. That is, the full cycle manifests an organic nature that contravenes the assumption of ***atomism***.

One notes in particular that any change in B is likely to involve a change in the amounts of material and energy that are required to sustain process B. Hence, whenever activity and resources are coupled, selection will act to reward and support those changes that bring ever more resources into B. Because this circumstance pertains to all members of the feedback loop, an autocatalytic cycle becomes the epicenter of a centripetal pattern of flows toward which as many resources as possible will converge (Figure 5).

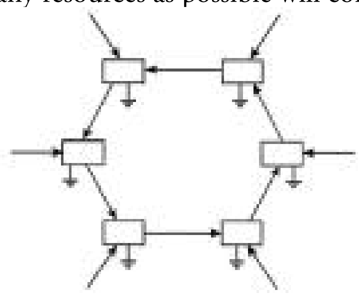

Fig. 5. Centripetal action as engendered by autocatalysis.

It is difficult to overstate the importance of centripetality to the phenomenon of life. Conventional Darwinism conveniently overlooks the role of "striving" in evolution (Haught 2003). Various organisms are engaged in an epic struggle, competing with each other, red in tooth and claw. But what drives the struggle? How does one demystify Darwinism? Here is what Bertrand Russell had to say on the topic: "Every living thing is a sort of imperialist, seeking to transform as much as possible of its environment into itself and its seed. . . . We may regard *the whole of evolution* as flowing from this "chemical imperialism" of living matter" (Russell 1960, **000**; au: give page no. of quote emphasis added). It is clear that by "chemical imperialism" Russell is identifying centripetality, and he correctly places it at the very core of evolution.

Conventional Darwinism, to the contrary, pivots all of evolution around competition. Some contend that this focus was the consequence of the social and economic milieu in which Darwin lived (Salthe 2006). Here it becomes evident that competition is actually corollary to (ontologically subsidiary to) centripetality, which rests upon notions of mutuality and beneficence. To see how competition derives from centripetality one need only consider how, whenever two loops partially overlap, the ensuing tendency is toward the exclusion of one of the loops. In Figure 6, for example, element D is assumed to appear spontaneously in conjunction with A and C. If D is more sensitive to A and/or a better catalyst of C, it is likely that the subsequent dynamics will so favor D over B that B will fade into the background or disappear altogether. That is, selection pressure and centripetality are capable of guiding the replacement of elements (Wicken and Ulanowicz 1988). It bears mention in passing that the same tendency to replace B with D could as readily replace a defective or destroyed B with another similar component B'—that is, the system repairs itself.

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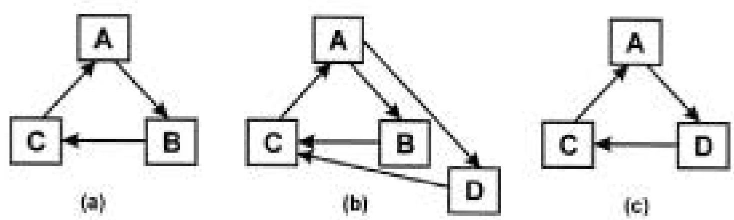

Fig. 6. (a) Original configuration. (b) Competition between component B and a new component D, which is either more sensitive to catalysis by A or a better catalyst of C. (c) B is replaced by D and the loop section A-B-C by that of A-D-C.

More generally, autocatalytic selection sometimes acts to stabilize, compartmentalize, and regularize behaviors across the physical hierarchy. Contrary to the rigidity imposed by the Newtonian assumption of ***universality***, under the ecological lens the consequences of an event or behavior at any point or time will rarely propagate up and down the hierarchy without attenuation. For example, the effects of noise at one level are usually mitigated by autocatalytic selection at higher levels and by energetic culling at lower levels. Through the action of processes nature takes on "habits" (Hoffmeyer 1993) and exhibits regularities, but the domains of such habits remain limited in time and space, and the universality of Newtonian laws is replaced by a *granularity* in the more elaborated cosmos (Allen and Starr 1982).

It is noteworthy that any autocatalytic selection pressure driving centripetality is exerted in top-down fashion. It is an agency proper to the macroscopic ensemble actively influencing its constituent elements. Not only does such mode of action directly contradict the Newtonian proscription of ***closure***, it also reveals that the effective agency behind the creation of new objects is not another object but a configuration of processes. The view that configurations of processes act as legitimate agencies in living systems has been termed *process ecology* (Ulanowicz 2004).

Enzo Tiezzi (2006) provided a didactic example of the central role that configurations of processes play in the phenomenon of life. He considered a dead deer that had just been killed by a hunter. It had the same mass, the same bound energy, the same genomes, the same microscopic and (virtually) the same macroscopic structure that it had possessed a few minutes before when it was fully alive. What is missing in death, however, is that the configuration of processes has vanished.

Tiezzi's example finally brings the topic of emergence front and center. For, if the sudden disappearance of a configuration of processes accompanies the cessation of life, might not those configurations also play the key role in the emergence of new forms of life? To recapitulate the ecological scenario thus far: Autocatalytic configurations of processes are constantly being impacted by a vast stream of complex singular events. By virtue of the coherence imparted by autocatalysis, the system remains indifferent to the vast majority of such impingements. A very small minority of those events will negatively impact the operation of the system, which then will have to reconfigure itself in adjustment to that perturbation and in anticipation of similar ones that might follow. In exceedingly rare circumstances, a form of complex chance will match hand-in-glove with the existing configuration of processes and propel the system into a wholly new mode of behavior. Such transition would constitute a legitimate example of radical emergence (Clayton 2004; Peterson in press). One recognizes it as a *totally natural*, albeit infrequent, element of the ecological dynamic.

An Ecological Metaphysic

au: I count only four bolded terms

The action of singular chance upon autocatalytic causal loops has now been demonstrated to violate at times every one of the five Newtonian postulates (denoted by boldface type in the preceding text). Simply put, the remnants of the Newtonian metaphysic are inappropriate to the description of living dynamics. It becomes necessary to identify an entirely new, but wholly naturalistic, metaphysic—an ecological metaphysic. The key to formulating a new metaphysic resides in the shift in emphasis from law to process. Needed is a new set of postulates more in keeping with the operation of processes.

Here it is useful to recall the three features of the Polya process noted earlier: that it involved chance, self-influence, and history. Two of these characteristics have been discussed in some detail. It is ontic chance, or more precisely radical contingency, that makes real change possible.

1. *Radical Contingency:* Nature in its complexity is rife with singular events. Most do not upset prevailing regularities, but on rare occasions one can carry a system into a wholly different mode of *emergent* behavior.

The second feature enables systems to maintain their integrities and grow. At its root lies autocatalytic action, which is a particular form of

2. *Self-Influence:* A process in nature, via its interaction with other natural processes, can influence itself.

Third, as Darwin long ago inferred, the system must retain some record of its past configurations. That is, it must possess a

3. *History:* The range of self-influence is constrained by the culmination of past changes as recorded in the system configurations. Such configurations can be static material forms, as are the genomes of Darwinian theory, but they could as well inhere in the topologies of interacting processes.

Starting with these three postulates, one may deduce in logicodeductive fashion most of the key organic behaviors exhibited by ensemble living systems, such as ecosystems, immune systems, social and economic systems, and so on (Ulanowicz forthcoming).

One may recognize two opposing tendencies in the foregoing narrative. Autocatalysis provides the motive for systems to grow and maintain themselves. Opposing this drive is the thermodynamic tendency for structures to degrade and dissipate. The immediate agonism between these directions ameliorates over the long run, however, and they are seen to be mutually obligate at a higher level: In the absence of radical contingency, novel structures could never emerge. Conversely, larger, more constrained structures perforce dissipate more resources. Overall the dynamic resembles a Hegelian dialectic (see also Callahan 2003; Keller 2005; Jackelén in press).

Cosmological Parallels

The drive toward more definitive structures, if allowed to proceed uninterrupted, would, as Popper (1990) intuited, lead to an evolutionary dead end. No further changes would be possible. Physicists will recognize in this dynamic their developing narrative for the evolution of physical matter and laws (Chaisson 2001). After the Big Bang, subtle asymmetries led to the self-selection of various enduring forms out of an initial homogeneous substrate, and with them appeared certain regularities in their interactions. Through progressive feedback, the forms and their interactions grew quite precise and stable, culminating in matter with its accompanying laws.

In this scenario, the stable material forms and the inexorable laws of physics actually derive from a more fundamental process, one that resembles the ecological metaphysic (Ulanowicz 2002). This shift in perspective prompts one to abandon the fatuous effort to explain the origin of life by starting with inert, dead forms—an exercise akin to trying to animate Ezekiel's dry bones (Ezekiel **xx:xx–xx**). The new vantage depicts both the elements of classical materialism and the domain of the living as resulting from a common, more fundamental process (Ulanowicz 2002).

au: give biblical reference for story

To summarize what has been suggested up to this point: One can achieve a more encompassing narrative by generalizing the agencies at work in nature from forces to propensities and by loosening the constraints under which nature transpires from laws to processes. Suddenly much, if not most, of the agency at work in living systems resides in configurations of processes rather than in objects. This new perspective leads to the formulation of an alternative metaphysic that is both simpler than and opposite to the legacy of the Enlightenment. In cosmological terms, process ecology appears to be *more fundamental than the material endpoints* that physical evolution has engendered. The ecological narrative demystifies Darwinism by identifying an agency behind the ubiquitous striving by living beings and has posited how new forms and behaviors could emerge naturally, including the beginnings of life itself. As fantastic as these new insights may appear, narrative has never strayed from the confines of methodological naturalism. No recourse has been made to the transcendental. There is nothing whatsoever to prevent a principled metaphysical naturalist from accepting the ecological vision.

A Middle Ground 'twixt Materialism and Theism?

au: perspectives pl?

Despite any excitement the new perspectives may generate in a small minority, it is unlikely that process ecology will supplant the conventional wisdom for two related reasons. The first was expressed in didactic fashion by Richard Lewontin:

> We take the side of science in spite of the patent absurdity of some of its constructs, in spite of its failure to fulfill many of its extravagant promises of health and life, in spite of the tolerance of the scientific community for unsubstantiated just-so stories, because we have a prior commitment, a commitment to materialism. It is not that the methods and institutions of science somehow compel us to accept a material explanation of the phenomenal world, but, on the contrary, that we are forced by our a priori adherence to material causes to create an apparatus of investigation and a set of concepts that produce material explanations, no matter how counter-intuitive, no matter how mystifying to the uninitiated. . . . (Lewontin 1997, **000**)

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By now it should be apparent that adopting the ecological metaphysic would require the materialist to modify significantly his/her fundamental beliefs about how the world operates. For example, one would have to abandon the Modernist requirement that material and efficient causalities always co-occur and return an Aristotelian attitude that material causality is often passive. Thus, one would have to forgo all talk of genes "directing" development and focus instead upon the network of protein and enzyme processes that actually read, select, and edit the genome and initiate subsequent development activity. As the dedicated materialist Stanley Salthe once explained it to this writer, the materialist needs to regard material more as passive necessity than as active agency. Few seem willing to make this shift.

The second, amalgamated reason for ignoring the ecological perspective was expressed by Lewontin in his very next sentence: "Moreover, that materialism is an absolute, for we cannot allow a Divine Foot in the door" (Lewontin 1997, **000**).

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There was no mention of the divine in the development of process ecology, however, so it is necessary to seek further for a motivation behind such resistance. Serendipitously, physicist Leonard Susskind suggested one while commenting on reactions to the current new rage in physics, "landscapes": "From a political, cultural point of view, it's not that these arguments are religious but that they denude us from our historical strength in opposing religion" (Susskind 2005, **000**). The loss of science as a weapon to be used against religion could indeed explain why many will refuse to embrace process ecology. Numerous issues touching upon the natural world divide theists from secularists—the existence of free will, emergence, immanent divine action, the efficacy of prayer, and theodicy, to mention but a few. The Newtonian metaphysic often has provided significant challenges to theistic positions on these questions. Process ecology, by comparison, pales as a weapon to wield against theism (Ulanowicz 2004). Not that any particular theistic belief follows from process ecology (with the possible exception of free will, which can be accepted as well by naturalists). Rather, the open world of process ecology requires that each individual choose whether or not the nexus of causality terminates behind singular events, and no test of the decision seems possible (Ulanowicz 1999b). It is as if an opaque "veil of ambiguity" exists to obscure forever the correct choice (Ulanowicz in press).

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It should be noted that the Newtonian consensus precipitated during an era of overweening clericalism. Out of fear, some of its formulators were keen to separate their neoscientific activities as far as possible from the supernatural, lest they risk excommunication or even extermination. Others aggressively sought to undermine the basis of authority possessed by the clerics. A common goal, then, became the creation of a chasm so deep as to separate irrevocably all scientific endeavor from anything remotely connected with the supernatural, and that chasm swallowed the domain of the living. The ensuing premise therefore came to resemble what Hans Jonas described as "an ontology of death," from which it has become nearly impossible to achieve a full and deep understanding of the phenomenon of life.

But the seventeenth and eighteenth centuries are long gone. At least in Western society it is not religious clerics who are impeding access to a richer understanding of life. As the agnostic Bateson implied, the fault seems to lie more with the self-ordained high priests of scientific orthodoxy, who cling rigidly to assumptions that point one in diametrically the wrong direction. Science is, however, the legacy of all humanity, agnostics and theists alike. No participant in the science-religion dialogue can escape the action of belief, and any act of faith always implies radical uncertainty. Scientific discussion should be free of ideology, tacit or overt. Science simply is the theater in which to observe, and at times possibly improve upon, the all-consuming play of life.

In this spirit of neutrality, the ecological metaphysic appears to offer a sharper and less colored lens through which to look at life. It replaces the Sisyphusian struggle to conjure up life from dead materials with a more direct approach that parallels rather than contradicts the evolutionary drama of the larger cosmos. It provides an "ontology of life" (Ulanowicz forthcoming) that focuses upon the real agencies that have formed humanity and are drawing it into the future. It opens a pathway for the *emergence* of a wholly new vision of nature.

NOTES

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1. One nanosecond = one billionth of a second—the timescale on which simple subatomic events normally occur.

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