A WORLD OF CONTINGENCIES

by Robert E. Ulanowicz

Abstract. Physicalism holds that the laws of physics are inviolable and ubiquitous and thereby account for all of reality. Laws leave no "wiggle room" or "gaps" for action by numinous agents. They cannot be invoked, however, without boundary stipulations that perforce are contingent and which "drive" the laws. Driving contingencies are not limited to instances of "blind chance," but rather span a continuum of amalgamations with regularities, up to and including nearly determinate propensities. Most examples manifest directionality, and their very definition encompasses intentionality. Contingencies, via their interactions with laws, can reinforce and maintain one another, thereby giving rise to enduring, ordered configurations of constraints. All of ordered nature thus results from ongoing transactions between mutualistic contingencies that constrain possibilities and entropic chance events that degrade order but diversify opportunities. Laws do not of themselves determine reality; interactions among contingencies do. For believers, the robust abundance of indeterminacies provides ample latitude for divine intervention, free will, and prayer. The priority of contingency also affords some insight into the meaning of suffering and evil.

Keywords: autocatalysis; centripetality; contingency; divine action; evolution; free will; metaphysics; mutualism; prayer; theodicy

An Unbalanced Dialogue

A significant factor in the secularization of Western society over the past 300 years has been the repeated attempts at demythologizing elements of Sacred Scripture by advances in science. By contrast, one only rarely encounters criticism of scientific theory by theologians. Such a lop-sided dialogue is, however, not healthy, neither for religion nor for science. Rather, to paraphrase the late Karol Wojtyla, who put it rather succinctly, a more balanced conversation should consist not only of science purifying religion of error and superstition, but also of religion warning science against idolatry and false absolutes (Wojtyla 1988).

Wojtyla's admonition immediately prompts the question as to what might constitute a false absolute in an endeavor that professes no absolutes.

Robert E. Ulanowicz is Professor Emeritus at University of Maryland, Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD 20688-0038, USA. His current mailing address is Arthur R. Marshall Laboratory, Department of Biology, University of Florida, Gainesville, FL 32611-8525, USA; e-mail: ulan@umces.edu.

[*Zygon*, vol. 48, no. 1 (March 2013)]

There are solid reasons to question the Enlightenment metaphysics that still undergird most of science today (Ulanowicz 2009a), but the focus here is on a particular proposition used by many in science to challenge faith. In particular, many secularists hold that the laws of physics are universal and never violated, and therefore they *determine* everything that can be observed. Thus it is that Nobel Laureates Murray Gell-Mann, Stephen Weinberg, and David Gross proclaim that all causality points downward and that there is nothing "down there" but laws of physics (Kauffman 2008). In the same vein, popular scientific figures like Carl Sagan and Stephen Hawking wrote that there simply is "nothing left for a Creator to do" (Hawking 1988). So prevalent and powerful is the belief in the absolute role of physical laws in nature that even a staunch theist like Philip Hefner, when asked if he believed in miracles, lamented that "God just doesn't have enough 'wiggle room'" (Hefner 2000).

What is a believing scientist to make of this situation? Many preeminent scientists are declaring that physics leaves no room whatsoever for God. How does one counter this charge without disrespecting such powerful intellects that have contributed abundantly to progress in their field? Wojtyla provides a lead: Even the finest intellects using impeccable logic, but proceeding from false absolutes, can arrive at erroneous conclusions. To be more precise, this belief in physicalism reflects an unwarranted minimalism on the part of its adherents. Such minimalism is apparent in many ways. Here the focus will be twofold—first upon the homogeneous nature of universal laws, such as the four force laws of physics, and second upon the complex nature of the arbitrary conditions that drive those laws. In particular, it will be argued that it is a false dichotomy to characterize natural dynamics as the interactions between the simplistic and distinct polar opposites "chance and necessity," as the world is so commonly described. Rather the realities of natural contingencies populate fully the spectrum between these extremes.

Regarding the laws, they are four in number and include gravity, electromagnetic, as well as weak and strong nuclear forces. Although there are numerous other constraints referred to in the literature as laws, they are not included in the physicist's minimalist canon and will remain outside of the ensuing discussion. Here it is noted that, in order to remain universal (i.e., true at all times and under all conditions), such laws can be expressed only in terms of universal physical characteristics, such as mass or electrical charge. To measure these attributes, it becomes necessary to ignore everything else about an object or a situation, except that which applies directly to the universal property under consideration (e.g., gravity or mass) (Bateson 1972). In other words, the force laws of physics deal completely and only with universal, homogeneous properties (Elsasser 1981). Anything else that applies to the object or situation at hand is relegated to what is known as the accompanying "boundary statement."

Looking at the Fuller Picture

It is common knowledge in physics that a full statement of any problem requires two elements: The first part, and the one that commands the most attention, is the universal law or a set of laws that governs the behavior of a given system within a particular space and over a given time. The problem formulation remains incomplete, however, until the investigator makes an accompanying set of statements about relevant circumstances that exist at the spatial boundary and/or at the start. The latter set of statements is called the boundary value problem. For example, one might wish to calculate the trajectory of a cannon ball. The appropriate law would be Newton's second law of motion in the presence of gravity. The specific trajectory and impact point cannot be calculated, however, until one at least stipulates the location of the cannon, the muzzle velocity and the angle of the cannon with respect to the earth—the boundary statement.

The nature of the boundary specifications differs radically from that of the laws in the sense that these stipulations must remain entirely contingent. That is, boundary contingencies in general must be absolutely arbitrary, for the important reason that if one could identify conditions at the boundary to which the laws could not conform, then by definition the laws would not be universal. Having established that circumstances at the boundaries must remain arbitrary, it becomes useful to pause to examine the broad range of phenomena that legitimately qualify as "contingencies."

The reason, why focus remains on the laws and little attention is usually paid to the boundary statement, is that boundary conditions have been implicitly assumed to be anything that an investigator *chooses* them to be. This implicit interjection of observer and choice provides tacit recognition that *intentionality* cannot be disqualified as a form of contingency. Under most problem statements, the chosen boundary conditions are of a regular and ordered nature. Nothing, however, prohibits boundary contingencies that can be characterized as "blind chance."

A Spectrum of Contingencies

Now, history has shown the mathematical theories of probability and statistics to have proved quite successful in dealing with blind chance, by which is meant random events that are simple, directionless, indistinguishable, and repeatable. But not all chance satisfies these criteria. For example, combined actions of multiple simple chance events can constitute a compound event. Such combinations need not be, and usually are not, directionless. Furthermore, physicist Walter Elsasser has shown that whenever more than about 80 *distinguishable* elements or chance events combine, the resulting amalgamation is referred to as physically unique, for it would take an interval more than a million times the age of the universe before that particular combination could be expected to occur again by chance (Elsasser 1969). For example, if a photographer were to take a snapshot from the mezzanine of Grand Central Station that captures a crowd of some 80 travelers bustling below, there is simply no physically realistic chance that any photographer will chance upon exactly the same set of individuals at some later time. Moreover, at various times of day, it may be readily evident that different preferred directions are taken by a sample of travelers. (For example, movement during morning hours will be more in the direction of the trains, whereas that in the late afternoon will be in the opposite direction.) Because they are not repeatable, unique events cannot be treated by common statistical techniques. Ulanowicz calls such unique chance events "radical," and such phenomena pervade the complex systems of ecology and the social sciences (Ulanowicz 2009a).

Furthermore, it appears to be a false absolute to assume, as Monod implicitly did, that a strict separation between chance and necessity is possible. In between blind chance and strict determinism lies a continuum of events characterized by the degree to which the arbitrary is constrained by the order with which it is fused. At one end of this spectrum blind, unconstrained chance occurs in a directionless environment. Once there are constraints of any sort, however (like the imbalance of loaded dice), the resulting *conditional* probabilities will differ from those calculated for blind chance (Depew 2011). Going even further, Karl Popper in his last treatise, *A World of Propensities*, pointed to conditional probabilities that grow progressively so constrained that certain outcomes dominate, although occasionally other "interferences" might still occur (Popper 1990). For example, during the early twentieth century over nine of ten young immigrants to America married someone from their own ethnic group, although a few would venture to take native-born spouses. Popper labeled such dominant outcomes (like the nine of ten) "propensities," and they were more general than laws, which he considered to be determinate only in a vacuum or under artificial conditions.

An entire spectrum of phenomena, then, can legitimately be called contingencies—starting with radical, novel chance, and running the gamut from blind chance to conditional chance to propensities and even to intentionalities (Grassie, 2012). It is a mistaken presumption to insist that blind chance and universal laws always act dichotomously (independently) in natural systems.

Order in the Face of Contingencies

This emphasis on the multifarious nature of contingency was not meant to divert attention from the obvious order one perceives in nature. And so the question arises, if so many types of contingency are continuously at work everywhere, how is it, if not simply by determinate laws, that there exists so much order and regularity in nature? To be sure, no one is

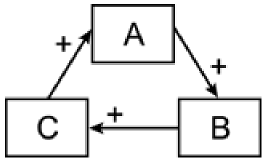

Figure 1. A three-component autocatalytic cycle.

denying that laws play a necessary and important role in the creation of such regularities, but that is hardly the whole story, nor even the crux of it; because in complex systems, and especially in living systems, laws appear to explain less about what is observed than do configurations of phenomena known as *mutualisms*.

Simple mutualistic behaviors were first treated in chemistry, where they were identified as *autocatalysis* ("auto" meaning "self" and "catalysis," the act of quickening—a process that through its interactions with others tends to speed itself up). One may envision autocatalysis as a loop of processes, wherein each member accelerates its immediate downstream neighbor. In Figure 1 for example, if process A facilitates another process, B, and B catalyzes C, which in its turn augments A, then the activity of A indirectly promotes itself. The same goes, of course, for B and C. In general, A, B, and C can be objects, processes, or events, and the linkages can be deterministic (mechanical) or contingent.

An ecological example of autocatalysis is the aquatic community that develops around a family of aquatic weeds known as Bladderworts (genus *Utricularia*, Ulanowicz 1995). All Bladderworts are carnivorous plants, because scattered along the feather-like stems and leaves of these plants are small, visible bladders (Figure 2a). At the end of each bladder are a few hair-like triggers, which, when touched by any tiny suspended animals (such as 0.1-mm water fleas), will open the end to suck in the animal, which then becomes food for the plant (Figure 2b). In nature the surface of Bladderworts always hosts the growth of an algal film. This surface growth serves in turn as ready food for a variety of microscopic animals. Thus, Bladderworts provide a surface upon which the algae can grow; the algae feed the micro animals, which close the cycle by becoming food for the Bladderwort (Figure 3).

The autocatalysis associated with life processes, when it is impacted by random singular (chance) events, results in nonmechanical behaviors (Ulanowicz 2009a). For one, autocatalysis exerts selection pressure upon all its participating elements. If there happens to be some contingent change, for example, in the surface algae that either allows more algae to grow on the same surface of Bladderwort (e.g., by becoming more transparent) or makes the algae more digestible to the tiny floating animals, then the effect of the increased algal activity that contingency induces will be rewarded two

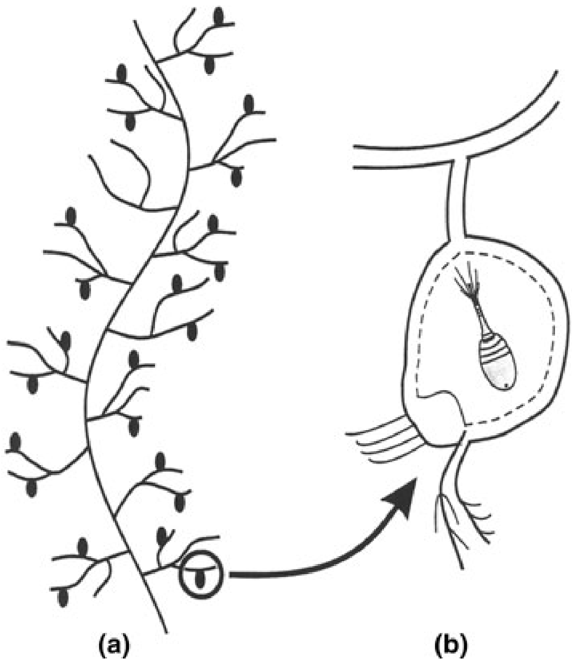

Figure 2. (a) Bladderwort stem with close-up (b) of bladder.

steps later by more Bladderwort surface. The activity of all the members of the triad will be increased. Conversely, if the change either decreases the possible algal density or makes the algae less palatable to the micro animals, then the rates of all three processes will be attenuated. Simply put, contingencies that facilitate any component process will be rewarded, whereas those that interfere with facilitation anywhere will be decremented.

One special feature of autocatalysis is essential to the life process: Thermodynamics requires that each step along the autocatalytic loop use energy and material to continue functioning. It follows from the argument used to explain selection that an increase of resource input to any component process will be rewarded. The result is that all the avenues of resources into the autocatalytic loop will be amplified—a phenomenon that has been called "centripetality" (Figure 4). Such centripetality, or pulling in, is evident, for example, in coral reef communities, which sequester major concentrations of nutrient resources well over and above those in the oceanic desert that surrounds them.

The ratcheting up of activity and its accompanying centripetality together constitute what is commonly referred to as "growth." Growth, especially in the geometric proportions described by Thomas Malthus, played a major role in Darwin's narrative. Unfortunately, the growth side of evolution has been downplayed by the later disciples of Darwin

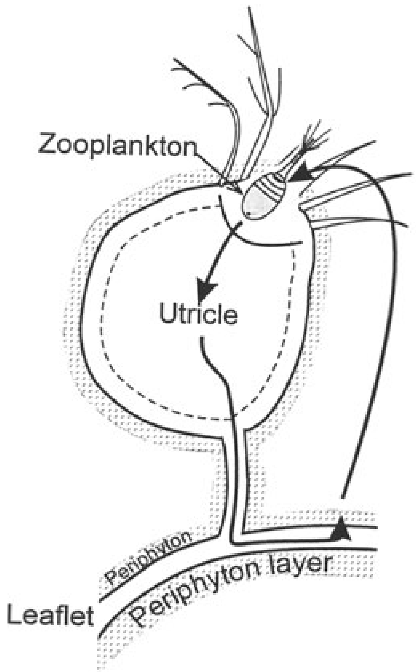

Figure 3. The cycle of mutuality in Bladderworts.

to the point where it now appears as a given not warranting further attention. But Darwin's full dynamic is bilateral and might be paraphrased as "Growth proposes, natural selection disposes" (Stanley Salthe, personal communication, 2011). Contemporary discussions of evolution thus overstate the eliminative role of nature, commonly referred to as "natural selection," but the enormous advantages imparted to some species via autocatalysis and its accompanying centripetality remain virtually absent from the Modernist narrative.

A Foundation of Mutualities

Another imbalance in contemporary evolutionary theory is its inordinate focus upon competition. Competition with other organisms, in combination with elimination by adverse physical circumstances, is said to account for the bulk of natural selection. Like growth, the existence of competition is assumed as a given. But it is the existence of autocatalytic centripetality that constitutes the origins of competition, because whenever multiple centripetalities arise within a limited pool of resources, *competition* among the associated configurations becomes the inevitable result. Viewed in this framework, competition becomes strictly derivative of centripetality, which

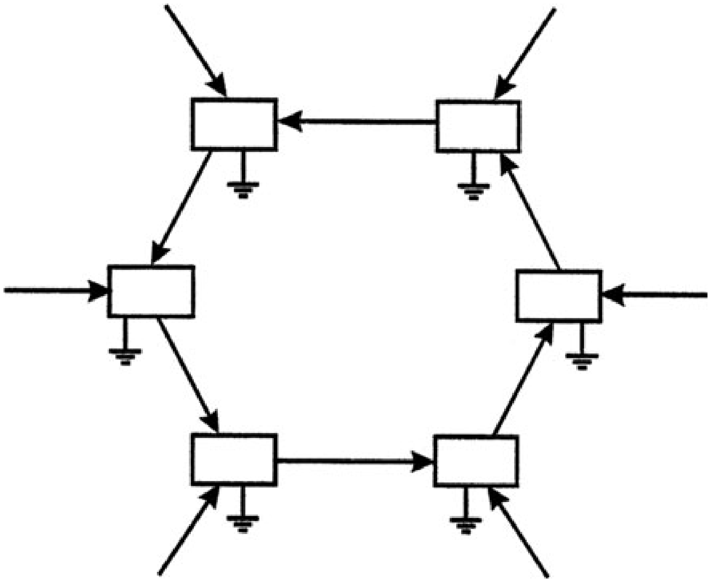

Figure 4. Centripetality resulting from autocatalysis. Arrows without origins are external inputs. “Ground” symbols are dissipations.

in turn owes its existence to mutualities at the next level down. To repeat, competition cannot arise, unless mutualities are already at work at the next level down. It is ironical that today one continually encounters conferences and papers devoted to resolving how observed mutualisms could possibly arise out of a natural world that is driven everywhere by competition. That problem is, of course, ill-posed, because it is mutuality that is fundamental and out of which competition ultimately derives.

Finally, the contemporary Darwinian scenario errs when it repeatedly and schizophrenically switches back and forth between random (chance) mutations of the DNA molecule and the (presumably lawful) behaviors of much larger organisms, such as feeding behaviors or camouflage (yet another example of the chance-necessity dichotomy). Excluded from this discussion is an entire spectrum of autocatalytic behaviors that are active at the biomolecular, cellular, and organ levels. As was just argued, each such loop promotes the dominance of its participants and can change in response to impacts from radical chance events that occur *at each of the intervening levels* (Ulanowicz 2005).

The Universal Conversation

In order to grasp the fuller picture, Darwin’s full narrative may be compared with the ancient dialectic proposed by the early Greek philosopher

Heraclitus, who saw nature as the outcome of two opposing tendencies—one that builds up order and another that tears it down. Unfortunately, what has been inherited from the followers of Darwin is an obsession with only the latter half of that dynamic. A possible cause for such incomplete treatment has likely been a conscious effort to eliminate mention of anything that does not correspond strictly with the metaphysical picture of the universe as a clockwork, in which matter reacts solely at the behest of mechanical laws.

One does not even have to go as far as biology to see just how one-sided the current view of our universe is. The preeminent physicist John A. Wheeler, for example, was deeply troubled by simplistic thinking on the part of his colleagues who were studying the physics of elementary particles (Wheeler 1980). His concern with was constructivism in physics that he thought was being mistaken for absolute reality. He worried not only that the body of scientific theory was being "constructed" in the philosophical sense of the word, but also that some new particles were actually being synthesized by the experimental apparatus and protocols. He illustrated his misgivings via what might be called Wheeler's "parable of the parlor game."

According to Wheeler, the development of science is like a game played by a number of guests at a dinner party. Waiting for dinner to be served, the guests elect to play the game "20 Questions," the object of which is to guess a word. In Wheeler's version, one individual is sent out of the room, while those who remain are to decide upon a particular word. It is explained to the delegated person that upon returning, he/she will question each of the group in turn and the responses must take the form of a simple, unadorned "yes" or "no" until the questioner guesses the word. After the designated player leaves the room, one of the guests suggests that the group *not* choose a word. Rather, when the subject returns and poses the first question, the initial respondent is completely free to answer "yes" or "no" on unfettered whimsy. Similarly, the second person is at liberty to make either reply. The only condition upon the second person is that his/her response may not contradict the first reply. The restriction upon the third respondent is that that individual's reply must not be dissonant with either of the first two answers, and so forth. The game ends when the subject asks, "Is the word XXXXX?" and the only response coherent with all previous replies is "Yes."

Contingencies that Stipulate Order

What usually first unnerves people about Wheeler's parable is the indeterminate nature of the outcome. (Parables are usually meant to generate unease in the listener.) The parallels with evolution, however, are even richer and deeper. Of especial interest are the rules of the game, which are meant to correspond to the laws of nature. One sees immediately that the rules of the parlor game do *not* determine the endpoint. They guide and constrain activity (presuming that the participants abide strictly by them), but they are incapable by themselves of specifying the outcome (Bartholomew 1984; Lonergan 1958; Longo et al. 2012; Salthe 2009; Ulanowicz 2012). This accords with our foregoing discussion about the role of physical laws in evolution. Those laws are not violated, but universal laws cast in terms of simplistic generalities are insufficient to deal with a hyperastronomical number of possibilities and to designate a single outcome from among the enormous number that satisfy all of the laws equally and exactly. Put more succinctly, laws enable, but they do not entail reality (Longo et al. 2012).

In Wheeler's game the specific outcome is the result of a dialogue between two parties. On one hand, the questioner is seeking to narrow progressively the field of possibilities, while the intent of the rest of the players is to maintain that field as wide as possible for as long as feasible. In nature the role of the questioner is played by natural selection, not only in its traditional eliminative sense, but also as part of the autocatalytic action that promotes the growth of its members while drawing resources away from nonparticipating elements Both actions, eliminative and autocatalytic, serve to narrow the number of persisting elements. In the same way that successive respondents in the game choose answers that will keep options open, selection in nature is opposed by all the arbitrary, redundant, inefficient, and noisy events that constantly degrade existing constraints within the system, while at the same time creating a broader manifold of new possibilities.

Of course, all metaphors are imperfect, and Wheeler's parable is no exception. It culminates in short order at a fixed endpoint, whereas natural evolution continues to act over deep time. That final endpoint, furthermore, preexists as a member of a population of only several million words, whereas the possibilities in evolution are infinite and often emerge as novelties. Finally, the natural "dialectic" between selection and disordering is not simply one of direct opposition. As philosopher Georg Hegel pointed out, many dialectics are carried out at more than one level. Although in the short run the two tendencies are antagonistic, over the longer term they can grow mutually interdependent: In order for autocatalysis to perform selection, it must have access to a continual renewal of contingencies. Conversely, the more rigidly streamlined a system operation becomes, the more resources it captures and dissipates. The two trends exist in tension with one another and neither can totally eliminate the other. Systems without structure and efficiency cannot compete; those without flexibility cannot adapt. One-sided maxims, such as unbounded efficiency, have no viable place in a realistic evolutionary theory (Ulanowicz 2009b).

Such disparities notwithstanding, Wheeler's parable suggests an astounding conclusion: It is not universal laws that create the many enduring forms that comprise the world. Rather, it is a transaction between opposing *contingencies* that actually results in the history that we inherit. Laws necessarily participate in the ongoing exchange; but they do not *drive* it.

It could be argued that one should have foreseen the pivotal role of contingencies by noting that all four constitutive laws are symmetrical with respect to time. By that is meant that if one has a video of any phenomenon strictly determined by law (such as the collision of two perfectly elastic billiard balls), it would look the same regardless of whether it is played forward or backward. There is simply no way that a set of such conservative behaviors could initiate temporal *process*. The temporal asymmetry that identifies process must enter via the boundary in the form of contingencies. That is, laws are the conservative glue that bind together contingencies, which constitute the actual agents of evolution.

The Drama Beyond Physics

This new and wider perspective on evolution has manifold implications for science, for society, and for theology. It is becoming increasingly apparent that the universe is decidedly not a clockwork—one in which everything is determined in rigid mechanical fashion by the laws of physics. Rather, as John Haught has suggested, a more appropriate metaphor for an evolutionary world is the drama, wherein the theatrical elements of unexpectedness, continuity, and time correspond in nature to contingency, self-reference, and history, respectively (Haught 2010, 2012). The popular material/mechanical depiction of the brain as a determinate machine must yield to one of a human psyche that exists at several interdependent levels and exhibits sufficient flexibility to act in an autonomous, intentional manner (Deacon 2011; Juarrero 1999). In the wider evolutionary scenario, "free will" is not just a possibility, it is central to the notion of humanity.

An expanded evolutionary narrative presents theologians with manifold opportunities and challenges. That universal laws do not determine this complex world reveals an abundance of heretofore unrecognized "wiggle room" at all levels of the universe. The Deist notion that God could have acted only at the beginning of the universe is now seen as being far too restrictive. The larger view finds the Creator with ample opportunities to remain in continuing dialog with creation (Bartholomew 1984). In particular, divine intervention no longer appears as an absurdity, nor is intercessory prayer necessarily in vain.

Perhaps the greatest challenge to faith for the largest number of people is the existence of suffering and evil (theodicy). A more complete description of evolution does not entirely resolve this enigma, but it does provide a new angle on the problem (Domning and Wimmer 2008; Ulanowicz 2011). Without contingencies there can be neither evolution nor progress. As in the biblical parable of the weeds and the wheat, eliminating all evils would impair opportunities for doing good and going forward. Thus, there are solid rational reasons to avoid Puritanism. Rational accommodation, however, does not extinguish the existential pain in the wake of catastrophic natural calamities or massive social evils. Such anguish can be dealt with only through the light of faith.

Theological Concerns

Doubtless, some theologians of the book religions will object to the process-based view of evolution outlined here, because it seemingly contradicts the Neo-Platonist foundations of both medieval Christian theology and Enlightenment science. Plato taught that pure, unchanging essences exist in relation to which all real entities bear incomplete correspondence. By contrast, process thinking and evolution could be construed to suggest that God actually changes. Here a popular notion from ecology might point the way to a reconciliation of sorts. Ecosystems are regarded by most ecologists as existing across a succession of levels, each characterized by a particular range of space and time (Allen and Starr 1982). Such levels couple only loosely with one another and connections between any two domains decrease with increasing distance between them (Salthe 1985). Phenomena at the largest scales appear constant relative to those at lower levels, just as the stars appeared fixed to ancient astronomers. Now, it would be unnecessarily restrictive to confine a Supreme Being to only the highest levels; God is assumed to be present and active at *all* levels. In so far as God exists at the highest realm, the Godhead remains unchanging. In as much as God may be active at lower levels, however, and in particular at human scales, God is free to react and change in response to the continuing dialog.

What theists are most likely to object to in this expanded notion of evolution is the dominant role played by contingency. To some the preponderance of contingency seems to play into the hands of those evolutionists who contend that everything visible is the consequence of blind, directionless chance (Gould 1990). But, as has been argued here, contingency extends well beyond blind chance. It even includes intentionality (which, because it is contingent, is a manifestation of free will). Although the genesis of some phenomena might be traceable to a particular class of contingency, the origins of many others will remain perforce ambiguous (Ulanowicz 1999): Was that particular job opportunity a matter of random luck, or was the hand of some higher agency at work? Was that tsunami due to an Act of God, or was it blind chance? The answers to such questions lie shrouded behind an "epistemological veil" (i.e., remain unknowable), and it falls to the particular faith of each observer to choose one way or the other (Ulanowicz 2009a).

Even having accepted such necessary ambiguity, some believers may remain unwilling to admit contingencies as the origin of all distinguishable phenomena. The idea of tracing all histories to seemingly arbitrary events seems to contradict all semblance of a planned creation. This objection, however, rests on the common convention of seeing all events as being "pushed" into existence out of the past. It would be unnecessarily restrictive to confine the action of God to our own limited horizons. Rather, scripture (Genesis 1:3 NAB) and theologians (e.g., Haught 2006; Teilhard de Chardin 2004) are both inclined to picture the Creator as "calling" nature into the future. If God is calling into being from the future, it makes little difference how unappealing the starting point may be, just as the unattractive nature of clay does not detract from a beautiful finished work of pottery or china.

A More Generous View of Reality

One obvious advantage of a comprehensive account of evolution is that it makes room for and highlights mutuality, the precursor to love. No longer is Social Darwinism the inevitable moral consequence of evolution. The root and drive of all evolution, and even of competition itself, is seen to be mutual beneficence (Russell 1960). This spotlight on mutual beneficence reminds one of Bonaventure's vision that all being rests upon the mutual love shared by the three persons of the Christian Trinity. It also can be argued that stable molecular forms represent an approach to the limit of autobeneficence in perfect equilibrium (Ulanowicz 2009c). Whence, most of the cosmos with which humanity is most intimately familiar bears "vestiges of the Holy Trinity" (cf. Robinson 2004).

What, then, can one say in summary about a more balanced evolutionary narrative? Here a quick look into history might be helpful. Until the early nineteenth century, both science and theology had been molded along Platonic lines—a *conservative* world in which nothing is either created or destroyed, a finished, unchanging natural tapestry. Everyone knows how religion was shaken during the middle of that century by Darwin's introduction of a *changing* world, and much has been made of the upheaval wrought by the realization that humans likely descended from lesser creatures. Far less ink, however, has been spilled over the simultaneous threat that evolution posed to the then-prevailing scientific conception of nature—initially by Sadi Carnot with his quantification of an irreversible, nondeterministic thermodynamics and later by Charles Darwin with his theory of an evolutionary biology (Carnot 1824; Darwin 1859). The response of the scientific community to both of these threats was nearly identical—to neutralize each challenge by attempting to withdraw into the comfortable world of conservation and reversibility. Statistical mechanists Ludwig von Boltzmann and Josiah Willard Gibbs attempted to reconcile Carnot's thermodynamics with the modernist view of a conservative physics (Boltzmann 1905; Gibbs 1902). Later Ronald Fisher and Sewell Wright employed virtually the same assumptions and mathematics to quantify the eliminative workings of natural selection (Fisher 1930; Wright 1968). These efforts erred insofar as they *ignored* any natural features that did not square with mechanical/material absolutes.

After a brief flirtation by religious institutions during the middle twentieth century to open themselves up to the larger natural and social world, the turn of the millennium unfortunately finds most retreating into a "fortress" of largely medieval theology or fundamentalism.

A Call to the Journey

What these parallel conservative movements in both science and religion ignore (at their own peril) are the greater opportunities inherent in a fuller description of evolution—a portrayal of reality neither as a finished tapestry nor as a mindless clockwork, but as a full-fledged, unfinished historical *drama* between two countervailing cosmic trends (Haught 2010). Evolution bids us, both scientist and theologian, to reverse the outcome of the collision between Hebraic and Hellenistic cultures in the centuries immediately prior to Christ. It was then that the Jewish tradition of dialog between humanity and God yielded to the image of a world of pure and unchanging essences, just as in the Greek world the ever-changing cosmos of Heraclitus had earlier given way to the fixed eternality of Parmenides and Plato. It becomes necessary now to recapture the scriptural image of God and humanity in dialog, working together on the continuing creation, and at the same time to reframe the picture of science as being in conversation with the nature it observes and describes.

Such transition can be accomplished only by revamping and reordering fundamental assumptions and discarding false absolutes (Ulanowicz 2011), by placing mutuality ahead of competition, by acknowledging the power of contingencies over law, by listening for, and responding to the call from the beyond the material. To be sure, the voice that calls beckons the hearer into strange and often uncomfortable territory. Just as Hebrew scripture favored the nomadic over the sedentary, scientists are now called to cast aside the security of their academic fiefdoms, clerics are called to renounce the trappings of ecclesial power. All are called to walk forward or to perish in place.

Involvement in drama always entails risks. But the plot itself also provides meaning and purpose. The pathway is bound at times to seem treacherous, but the one who beckons also reassures that the traveler is never alone.

Evolution is indeed a glorious drama! It is not to be shunned. Neither is it meant to be constricted by false absolutes, for it is only when seen in its entire breadth that it is able to provide a refulgence of hope.

Acknowledgments

The author wishes to thank his wife, Marie A. Ulanowicz, for helping him to simplify several versions of this manuscript. Colleagues Malcolm Dean, Andrew D. Hanson, John F. Haught, Stanley N. Salthe, Bruce H. Weber, and Joseph F. Wimmer kindly provided written suggestions to help clarify the first draft. William Grassie was helpful in urging the author to adopt a term other than "chance" to refer to the broader spectrum of aleatoric events. Finally, Daryl P. Domnimg and Andrew J. Robinson contributed detailed reviews of the evolving manuscript. This text is based on a talk given by the author on April 14, 2012 at the Conference, "Atoms and Angels," which took place at the Washington Theological Union in Washington, DC, and was sponsored by the John H. Templeton Foundation.

References

Allen, Timothy F. H., and T. B. Starr. 1982. *Hierarchy*. Chicago: University of Chicago Press.

Bartholomew, David J. 1984. *God of Chance*. London: SCM Press.

Bateson, Gregory. 1972. *Steps to an Ecology of Mind*. New York: Ballantine Books.

Boltzmann, Ludwig. 1905. *Wissenschaftliche Abhandlungen*. Leipzig: J. A. Barth.

Carnot, Sadi. 1824. *Reflections on the Motive Power of Heat* (translated 1943). New York: ASME.

Darwin, Charles. 1859. *On the Origin of Species by Means of Natural Selection*. London: John Murray.

Deacon, Terrence W. 2011. *Incomplete Nature: How Mind Emerged from Matter*. New York: W. W. Norton.

Depew, David J. 2011. "Accident, Adaptation and Teleology in Aristotle, Empedocles and Darwinism." In *Biological Evolution: Facts and Theories*, ed. Gennaro Auletta. Marc LeClerc, and Rafael A. Martinez, 461–79. Rome: Gregorian and Biblical Press.

Domning, Daryl P., and Joseph F. Wimmer. 2008. *Evolution and Original Sin: Accounting for Evil in the World*. Herndon, VA: The Alban Institute.

Elsasser, Walter M. 1969. "Acausal Phenomena in Physics and Biology: A Case for Reconstruction." *American Scientist* 57:502–16.

———. 1981. "A Form of Logic Suited for Biology?" *Progress in Theoretical Biology* 6, 23–62.

Fisher, Ronald A. 1930. *The Genetical Theory of Natural Selection*. Oxford: Oxford University Press.

Gibbs, Josiah Willard. [1902] 1981. *Elementary Principles in Statistical Mechanics*. Woodbridge, CT: OxBow Press.

Gould, Stephen Jay 1990. *Wonderful Life: The Burgess Shale and the Nature of History*. New York: W. W. Norton.

Grassie, William. 2012. "Many Windows: Reflections on Robert Ulanowicz's Search for Meaning in Science." *Axiomathes* 22:195–205.

Haught, John F. 2006. *Is Nature Enough? Meaning and Truth in the Age of Science*. New York: Cambridge University Press.

———. 2010. *Making Sense of Evolution: Darwin, God, and the Drama of Life*. Louisville, KY: Westminster John Knox Press.

———. 2012. "Robert Ulanowicz and the Possibility of a Theology of Evolution." *Axiomathes* 22:261–68.

Hawking, Stephen W. 1988. *A Brief History of Time: From the Big Bang to Black Holes*. New York: Bantam.

Hefner, Philip. 2000. "Why I Don't Believe in Miracles." *Newsweek*, 1 May, 61.

Juarrero, Alicia. 1999. *Dynamics in Action: Intentional Behavior as a Complex System*. Cambridge, MA: MIT Press.
Kauffman, Stuart A. 2008. *Reinventing the Sacred: A New View of Science, Reason and Religion*. New York: Basic Books.
Lonergan, Bernard J. F. 1958. *Insight: A Study of Human Understanding*. New York: Longman, Green, and Co.
Longo, Giuseppe, Maël Montévil, and Stuart A. Kauffman. 2012. "No Entailing Laws, but Enablement in the Evolution of the Biosphere." *arxiv*:1201.2069v1.
Popper, Karl R. 1990. *A World of Propensities*. Bristol, UK: Thoemmes.
Robinson, Andrew J. 2004. "Continuity, Naturalism, and Contingency: A Theology of Evolution Drawing on the Semiotics of C. S. Peirce and Trinitarian Thought." *Zygon: Journal of Religion and Science* 39:111–36.
Russell, Bertrand. 1960. *An Outline of Philosophy*. Cleveland, OH: World Publishing Company.
Salthe, Stanley N. 1985. *Evolving Hierarchical Systems*. New York: Columbia University Press.
———. 2009. "A Review of *Signature in the Cell: DNA and the Evidence for Intelligent Design* by S. C. Meyer." *Philosophy Pathways*, 146. Available at <http://www.philosophypathways.com/newsletter/issue146.html>.
Teilhard de Chardin, Pierre 2004. *The Future of Man*. New York: Doubleday Image.
Ulanowicz, Robert E. 1995. "*Utricularia*'s Secret: the Advantage of Positive Feedback in Oligotrophic Environments." *Ecological Modelling* 79:49–57.
———. 1999. "Out of the Clockworks: A Response." *Estuaries* 22:342–43.
———. 2005. "A Revolution in the Middle Kingdom?" In *Micro-Meso-Macro: Addressing Complex Systems Couplings*, ed. H. Lillienstroem and U. Svedin, 73–90. London: World Scientific.
———. 2009a. *A Third Window: Natural Life beyond Newton and Darwin*. West Conshohocken, PA: Templeton Foundation Press.
———. 2009b. "The Dual Nature of Ecosystem Dynamics." *Ecological Modelling* 220:1886–92.
———. 2009c. "Increasing Entropy: Heat Death or Perpetual Harmonies?" *Design and Nature and Ecodynamics* 4(2):1–14.
———. 2011. "Process and Ontological Priorities in Evolution." In *Biological Evolution: Facts and Theories*, ed. Gennaro Auletta, Marc LeClerc, and Rafael A. Martinez, 321–36. Rome: Gregorian and Biblical Press.
———. 2012. "Widening the Third Window." *Axiomathes* 22:269–89.
Wheeler, John A. 1980. "Beyond the Black Hole." In *Some Strangeness in the Proportion*. ed. H. Woolf, 341–75. Reading, MA: Addison-Wesley.
Wojtyla, Karol. 1988. "Letter of His Holiness John Paul II to George V. Coyne," 1 June.
Wright, Sewell. 1968. *Evolution and the Genetics of Populations: A Treatise*. Chicago: University of Chicago Press.