FROM PESSIMISM TO HOPE: A NATURAL PROGRESSION

by Robert E. Ulanowicz

Abstract. Mutual critique by scientists and religious believers mostly entails the pruning of untenable religious beliefs by scientists and warnings against scientific minimalism on the part of believers. John F. Haught has been prominent in formulating religious apologetics in response to the challenges posed by evolutionary theory. Haught's work also resonates with a parallel criticism of the conventional scientific metaphysics undergirding neo-Darwinian theory. Contemporary systems ecology seems to indicate that nothing short of a complete reversal of the Enlightenment assumptions about nature is capable of repositioning science to deal adequately with the origin and dynamics of living systems. A process-based alternative metaphysics substantially mitigates several ostensible conflicts between science and religion.

Keywords: autocatalysis; chance; cosmology; dialectic; evolutionary theory; history; metaphysics; process ecology

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THE NATURE OF THE DIALOGUE

In reference to the dialogue between science and religion, Karol Wojtyla (1988) remarked succinctly, "Science can purify religion from error and superstition. Religion can purify science from idolatry and false absolutes." Certainly, there is no dearth of scientists who would deny religion any role at all in critiquing their enterprise, but Wojtyla's second assertion deserves serious consideration, nonetheless. His use of "idolatry" and "absolutes"

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implies a criticism of the metaphysics by which most of science operates. Wojtyla's challenge is likely to engender contemptuous dismissal by many, but closer examination reveals that his criticism is a constructive one that is wholly commensurate with the scientific method itself.

The expurgation of error and superstition translates into the rejection of false hypotheses, or what in the philosophy of science is commonly termed an alpha-type error. The logical complement of this mistake, a beta-type error, is the rejection of valid hypotheses. Repeated beta-type errors can lead to aberrant minimalism. Because the two errors are complementary, increasing efforts to avoid either error drives up the likelihood of committing the other. That is, by zealously implementing Occam's Razor to make science as simple as possible, one runs a growing risk of turning a blind eye toward perfectly legitimate events, processes, and hypotheses. The balance is not exclusively the concern of those in the science-religion dialogue. Any number of secular investigators also are concerned that the neo-Darwinian schema has calcified into rank minimalism (Kauffman 2008; Salthe 1989; Mazur 2008.)

The role of theologians in the science/religion conversation has primarily been to respond to challenges posed by scientists. In so doing they have pruned away unnecessary beliefs and opened the eyes of the faithful to new aspects of the image of God. Thus it was that John Haught ([2000] 2008) revived emphasis on the kenotic nature of God's love and the role it plays in the evolutionary drama. He constantly urges *all* parties to the conversation to read the text more deeply—regardless of whether the text is religious or scientific (Haught 2003).

Trained primarily as a theologian, Haught is understandably reluctant to comment on new initiatives that arise from within science. His policy is to avoid "rogue science" in order to concentrate on interpreting the results of orthodox endeavors (Haught 2004). He would likely be unsettled to learn that his works might have inspired anything in believers beyond mild criticism of the contemporary scientific ethos. But rogues do arise, both believers and secularists, who question the very metaphysical pillars of science and who find palpable succor in Haught's writings. What follows is an outline of how Haught's ideas have influenced one particular effort to reconsider the metaphysical assumptions of science—not just to lessen the confrontations between religion and science but also to reposition science to be able to apprehend the process of life in a more fundamental and realistic way.

The Living Dead

The contemporary assumptions about how nature works did not appear out of a historical vacuum. At the time of the Enlightenment, clericalism was rampant throughout Europe, and those involved in the nascent project that became modern science had to remain circumspect about what they could espouse (as was made evident by the famous tribulations of Galileo). Early investigators had to stay well clear of the numinous, lest they risk excommunication or extermination. In self-defense they endeavored to put as much distance as possible between their work and the transcendental; and, for good measure, from natural life as well. The result was a metaphysics cast entirely in terms of the material and the mechanical—the world of the nonliving.

Haught has outlined the abrupt reversal in the conventional wisdom regarding life and death that occurred in the wake of such Enlightenment circumspection (2001). Prior to the seventeenth century life had been regarded as ubiquitous and ascendant. It was thought to be present everywhere, even in what now are commonly regarded as purely physical phenomena. Therefore, the chief intellectual challenge for pre-Enlightenment philosophers was to explain the exceptional nature of death.

With the ascendance of the Newtonian worldview, the pendulum swung radically in the opposite direction. Virtually all the universe was now considered to consist of dead, quiescent matter that moves according to deterministic and inexorable laws, which by their simple natures appear to leave no room for the irreversible, asymmetric, and contingent phenomena associated with living systems. As a result, one of the most pressing scientific and philosophical questions of today has become the emergence of life: How could life possibly have arisen out of such a dead universe?

The reaction to clericalism was not always motivated by defense. Some saw in science a weapon that could be used to counter the beliefs that stood behind clerical powers (Susskind 2005). This aim became more evident as soon as science began to enter the realm of living systems, as can be seen, for example, in Thomas Huxley's interpretations of Darwin's theory. Some felt compelled to join in the "Modern project of desacralising the natural world" (Haught 2009, 81). The century following 1860 produced manifold examples of scientists indulging in what Haught has characterized as "metaphysical impatience" ([2000] 2008, 109)—the attempt by one side in the science/religion dialectic to "seize the territory" of the other and extirpate it. The metaphysic that supported those attempts has been described by Hans Jonas as an "ontology of death" (1966, 20).

The Essentialist Picture

The Enlightenment worldview consisted of five axioms that were formulated by consensus in the wake of Isaac Newton's *Principia* around the turn of the nineteenth century. David Depew and Bruce Weber (1995) conveniently enumerated the basic assumptions:

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.
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, in principle, be specified with arbitrary precision.
5. Physical laws are *universal*. They apply everywhere, at all times and all scales.

The most problematic of these postulates for religion was that of closure. It amounted to an "explanatory monism" (Haught 2009, 86). The combination of closure with atomism dictated that all causality derives from events at lesser scales (reductionism). Thus, Carl Sagan, in summarizing his television show on biological evolution, after showing captivating images of dinosaurs cavorting and doing ferocious battle with each other, declared, "These are some of the things that *molecules* do!" The combination of closure with universality implied that nothing could happen in the natural world except that it be elicited by a scientific law. In the words of physicist Carl Sagan, there is "nothing for a creator to do" (in Hawking 1988, x). This metaphysic became an implicit basis for the faith of many scientists (Haught 2009, 6, 17, 45). It was dogma taken at face value (Haught [2000] 2008)—what Wojtyla apparently was referring to as "idolatry and false absolutes."

Of course, it would be highly simplistic to assert that the entire Newtonian metaphysic reigns foremost in the minds of scientists, because no one today believes fully in all five tenets (Ulanowicz 2009a). Soon after Pierre-Simon Laplace ([1814] 1951) had exulted in the absolute power of Newtonian laws, Sadi Carnot ([1824] 1943) demonstrated the irreversible nature of physical processes. Charles Darwin (1859) was among the first to introduce history (that is, irreversibility and indeterminism) into his narrative. Then, at the beginning of the twentieth century, relativity and quantum theories surfaced to cast serious doubts upon universality and determinism. Today the body of the Newtonian consensus lies in tatters.

Such setbacks notwithstanding, its frayed threads continue to hold enormous sway over contemporary science (Ulanowicz 2009a). In particular, closure is strictly maintained in the neo-Darwinian scenario of evolution (Dennett 1995). Evidence that atomistic reductionism continues to dominate biology can be seen in the contemporary prominence of molecular biology. A surprising number of scientists continue today to eschew the reality of chance, believing instead that probability is merely concealing an underlying determinism (for example, Bohm 1989). By definition, the notion of chance sits uncomfortably alongside the axioms of determinism and reversibility. Furthermore, reversibility was shown by Aemalie Noether (1983) to be the obverse side of the concept of conservation. Thus, all is conserved; the Newtonian world is one in which nothing new can happen. The laws of physics have always prevailed and have determined all that one now observes. There is "no room for indeterminacy, accidents or freedom" (Haught 2009, 106).

A Messy and Uncertain World Withal

As mentioned above, Carnot demonstrated that all real processes are irreversible in nature. As a consequence, the paramount conundrum of physics during most of the nineteenth century became how to reconcile the reversibility of events at the microscopic (molecular) level with macroscopic irreversibility. Ludwig von Boltzmann (1905) and Josiah Willard Gibbs ([1901] 1981) were able to paper over this contradiction by assuming that matter at the microscopic level is randomly distributed. This assumption was part of the "Ergodic Hypothesis," which has been accorded a privileged status in the history of science. Some individuals, such as Oliver Penrose (2005), are beginning to challenge the wisdom of that precept, because contemporary scenarios of the development of the cosmos involve early conditions that are the very antithesis of ergodicity.

The determinate world of Newton (and Albert Einstein) was dealt a further serious blow with the emergence of quantum theory during the early twentieth century. Quantum physics culminated in the Copenhagen School, which portrayed chance as rampant in the submolecular world. Virtually everyone now agrees that the quantum domain is "messy and uncertain" (Haught 2009, 12). In an attempt to recapture prediction, scientists have developed analytical tools, such as probability theory and statistics, to deal with chance, which now is confined to the netherworld of the microscopic. The interaction of blind chance below with the regularity of macroscopic law above has yielded the schizoid (Ulanowicz 1986) contemporary narrative of evolution in the living realm. The irritation caused by chance has been neatly circumscribed, so that the Newtonian picture was repaired and the advantage of prediction retained, albeit in a statistical sense. Sagan and Hawking were able to escape criticism when they claimed that any potential creator is now perforce unemployed.

But perfection closes off evolution (Haught 2009, 107), and nature is rarely as simple as one is inclined to portray it, as Wojtyla warned. In particular, chance does not appear always to behave according to common assumptions. Conventional probability theory makes the tacit assumptions that chance events are simple, generic, and repeatable (Ulanowicz 2009a); however, physicist Walter Elsasser (1969) demonstrated that the overwhelming majority of stochastic events in biology are *totally* unique, never to be repeated (Ulanowicz 1999). This sounds at first like an absurd claim, given the enormity and age of our universe, but it is easy to defend. Elsasser noted that there are fewer than 10^{85} elementary particles in the whole known universe,[1] which itself is about 10^{25} nanoseconds old.[2] This means that, at the very most, 10^{110} simple events could have occurred over all physical time. It follows that if any event has considerably less than 10^{-110} probability of reoccurring, it will never do so in any physically realistic time.

Of course, 10^{110} is a genuinely enormous number. It does not, however, require Avogadro's Number (10^{23}) of distinguishable entities to create a number of combinations that exceeds Elsasser's limit on physical events. It does not require billions, millions, or even thousands. A system with only 75 or so identifiable components will suffice. It can be said with overweening confidence that any event *randomly* composed of more than 75 distinct elements has never occurred before in the history of the physical universe. One can safely assume, then, that ecosystems or social systems that comprise hundreds or thousands of distinguishable organisms must not just reckon with an occasional unique event—they are perfused with them. Unique, singular events are occurring all the time, everywhere, and at all scales!

In order to apply probability theory to chance phenomena, a necessary condition is that the events in question must occur at least several times, so that a legitimate frequency can be estimated. Singular events occur only once, never to be repeated, so any probabilities one may assign to them transcend physical reality. Furthermore, such singular events constitute actual holes or gaps in the causal fabric. Akin to Heisenberg uncertainties or the Pauli Exclusion Principle, the singularities are a *necessary* part of nature, not some epistemological lacuna that eventually will yield to theoretical elaboration. It is this rational necessity for lacunae that allowed Haught to claim that the content of his writing could not be reduced to the laws of chemistry and physics (2009, 71).

The roots of indeterminism are now clear: The combinatoric number of possibilities overwhelms the ability of laws to determine (Kauffman 2008; Ulanowicz 2009a). No possible combination of the four force laws of physics and the two laws of thermodynamics can be stretched to cover all the conceivable changes among a complex system having, say, 35 loci for incremental change. Any particular parametric specification of laws will be satisfied by a very large multiplicity of possibilities. Laws do constrain complex biological phenomena but are insufficient to determine results. The agency that specifies outcomes must lie elsewhere. But where?

LIVING ORDER OUT OF DEATH?

The answer is process. By far the larger contribution to the ability of patterns among living beings to persist in the face of perturbations is made by process, although its role is rarely recognized. Darwin's theory, for example, does not constitute a law in the sense of physics.[3] Nor does it, as Francisco Ayala (2009) contends, serve mainly to advance the project of "matter acting according to law." Rather, Darwin's theory was the first detailed description of the action of process.

Process has been a common theme in philosophical circles for well over a century (Peirce 1892; Whitehead 1929). Scientists, however, have chosen to ignore or downplay process because its ramifications play havoc with prediction, and no one wants to lose control (Haught 2009, 38). To be clear about what process entails, I proffer the following definition: *A process is the interaction of random events upon a configuration of constraints that results in a non-random but indeterminate outcome* (Ulanowicz 2009a, 29).

The juxtaposition of *non-random* with *indeterminate* in process is somewhat confusing at first, so a simple example is in order. The Hungarian mathematician György Pólya formulated a process named after him as "Polya's Urn" (Cohen 1976; see Ulanowicz 2010, 397–98). One begins with a collection of red and blue balls and an urn containing one red ball and one blue ball. The urn is shaken and a ball drawn blindly from it. If that ball is blue, a blue ball from the collection is added to it, and both are returned to the urn. The urn is shaken and another draw made. If the ball drawn is red, it and another red ball are placed into the urn, and so forth. One then asks whether a long sequence of such draws and additions would culminate in a ratio of red to blue balls that converges to a limit. Indeed, after some 1,000 draws, the ratio converges to the close neighborhood of some constant. That is, the ratio becomes progressively nonrandom as the sequence of draws continues. What would happen if the urn were emptied and the starting configuration recreated? Would the subsequent series of draws converge to the same limit as the first? It almost certainly will not. After a second 1,000 draws it will approach as its limit any real number from the interval 0 to 1. The first series of draws may converge to the limit 0.53826; the second could asymptotically approach 0.19629. The Polya process is *indeterminate*. Multiple repetitions of the process reveal that the color ratio is progressively constrained by the particular series of draws (the history) that has already occurred. Such radical indeterminacy is incongruous with a nature that is governed entirely by laws, so it is not surprising that the successors of Darwin attempted to put his theory back into something resembling a Newtonian box (and many, including Ayala, continue that effort today).

For later reference, three features of the artificial, simplistic Polya process are noted:

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

Although effective and didactic, Polya's Urn is an entirely artificial construct. Are there natural processes (in addition to Darwinian selection) that act in the same modes? Anthropologist Gregory Bateson (1972) provides a generic clue with his observation that the outcome of random noise acting upon a feedback circuit is usually nonrandom. A particular form of such feedback, autocatalysis, provides an intriguing example (Ulanowicz 1997). Here autocatalysis means any configuration of a positive-feedback loop wherein the direct effect of every link on its downstream neighbor is beneficial (see Ulanowicz 2010, 398).

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

The feature of autocatalysis most germane to evolution is that it exerts selection pressure upon all of its components as well as any of their attendant mechanisms. Any change in a characteristic of a component that either makes it more sensitive to catalysis by the upstream member or a better catalyst of the element that it catalyzes will be rewarded. Other changes will at best be neutral but more likely will be diminished by the feedback.

WHENCE STRIVING?

A significant aspect of autocatalytic selection is that it re-enforces those changes that bring more material or energy into a participating element, resulting in what can be called (in Newton's word) "centripetality." That is, the loop of autocatalytic processes functions as a virtual center of attraction for material and energy.

It is well-nigh impossible to overstate the importance of centripetality to the phenomenon of life, although it is almost never listed among life's necessary attributes. Haught (2003), for example, related how conventional Darwinism pointedly ignores the role of "striving" in evolution. As evolutionary theorists repeatedly stress, all the various living organisms compete with one another in an epic struggle. Haught asks simply, What accounts for their drive? Such striving either is downplayed in contemporary narratives or considered merely epiphenomenal to evolution. A notable exception to such negligence was the opinion of Bertrand Russell: "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" ([1960] 1993, 22). There is no mistaking that by "chemical imperialism" Russell was writing about centripetality; and, from the perspective of the systems ecologist, he correctly placed it at the very center of evolution.

With all the focus on competition, no one seems to want to acknowledge that centripetality is a prerequisite for competition. Without the action of centripetality at one level, competition cannot arise at the next. To discern the necessity of centripetality for competition it is useful to return to the autocatalytic cycle A → B → C → A. Now, suppose an element D appears spontaneously in conjunction with A and C. If D is more sensitive to A and/or a better catalyst of C, the ensuing dynamics of centripetality will so favor D over B that B will either fade into the background or disappear altogether. That is, selection pressure and centripetality can guide the replacement of elements.

Because centripetality arises out of mutuality, it follows that the latter is essential, whereas competition is an accidental consequence. The ramifications of this ontological priority are revolutionary. In Darwinian discourse competition trumps all—and often it *is* the deciding factor. But it is imperative to keep in mind that competition can arise only out of a preexistent mutuality. Today entire conferences are held to investigate how cooperation can possibly appear in a world dominated by competition (see, for example, *http://www.biocomplexity.indiana.edu/events/biocXI/*). Such preoccupation with competition reveals widespread innocence about its actual origins.

The priority of mutualism also has moral ramifications. Although many still feel it impossible to proceed from an existential *is* to a normative *ought*, the ethos of a human community usually is coupled with how it perceives nature. Preoccupation with competition is likely to promote it as the preferred form of behavior. Quite another prescription could follow from an acknowledgment that mutual beneficence (the drive behind centripetality) lies at the kernel of life. A focus on competition is likely to bring about a world according to Huxley; turning the spotlight on mutual beneficence could lean society more in the direction of Giovanni di Fidenza. In any event, ethics should definitely not be regarded as accidental "misfirings" by nature—arbitrary departures from the press of competition forced by evolution (Dawkins 2006; Haught 2009, 72). Such thinking reveals a flawed and inverted reading of ontic priorities.

Returning now to the origins of competition, one sees that not only can D replace B, but E might replace C, and F, A, so that in the long run the lifetime of the autocatalytic configuration (now F → D → E → F) can exceed the persistence of any of its components and/or their attendant mechanisms. Such supervenience by the whole over its parts explicitly contradicts the Newtonian dictum of *closure* (Clayton 2004). The other Newtonian postulates fare no better. *Determinism* is obviously a chimera in systems rife with complex chance. The asymmetry of autocatalysis makes a system *irreversible*. That each component develops in the context of its co-participants renders all members of an autocatalytic ensemble highly codependent over the course of time and abrogates *atomistic* decomposition. Finally, the domain of any individual process is circumscribed in time and space and subject to mitigation by processes at other levels. Processes are not *universal*.

A Call for Metaphysical Reform

Complex dynamics violate each and every one of the five Newtonian pillars, rendering the old foundations completely unreliable. What possibly could replace them? Recognizing that the Newtonian postulates arose out of preoccupation with laws acting on material, possibly the time has come to redirect the focus of science. As Haught cautions (2009, 51), too much emphasis seems to be placed on objects. An evolutionary world appears to function more by way of process, and conceivably therein lies a fertile new direction.

At this juncture it is helpful to recall the three attributes of Polya's Urn: chance, self-influence, and history. In line with the new focus on process, it may be feasible to formulate an alternative set of fundamental assumptions around these properties of process dynamics (Ulanowicz 2009a).

The first postulate would establish chance as a reality:

1. *Radical contingency:* Nature in its complexity is rife with singular events.

Organic systems are continuously being affected by unique contingencies, but the self-stabilizing properties of autocatalysis prevent most such events from upsetting the system integrity. A minuscule few could carry a system into a wholly different mode of *emergent* behavior, but that shift is now perceived as an entirely *natural* phenomenon (Ulanowicz 2007). Note that the first postulate stands as the antithesis of Newtonian determinism.

It was mentioned how the constraints mandated by closure and atomism do not allow sufficient flexibility for systems to maintain their integrities and grow (Haught 2009, 107; Ulanowicz 2009a). Autocatalytic action, a particular form of self-influence, is, by contrast, capable of imparting both form and pattern to living systems. Accordingly, the second postulate becomes

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

The second postulate overtly contradicts the stricture on closure. Causality at the level of the system itself and influence from above are both legitimate events in the process narrative (and also more in line with the Aristotelian view on causalities [Haught 2009, 85]). As for atomism, it appears an outright distraction from the prevailing causality by configurations of processes.

The third consideration supports the intuition by Darwin that history plays a necessary role in complex dynamics. Complex systems must possess a

3. *History:* The effects of self-influence usually are constrained by the culmination of past such changes as recorded in the configurations of living matter.

In a scientific world preoccupied with matter, the prevailing conception of history is almost certain to be dominated by DNA and similar molecular forms. But it is important to bear in mind that the first records of organic history were more likely written into the topologies of stable, long-lived configurations of processes. Including history among the foundational hypotheses obviates the Newtonian assumption of reversibility. As for universality, it clearly does not pertain to the finite domains of individual processes.

These three postulates together constitute a natural platform upon which to erect an ecological perspective on life.

The shift away from objects and laws and toward processes engenders two corollary tenets. The first is that agency in the developmental scenario is exercised more by configurations of processes than by objects. Life itself is intimately bound up with configurations of processes. An example of this identity was provided by Enzo Tiezzi (2006), a professor of thermodynamics and part-time hunter. Tiezzi had just shot a deer on his estate and immediately asked himself what was different about the deer now dead from that which had been alive three minutes earlier. Its mass, form, bound energy, genomes, even its molecular configurations, all were virtually unchanged immediately following death. What had ceased and was no longer present was the *configuration of processes* that had been coextensive with the animated deer—the very attribute by which the deer was recognized as being alive. The legitimacy of configurations of processes as agencies in living systems returns many observables, heretofore dismissed as "epiphenomena," to the orbit of science (Haught 2009, 83).

The second corollary of the ecological perspective is that one discerns two opposing propensities in the dynamics of living systems. Autocatalysis supplies the animation for systems to grow and maintain themselves; however, the well-known consequences of the second law degrade and dissipate system structure. This transactional perspective is hardly new. Diogenes reported how Heraclitus regarded nature as the outcome between the antagonistic tendencies to build up and to tear down. This direct conflict wanes at higher levels, because without the action of radical contingency novel structures could never emerge (Callahan 2003; Ulanowicz 2004; Keller 2005; Jackelén 2009; Haught 2009, 107). Conversely, larger, more constrained structures perforce dissipate more resources.

The three foundational postulates and their two corollary observations constitute what, for want of a better term, is called "process ecology" (Ulanowicz 2004; 2009a). Parallels with the better-known school of process theology (Haught 1984), although more than accidental, are not exhaustive. Neither school should be judged on the basis of the other.

The process view of life does not dispense with the necessity of the material. It does diverge strongly from the stance of *hard* materialism, that is, the Newtonian presumption that all causality proceeds from material. An exaggerated focus on material per se as cause characterizes what Haught calls "scientism" (2009, 38). From the ecological viewpoint, material is still required for process, but its direct action is exerted at scales well removed from those relevant to explanation and understanding.

There are fewer postulates in the ecological perspective (3) than those that support the Newtonian framework (5). Such simplification should give pause to those who are quick to posit Occam's Razor as justification for neo-Darwinian minimalism (Haught 2009, 88). It is indeed true that the core dynamics of Darwinian selection are about as simple as one can imagine, but is that the whole story? (The beta-question.) Physicists, for example, caution that one must regard a problem in its entirety, and that includes the particular boundary constraints in addition to the generic working dynamics (Ulanowicz 2004). Ever faithful to Newtonian tradition, Darwin took pains to place natural selection external to his dynamics. By his choice, Darwin (possibly unintentionally) diverted attention away from the implicit boundary constraints (what is lumped under the rubric of "natural selection"), which remain arbitrarily and inexorably complicated. In the ecological scenario, by contrast, a degree of the selection occurs via active formal agency *within* the internal dynamics, thereby simplifying the accompanying boundary value problem. It is likely that the slightly more complicated dynamics of process ecology more than compensate in providing a far simpler overall narrative of development and evolution.

Reading the Texts More Deeply

Process ecology in no way abrogates scientific laws or conflicts with any of the empirical evidence that has accumulated over the past three centuries. However, a problem arises in that the human mind grasps more readily those events that may transpire in homogeneous, rarefied, and weakly interacting systems. Familiarity with such a context has led to a framework for how nature operates that now is found wanting whenever variety and complexity overwhelm the ability of law to specify outcomes. Furthermore, according to current cosmology, material, as it is commonly known, did not appear until several steps into the evolution of the physical universe (Chaisson 2001). Material was the result of an evolutionary-like process. That is, before material came to be, process was. In short, the beginnings of the universe are now conceived as the stark antithesis of a rarefied and weakly interacting system. On hindsight, therefore, most elements of the classical framework are now seen to be special, degenerate cases of more general processes. It now appears that the conventional metaphysics of the early nineteenth century no longer provides adequate guidelines for the study of life and is likely to be misleading about the nature of reality.

To summarize, some of the ontological considerations prompted by the shift to a process-based metaphysic have suggested that process, long the neglected orphan in scientific discourse, should move to center stage and displace, but not abrogate, law and material objects (Ulanowicz 2009b). Several attributes formerly thought to be universal now appear circumscribed: Determinism applies to a vanishingly small class of rarefied phenomena. Atomism appears to be possible only in the purely physical realm. Monist trends, when pursued to their minimalist extremes, lead inevitably to failure in a world that is shaped by dual, opposing propensities. Causalities deriving from smaller scales now act alongside supervenient influences from higher levels. Natural selection can transpire within a system and not just interject itself from outside. History is of fundamental importance. Ontic, unique chance gives rise quite naturally to the emergence of new phenomena.

Probably no other topic straddles the interface between science and religion more than the origin of life. As Haught posed the question, "How can life possibly emerge from dead matter?" (2001) Process ecology obviates this question, because it is not matter per se that gives rise to life. Rather, it is the same process of evolution that has engendered both matter and life. This likelihood is perhaps best illustrated by the ecological scenario for the origin of life as described by H. T. Odum (1971), who argued that it was necessary for proto-*ecological* systems to already be in existence before proto-*organisms* could arise. (Again, this posits the ontological priority of process over objects.) His scenario was that at least two opposing (agonistic) reactions (like oxidation-reduction [Fiscus 2001]) would transpire in two separate spatial regions, one hosting a source of energy and the other providing a sink for the entropy created by use of the source. In addition, the products from each region had to be transported to the other domain.

Such a "proto ecosystem," or circular configuration of processes, provides the initial animation notably lacking in most other scenarios for first life. Those scripts focus on the chemical precursors of life, which at some point are assumed to mysteriously assemble into living entities. It has been argued that circular configurations of processes can exert selection on their constituents and can give rise quite naturally to more complicated but smaller cyclical configurations (proto-organisms). The latter transition poses no particular enigma. In irreversible thermodynamics processes are assumed to engender (and couple with) other processes as a matter of course—as when large-scale turbulent eddies shed smaller ones, or when large-scale galaxies spawn stars within themselves (which in turn create the heavy elements necessary for life). Process ecology, whereby objects are created by configurations of processes, provides a more welcoming milieu for the origin of life.

If process ecology can remove the discussion of the origin of life from the netherworld of molecules, it should be no surprise that it also can mitigate several ostensible conflicts between science and faith (Ulanowicz 2004). If, for example, emergence is a legitimate, natural outcome in process ecology, free will no longer stands as an enigma. In fact, several levels separate the firings of neural synapses from the higher, slower cognitive functions directly involved in decision making (Juarrero 1999; Murphy and Brown 2007). There are ample opportunities for chance to enter the network of processes. But chance is not the only actor. Those larger-scale functions innately couple with the external world and, in the case of humans and the higher mammals, with culture at large. Electrons move with each thought that an individual has, but the causal flexibility seen in complex systems coupled with the influence of larger external events on the patterns of those movements can no longer be disregarded. The notion that bottom-level neural firings fully determine higher-level outcomes appears most implausible (Ulanowicz 2009a).

Theodicy, the problem of evil and suffering, cannot be circumvented as readily as the issue of free will, but its complexion does change in the light of process ecology. As mentioned, in a world resulting from opposing tendencies, the full extirpation of petty evil and its attendant sufferings would foreclose evolutionary change (Haught 2009, 107). Evil, then, becomes a problem more of magnitude than of ontology. If Einstein had been unable to misappropriate time from his job at the Swiss Patent Office to develop special relativity, the world would now be the poorer. The Holocaust, earthquakes, and cancer in children all are matters of a quite different magnitude.

Perhaps the most contentious issue in the religion-science dialogue is that of divine intervention. Since the dawn of the Enlightenment apologies by theologians defending divine intervention have repeatedly been beaten back in the face of ineluctable, universal physical laws. As believer Philip Hefner (2000) lamented, it appears that God just doesn't have any "wiggle room" left to act in nature. One positive outcome of this dialectic for religion has been to highlight the passive or kenotic side of God, which had lain too long in shadow (Haught 2000). Certainly, anyone wanting to attribute a specific event to the direct action of the divine would face an almost impossible task defending such an assertion. Nonetheless, the universe as portrayed by process ecology is hardly wanting in wiggle room. Reality is shot throughout with stochastic events, many of which are complex and not "blind" or adirectional. From a purely rational perspective, it likewise becomes impossible to disqualify divine intervention as a factor in any specific event. It follows that intercessory prayer may no longer be dismissed as fatuous (Haught 2009, 78).

As Haught's work has demonstrated, evolution should not evoke fear or dismissal in believers. What is necessary is that both scientists and believers commit themselves to reading both sets of texts more deeply (Haught 2003). It is not the case, as some have contended, that nothing lies at deeper levels (Haught 2009, 30). Criticism of religious beliefs by scientists has forced the faithful who appreciate the rational to examine their texts at a deeper level and often to discover new inspirations. At the same time, the understanding is growing that evolution is far more interesting and far-reaching than a game played by tiny pieces of matter. Hence, scientists are remiss as well, unless they make an effort to read their texts at greater depth. Evolution can inspire such awe and wonder among those who accept it that it is capable of bridging the gap between the sciences and the humanities that has endured for the last three hundred years (Snow 1963). In order to achieve such reconciliation, however, evolution must be viewed for what it is—a process—not a law or simply a theory.

From Pessimism to Hope

This rendition of process ecology has been latticed with references to Haught's ideas. Not that all references to his work portray his ideas in exactly the light that he intended. In the natural world, features or behaviors of an organism that have evolved under one set of circumstances can serve entirely different functions in another context. Like living species, ideas can evolve beyond their origins. This shift is known in evolutionary theory as Darwinian preadaptation, and Stuart Kauffman (2008, 100) notes that preadaptation defies prediction because the "adjacent possible" (the scope of possible changes) is usually combinatorically large and unmanageable.

Although there may be differences of opinion between Haught and myself, the overriding consilience between our initiatives lends them robustness and plausibility. This situation, whereby mutuality enables ideas to persist, contrasts markedly with the neo-Darwinian view of evolution. Richard Dawkins (1976), for example, formulated the notion of "memes," fundamental units of cultural transmission that propagate through society—in analogy with genes or viruses. Dawkins cited tunes, ideas, catchphrases, clothes fashions, and ways of making pots or building arches as examples of memes. In his scenario memes are to be considered the atomistic building blocks of society that compete against each other for dominance and survival.

Dawkins was on the right track in drawing the analogy between the evolution of ideas and that of the natural world. Ideas do often compete, and at times one idea will extirpate another. But anyone familiar with intellectual discourse will immediately recognize that whether or not a concept persists—the "truth" of an idea—has mostly to do with its mutual relationships with other ideas. Absent these, it has no chance whatsoever to compete. Yet again, mutuality is seen to be essential; competition is secondary, accidental, and derivative by comparison.

Stanley Salthe warned that minimalist notions, by dint of their simplicity, can become "colonial" (1989, 175), by which he meant that the temptation arises to use them virtually everywhere, even in situations to which they do not apply. The real danger appears when minimalist constructs are promulgated by individuals who are convinced that they have the answers to *all* the questions, and they happen to be correct *some* of the time. Thus it is in the neo-Darwinian schema, wherein competition is assumed to be central and essential. It trumps all else. Survival, however, more often depends on other circumstances.

Within the realm of theology, certain ideas are at times branded as heretical by the powers that be. It is relevant here to note that over the history of the Christian church, heresies rarely have constituted full and outright falsehoods. Most have contained an element of truth pushed to its (minimalist) extreme (Mesa 2008). Wojtyla, an astute student of church history, was certainly aware of this nature of heresy, and he likely also had the best interests of science in mind when he issued his warning against idolatry and false absolutes.

This discussion cannot end without mention of one of Haught's most well-known characterizations. He saw the purported endpoint of the universe in heat death as the cornerstone of what he called a "cosmic pessimism" ([2000] 2008, 115; 2003, 23). This attitude is still quite fashionable in most academic circles—having become a secular eschatology, so to speak. But the shift from the Newtonian metaphysic to process ecology has made it evident that such pessimism rests upon premises (rarefaction, homogeneity, weak interaction, equilibrium) that, frankly, did not characterize the beginning and subsequent history of the actual universe. These assumptions nonetheless retain privileged status in the marketplace of scientific ideas. Process ecology does not lead inevitably to heat death (Ulanowicz 2009b). By focusing on configurations of processes it is possible to demonstrate that, in far from equilibrium systems, heat death is not the sole result of declining resources. Configurations of "perpetual harmony" may precipitate as well.[4]

Pessimism, it seems, is nurtured by assumptions that cast the story of the universe backward (Ulanowicz 2009a)—inferences drawn from the construct of an essentialist world of stasis and ubiquitous death. The world illumined by the spotlight on process is, by contrast, a Heraclitean picture of forward movement and change, hospitable to life in all its manifold dimensions. Within such a universe the phenomenon of evolution and the humans who study it are truly at home (Kauffman 1995). Although the endpoint portrayed by the process worldview is by no means yet clear, the vision itself provides ample latitude for hope.

Notes

1. Today the figure is put at closer to 10^{81}.
2. A nanosecond is one-billionth of a second—the timescale of atomic reactions.
3. Logic forbids laws as they appear in physics from arising in biology (Elsasser 1981; Ulanowicz 2009a).
4. Although the analogy is loose, one cannot help but recall Pierre Teilhard de Chardin's "Omega Point."

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