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Causality, Chaos, and Consciousness: Steps Toward a Normative Cosmological Principle in an Evolving

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The intent of this paper is to present a conceptual model of a physical and biological universe in a state of constant change and evolution, based on three principal ideas: (a) neo-Aristotelian notions of reciprocal causality, (b) chaotic dynamics and contingencies of self-organizing systems, and (c) emergence of consciousness and sense of moral purpose in humans. While these different ideas and conceptual frameworks may seem unrelated at first glance, it will be shown that they have certain common and interconnected features that are quite illuminating for developing a process- and ecologically-based ontology of an evolving universe. It is hoped that such an approach would lead to an articulation of *a normative cosmological principle that* is consistent with Alfred North Whitehead's organismic metaphysics and process-based ontology, as extensively developed in *Process and Reality.*

I. Causality and Determinism

We shall begin by looking at the definitions of cause and effect within an Aristotelian classification system. In his *Physics,* Aristotle identified four types of causal relations: *material, formal, efficient* and *final*. It should be noted that while medieval scholars relied heavily on *final causes* in their descriptions of the natural world, modern developments in the natural sciences since the fifteenth and sixteenth centuries have placed almost exclusive emphasis on *efficient cause* as the basic determinant of physical and biological events. In *Process and Reality,* Whitehead mentions this Inversion of causal emphasis as follows:

> [Aristotle's] philosophy led to a wild overstressing of the notion of "final causes" during the Christian middle ages; and thence, by a reaction, to the *correlative overstressing* of the notion of "efficient causes" during the modern scientific period. (PR 84,

emphasis added)

Today, efficient cause has become the prevailing deterministic norm for the natural sciences, since final or teleological causes either have been ignored or effectively expunged from its logically constructed world-view. Modern physical and biological sciences have replaced the former reliance on divine or teleological explanations of natural phenomena by its current emphasis on efficient or proximal causes which depend entirely on a deterministic chain of past events. This point of view has become so prevalent that **it** remains essentially unchallenged in the scientific community.

In this paper, we shall try to demonstrate the conceptual limitations and epistemological shortcomings of such a narrowly construed causal system in the natural sciences. As such, we wish to recover the intrinsic value of the original Aristotelian classification scheme on causality. Let us take the *construction of a building* as an illustrative example of re-utilizing such an Aristotelian causal scheme. Here, we may identify the *purpose of final cause* of our actions as the erection of the building, so that every act we take in its construction *is guided or shaped* by our desire to meet that goal. Hence, in addition to past events that necessarily "determine" our current activities, future objectives also guide us in selecting what we are engaged in at the present moment. In this example, there are a number of efficient or proximal causal agents -- such as architects, site managers and construction workers -- who participate in the construction of the building. But they do so because they have a common purpose of completing the construction of a building in the near future. From a temporal perspective, it is clear that each act we take in the present is determined *both* by past actions (efficient causes) and by the goals we have set in the future (final causes).

For the sake of completeness, let us now include other causal factors that are derived from the original Aristotelian classification scheme. In addition to efficient and final causes, the construction of the building is based on a plan or a blueprint *(formal causes)* and requires the use of proper building resources *(material causes).* Thus, we see the essential soundness of the Aristotelian causal system: once a decision about the future has been made, it requires us: (i) to choose a plan (formal cause), (ii) to select needed resources (material cause), (iii) to execute a set of activities (efficient cause), in order (iv) to achieve one’s final goal (final cause).

We shall now introduce an additional element or modification to the above classification system. We shall label this as an *expanded neo-Aristotelian causal scheme.* To begin with, let us designate the final cause of constructing a building as *Objective A.* We pose the following question: why are we constructing the building in the first place? One answer would be: to provide *shelter* to human beings. Are building structures the only means by which we may provide shelters to human beings? No, they are not, but regardless of what specific means we may choose for housing human beings, the basic objective remains the same, i.e., human shelter. We shall designate such an *expanded purpose or final cause* as *Objective B.*

It is clear that Objective *B* (shelter) is broader and more general in scope than Objective *A* (building). What then are the efficient, formal and material causes to achieve Objective *B?* They are clearly different from those related to Objective *A,* since there has been a *qualitative* change in the nature of its causal connections. For instance, under Objective *B,* the formal and material causes are no longer related merely to building plans or resources alone, but also to alternative housing options, i.e., they include both naturally occurring and man-made shelters in their choices. The efficient causal agents are no longer planners and builders of houses alone, but also include explorers and discoverers of natural shelters. In other words, the notion of shelter under Objective *B* is *conceptually more generic* than those of building structures under objective *A.* With Objective *B,* we have pushed the boundaries of final causes (Or teleology) beyond those of Objective *A.*

We may next ask if there are final causes that are significantly more general than either Objectives *A* and *B.* In the above example, the final cause for constructing shelters is *to maintain and preserve the lives of human beings:* this we shall designate as *Objective C.* While such a goal is the objective of human communities, are we able to identify an even broader set of final causations? For example, the preservation of human beings requires *the preservation of other living organisms (Objective D)* upon whom humans depend for food and energy. Thus, it would appear that the *reciprocal preservation* of the biosphere as a whole (Objective *D)* is a more generic final cause than the preservation of the human species (Objective *C*). In order to achieve such an biospheric objective, we must also *sustain the geo-biochemical cycles on earth (Objective E).*

To expand such a causal scheme to its logical conclusion, we should view it from a more cosmological context. Thus, to achieve Objective *E,* we must have *an intact solar system (Objective F*), which, in turn, requires *the long-term stability of the Milky Way galaxy* (*Objective G*). Finally, the preservation of our galaxy (and other galaxies) depends upon *the preservation of a stable and evolving universe* as a whole *(Objective H).* It would appear that the "ultimate objectives" between constructing a building for human shelter and the existence of an evolving and stable universe may be linked through a reciprocal series of incremental causal connections. The above series of final causations or teleologies may be summarized as follows:

Building (A) < -- >Shelter (B) < -- >Human L~(C) < -- >Bios-phere ('D)

< -- >Planet Earth (E) < -- >Solar System (F) < -- >Milky Way(G) < -- > Universe (H)

From the above, we see that *as we increase the horizon of each final cause, we bring about a corresponding expansion of other causal factors.* For example, the preservation of the human beings and the biosphere (Objectives *C* and *D*) depends upon a mutual web of causal interconnections between different species on earth -- e.g., the nature of the food chain, material resources, energy fluxes, ecosystem

dynamics, etc. In such a biospheric model, the causal interconnections are the vast proliferation of extinct and living species, that continue to be related to each other over time and space. In other words, the biosphere is a mutually linked system, so that any major break or perturbation of its locally-dependent relationships may result in a drastic loss for the global whole. While we may designate *natural selection* of adaptive species as the *efficient cause* of biological evolution, its final *cause* may now be defined as the *mutual preservation* of all biological species on earth. Thus, biological evolution appears to be associated with a final causation or teleology *– the reciprocal maintenance and proliferation of adaptive species over the phylogenetic scale in an evolving and stable physical universe.*

II. Chaos and Contingency

While the above neo-Aristotelian expanded classification scheme on causality is useful in pointing out current epistemological deficiencies in the natural sciences, it is still not logically complete for our present purposes. For instance, within its conceptual framework, it is unable to account for the appearance of contingency, creativity or unexpected novelty in the physical and biological universe. For this we must now turn first to quantum mechanics and then to recent developments in chaos or complexity theories. In addition, we shall briefly examine the nature of far-from-equilibrium thermodynamic systems, where stochastic or random processes are generally prevalent.

Until very recently, the notion of contingency of events received very little emphasis in the natural sciences. Since the fifteenth and sixteenth centuries, the prevailing classical world view was defined entirely upon deterministic terms, leaving no room for chance in the universe. Events in the natural world followed a strictly causal pattern, along a predictable temporal order, such that every well-defined event or action would lead to similar outcomes. However, the introduction of quantum mechanical principles in the early part of this century brought about a dramatic change In our notions of causality, by allowing the concept of non-deterministic evolution of dynamical systems to gain ground in the natural sciences.

In quantum mechanics the exact spatial location of sub-atomic particles (e.g., an electron) is no longer viewed as a meaningful concept. This point of view is completely contrary to the deterministic principles of classical mechanics, where the spatial trajectories of macroscopic bodies could be determined to arbitrary degrees of accuracy. In quantum mechanics, we are unable to specify (even in principle) the precise spatial coordinates of a elementary particle without sacrificing the knowledge of its -velocity or momentum altogether. For these reasons, we can only determine the *probabilities* of an elementary particle's coordinates within a specified spatial boundary. Under such constraints -- i.e., those imposed by Heisenberg's Uncertainty Principle -- a strictly deterministic description of the dynamics of elementary particles is precluded for all sub-atomic systems. We have thus introduced, at a

very fundamental level, the notion of contingency and randomness of physical events into the natural sciences.

We shall now review the non-deterministic features of chaos theories that lead to self-organizing systems. It is often stated that non-linear dynamical systems derived from chaos theory are deterministic in nature. For instance, the phrase "deterministic chaos" is frequently employed to describe the repeated formation of "random" patterns of dynamical trajectories of nonlinear systems. Technically speaking, such a designation is not entirely incorrect, since the use of a given mathematical algorithm (which describes the time series progressions of a non-linear system) always give the same global patterns in its phase-map plottings. It was soon realized, however, that such an apparently "deterministic" view also gave us a highly misleading picture of nonlinear dynamical systems. To begin with, while the overall *global* features of the phase-map of a specific non-linear system is predictable, the actual *local* trajectories do not follow pre-ordained and precise pathways.[1] This is because the dynamical trajectories of non-linear systems tend to *"bifurcate"* at certain temporal or ordinal points in its phase mappings, such that the choice of bifurcated pathways is completely stochastic or unpredictable. That is, at the "local" level, the choice of dynamical pathways is a completely *random* event and, therefore, is non-deterministic.

In chaos theory, what we have achieved is highly significant, since we have introduced the notion of randomness or contingency in a classical dynamical system at any spatial or temporal scale, without invoking quantum indeterminacy only at a sub-atomic or microscopic level. Similarly, in *far-from-equilibrium* thermodynamic systems, I. Prigogine, G. Careri and others have described the stochastic nature of their underlying non-linear dynamics,[2,3,4] In such an *open* or energetically dissipative thermodynamic system that maintains a dynamical steady-state, the local entropy of the system decreases, which (depending on the rate of dissipation) often lead to the appearance of "self-organized" structures.[5] Thus, *randomness and chance appear within all dissipative systems.* This view was succinctly stated by Careri as follows:[6]

> *[C]hance plays a decisive role in the choice of new structures,* by taking the system farther and farther away from equilibrium in an unpredictable direction. Thus the forced evolution of the system from one new structure to another must in part have a "historical" character because of the influence of the preceding situation, but it also has a "nondeterministic" character caused by the series of bifurcations it must come across.. This gives the system *several alternative possibilities of evolution that cannot be predicted because each branch of bifurcation is selected at random* at the moment of instability (first emphasis in original).

Before leaving this brief discussion on chaos theory, one additional feature of non-linear dynamical system should be mentioned. This relates to the *sensitive dependence* of non-linear systems to the *initial*

values of its dynamical parameters (often referred as the "butterfly effect," a phrase coined by the meteorologist E.N. Lorenz).[7] In such a system, even the smallest change (or uncertainty) of initial values of a non-linear or dynamically coupled system, show long-term *divergence* of its phase-map trajectories, leading to the formation of a basin of so-called *"strange attractors."* It would appear that the long-term deterministic predictability of dynamical systems (e.g., planetary orbits in the solar system) of classical mechanics in fact is illusory and does not reflect the underlying "non-deterministic" nature of physical systems over a sufficiently extended period of time. Classical Laplacian determinism had assumed that an "operational" truncation (or first-order approximation) of initial values of dynamical parameters were a mathematically rigorous approach for accurately predicting the future (or past) state of physical events. This naive point of-view appears to be untenable for physical systems with any degree of non-linearity or if they contain even weak interactive coupling terms. In the final analysis, this lack of determinism includes *all* natural phenomena, since no known physical or biological systems are strictly linear or non-interactive in form. Thus, non-deterministic (or non-predictable) outcomes *must occur* for all dynamical systems if they are examined at a sufficiently refined scale of computational analysis.[8]

III. Consciousness and Purpose

We have arrived at the final part of our three-fold examination of ontological principles that underlie the dynamical process of an evolving physical and biological universe. We shall now examine the goal-seeking and purposeful aspects of *cultural evolution* in human societies and contrast them to the apparent lack of such teleology in biological evolution. We shall examine also the nature of human consciousness and moral values in order to determine if they have any unique characteristics that could assist us in distinguishing between causal and contingent features of an evolving biological or social system.

In recent years, natural scientists have considered the possibility that the *emergence* of human cultural evolution have distinct and novel characteristics that are not simply reducible to biological or genetic factors. Following T. Dobzhansky and F. Ayala, we may define the concepts of *internal* (or natural) and *external* (or artifactual) *teleology* as conceptually useful terms in describing causal features in biological and cultural evolution.[9] Such a definition of internal and external teleology was recently summarized by Ayala as follows:[10]

> Objects purposefully designed to send a certain function by the actions of an agent have *external teleology*. Behaviors or actions purposefully performed by an agent *seeking certain goals* are also endowed with external teleology. A person mowing a lawn or purchasing an airline ticket is acting teleologically and these actions may also be seen as teleological, in the external sense.... *Internal teleological systems* are accounted for by natural selection which is *strictly*

> *mechanistic* process. *Organisms and their parts are teleological systems in the internal sense* .... The evidence from paleontology, genetics and other evolutionary sciences is also against the existence of any immanent force or vital principle directing evolution toward the production of specified kinds of organisms (emphases added).

Thus, the *natural selection* of adaptive species in biological evolution may be looked upon as an *internalized teleology*, since there is no "conscious" (or self-directed) attempt to choose "desirable traits" on the part of mutating organisms. For example, according to Darwinian evolutionary principles, when primitive reptilian species mutated to develop bird-like wings, they did so in an unselfconscious (or "blind") adaptation to a changing natural environment. That is, there was no conscious attempt on the part of individual reptiles to seek such biological changes, since a series of random genetic mutations (over a sufficiently long span of time) took its natural course to achieve an environmentally adaptive bird-like species. Hence, biological adaptation may be viewed as *an entirely "natural" or organic process* wherein there is no apparent design or overarching purpose in the evolutionary scheme.

In contrast to biological evolution, *cultural evolution* appears to be an *externalized teleology*, since a sense of purpose and the setting of "conscious" goals are distinctively human characteristics. To a lesser extent, however, one may also observe purposive activities among animals, especially among species at the upper end of the phylogenetic scale. On the other hand, the presence of a complex and highly developed "culture" among mammalian species (e.g., primates) do not seem to have occurred over the period of biological evolution on earth. Thus, cultural evolution, while in the first instance arises from and is dependent on genetic or biological factors, must now be viewed principally as an *"epigenetic" or emergent phenomena.* In other words, cultural evolution is an explicitly purposive and conscious activity, whose historical developments are only *marginally linked* to the selection of adaptive biological traits in a changing natural environment.

We may conclude, then, that goal-setting and purposive activity is a *fundamental factor* in cultural evolution, and that final causes -- in the form of externalized teleologies -- play a significant role in the activities and social relationships of human beings. But what are the final/efficient causal relationships that govern the process of cultural evolution? In our earlier discussions on causality, we examined a series of increasingly broader set of objectives in order to maintain and proliferate human and other life-forms on earth. The preservation of human life was linked mutually to the presence of other stable forms of biological organisms; this subsists in a homeostatic and well-balanced ecosystem on earth. In turn, global biospheric stability necessitated the long-term reciprocal existence and viability of other astronomical bodies -- ultimately, the observable universe as a whole.

From the above discussion, it appears that conscious human behavior, In its cultural and moral context, encompasses *both* biological and

cosmic evolutions. Therefore, we may pose the following question: is there a cosmological principle that describes the *sustenance* of physical, biological and human evolution in the universe? To see if such a far-reaching conclusion is warranted, we shall now examine the incorporation of such a cosmological perspective within the ontological tenets of Whitehead's process philosophy.

IV. Cosmological Imperatives of a Process-Based Ontology

Whitehead's principal aim in developing a metaphysics of an organismic universe was to transcend the self-imposed conceptual boundaries and rigid conventions of the natural sciences. In doing so, he moved away from the narrow constraints placed on modern science by the use of metaphorical language that often gave a highly restricted picture of the natural world. For example, for the frequently used word "events" (used in describing natural phenomena in space-time coordinate systems) he substituted the term "actual occasions," which for him gave a more accurate (and richer) picture of "real" or "concrete" happenings in the natural world.[11] In this regard, he avoided the use of such commonly employed metaphysical terms such as "sensation" and "perception" -- derived from seventeenth and eighteenth philosophers such as Locke, Berkeley, Hume and Kant -- since for him they had a narrow psychological rather than appropriate epistemological meanings. Related to this was his concern that natural scientists and philosophers frequently indulged in what he termed the "accidental error of mistaking the abstract for the concrete" ("fallacy of misplaced concreteness," SMW 51).

We shall first examine Whitehead' s notions of *"prehension"* and *concrescence,"* which are his attempts to place "actual occasions" within a causal framework. To begin with, Whitehead divides the universe into two major categories of "real" objects: (a) *"eternal objects"* (or pure potentials), and (b) *"actual entities"* (also synonymous with "actual occasions" or "final realities") (PR 22-24). While eternal objects subsist, their togetherness (or relatedness) brings about seemingly separate entities into a *unity* (or conjunction) of "actual entities" or occasions into a *"nexus."* Thus, *"prehension"* is described as an incomplete and partial bringing together of "actual entities" into a "nexus":

> Any such particular fact $_0$f togetherness among actual entities is called a nexus . . . .The ultimate facts of *immediate actual experience are actual entities, prehensions, and nexus.* All else is, for our experience, derivative abstraction (PR 20, emphasis added).

The highly complex (and often opaque) vocabulary of Whitehead's *Process and Reality* may obscure at times the foundational simplicity of his metaphysics. On the other hand, in his earlier publication, *Science and the Modern World,* Whitehead spoke with less formality in expressing the main outlines of his process-based philosophy:

> *We conceive actuality as in essential relation to an*

> *unfathomable possibility*. Eternal objects inform actual occasions with hierarchic patterns, included and excluded in every variety of discrimination. Another view of the same truth is that *every actual occasion is a limitation imposed on possibility,* and that by virtue of this limitation the particular value $_0$f that shaped togetherness of things emerges.... But there are no single occasions, in the sense of isolated occasions. *Actuality is through and through togetherness* -- togetherness of otherwise isolated eternal objects, and togetherness of all actual occasions (SMW 174, emphasis added).

Thus, starting with isolated (or disjunctive) "eternal objects," they become manifested through a process of "prehension" into "actual entities," that leads to the unity (or conjunctive) togetherness of "actual entities," described as a "nexus" of possible (or subjunctive) "actual occasions." In simpler language, we may state that primordial objects in the universe (grounded in an ineffable reality) are *causally transformed* into a limited set of cosmological, biological and cultural entities, which at the same time, allows for an endless number of creative outcomes and novel possibilities.

The process of bringing "eternal objects" and "actual entities" into creative and novel nexus of "actual occasions" is termed by Whitehead *concrescence."* Thus, he states:

> [T]he *"production" of novel togetherness is the ultimate notion embodied in the term "concrescence."* These ultimate notions of "production of novelty" and of concrete togetherness" *are inexplicable either in terms of higher universals* or in terms of the components participating in the concrescence. The analysis of the components abstracts from the concrescence. The sole appeal is to intuition. (PR 21-22, emphasis added)

The process philosophy of Whitehead is essentially a metaphysics of concrescence, inasmuch as it is based on the "ontological principle," which states that all "actual entities" and "actual occasions" comes from "something" and not from "nothing" (PR 244). That is, all "actual occasions are prehensively derived from "eternal objects" or forms of definiteness which are associated with God as the *ground of concrescent being* -- in contrast to the Aristotelian deistic concept of an omnipotent being as the "prime mover." Moreover, it goes well beyond the conventional notions of an absolute deity as the original creator of the universe. For instance, in the novel togetherness of "concrescence," there is "creative advance" that is *not determinable* in an temporal (or ordinal) sense. In other words, there is nothing in the physical, biological and cultural dimensions of the universe where there is a fixed and determinate causality. In process philosophy, therefore, the omnipotence of the Creator (as the original ground of being) is no longer deemed absolute, but appears circumscribed and indeterminate.

VI. Towards a Process-and Ecologically-Based Ontology

Let us now briefly review what we have uncovered in our

examination of non-deterministic and reciprocal causalities and the emergence of human consciousness and purposive actions, so as to place them within the context of a process-based ontology. In our discussions of chaos or complexity theory, we have established the underlying non-deterministic (Or stochastic) nature of all dynamical systems with interactive and self-organizing component parts. We have shown that strict determinism can be invoked *only* if we assume that all second and other higher order (i.e., non-linear) terms are negligible in a dynamical system. While such simplifying assumptions were deemed acceptable in the past, they can no longer be regarded as a correct reflection of the underlying dynamics of any realistic natural system.[12] Above all, we have shown the contingent (or probabilistic) nature of all dynamically evolving systems at both the microscopic (atomic and sub-atomic) and macroscopic (terrestrial) levels.

We have discussed cultural evolution in human societies as an emergent phenomenon of biological evolution. It appears that human beings (and, to a lesser extent, other biological organisms) act in a conscious and purposive manner. In this regard, we described two types of biologically-based teleologies: (i) an *external* teleology, where there is a deliberate and conscious setting of goals, those that are generally found among human beings and possibly in higher animals; and (ii) an *internal* teleology, where there is no self-directed or conscious goal-seeking on the part of living organisms, such as in the natural selection of favorable traits among biologically adaptive species. From a purely evolutionary point of view, "inner" (or non-self-directed) teleologies led to the appearance of conscious beings in the universe who are governed by "external" (or self-directed) teleologies. While such a provisional teleology is a useful starting point, it is only partially complete when viewed in the larger context of biological and cultural evolutions. For instance, how are we to account for the "external" or goal-seeking teleological features of the evolution of human societies within a seemingly non-purposive physical universe? Moreover, we must account also for the presence of chance and contingency in the natural world, such that the present evolving universe is not a strictly deterministic outcome of the original cosmic "big bang."

It would be illuminating to place the questions posed above within the metaphysical framework of a process-based ontology. In Whitehead’s philosophy, the whole of reality (in its broadest sense) is embodied in the "concrescence" of the moment -- i.e., in the evolution of the "actual occasions" through the unconscious (and richly endowed) "prehensions" and unity (or togetherness) of "actual entities" ("nexus"). Only by a process of physical and conceptual "prehensions," "feelings" and "experiences" -- through several levels of increasing awareness -- do we arrive at a final resolution in acts of self-cognition and conscious purpose.[13] In other words, Whitehead believed that *conscious and purposive acts are the tip of a "prehensive" iceberg* that remains below the level of consciousness, yet participates in every moment of concrescence, resulting in novelty and creativity in an evolving universe.

Let us put the above process-based ontology within a neo-Aristotelian classification scheme of causality. We have identified such a logical system as an ever-widening series of reciprocal final causations that have corresponding material, formal, and efficient causes. We accomplished this by commencing with purposive and conscious actions of humans (e.g., in the construction of a building structure), which required the sustenance of other entities (plants, animals, planets, galaxies, etc.) within the spatial and temporal framework of an evolving universe. We shall now designate this fundamental reciprocal causal relationship in space and time as *the principal underlying ontological basis for existence*. While biological evolution of adaptive species may have occurred through a series of localized internal (or non- purposive) teleologies, the concrescence or bringing together of physical and biological processes corresponds to both a globally internalized (non-purposive) and globally externalized (purposive) teleology of the observable universe. In its broadest sense, we may *initially* state the cosmological principle in a process-based ontology as follows: the emergence of purposive actions and consciousness within the creative and novel concrescence of an evolving physical and biological universe.[14]

More importantly, the reciprocal causalities within the concrescence of a process-based ontology brings about an awareness of an added *ethical* dimension in an evolving universe. We may identify it, especially in its prehensile and emerging state, as a *cosmological moral imperative,* that both drives and sustains the evolutionary process. We are now able to detect a heightened sense of responsibility that attends any action taken by self-aware and conscious sentient beings in a mutually dependent and causally related universe. Which means that every step taken in such an evolving universe becomes charged with a sense of personal or collective responsibility. However, in a process and ecologically based ontology, such an ethical or normative plane is not given *a priori* as a fixed or non-changing Platonic ideal, but is derived continually within the concrescence of an ever-changing and evolving universe. In other words, in a process-based ontology, there are no transcendental ethical rules about right or wrong courses of actions. Here one’s sense of moral responsibility and consequent courses of actions depend on "actual occasions" and whole "experiences." While a process-based ontology may avoid prescribing an immutable set of moral principles, we may yet discern -- within its existential uncertainties and contingencies -- a universal normative principle that reflects the reciprocal causal unity and "novel togetherness" of the many becoming one.

Initially, in our epistemological investigation of a process and ecologically based ontology, we demonstrated an evolving physical and biological universe that was filled with potential novelty and creativity. We are now presented with a more ethical, albeit largely anthropocentric, view of human responsibility in the context of such an evolving and interdependent universe. This means that as human ingenuity in controlling the natural world increases, the potential for affecting the physical and biological environments on earth (and presumably, elsewhere in the universe) is greatly enhanced. In this

century alone, we have witnessed the build-up of unimaginable weapons of destruction, while at the same time human societies continue to strain the carrying capacity of natural systems on our small planet. In short, we are technologically capable of adversely impacting many, if not all, living organisms and their life-support systems on earth.

In both the short and long-term, human beings have an enormous and abiding burden of responsibility for maintaining the viability of the natural world within the context of an evolving physical and biological universe. However, in such a process and ecologically based ontology, ethical reflections and choices of actions can only be effectively carried out in an interdisciplinary and multi-cultural context, since no single scientific, philosophical or normative point of view will suffice. As envisioned by Whitehead, an ever-present and mutually respectful synthesis of art, science, culture and religion is needed in all facets of our lives. It is here where the experiential "nexus" of scientific knowledge, artistic creations, moral values and spiritual wisdom meet and reside. In such an aesthetic, intellectual and ethical context, a *normative cosmological principle* may now be emphatically stated as follows: *the acceptance of a deeply-rooted sense of human responsibility with respect to all creation (both inanimate and animate) in an evolving physical and biological universe.*

Notes

1. Edward Ott Chaos in Dynamical Systems (New York: Cambridge University Press, 1993).

2. Ilya Prigogine, *From Being to Becoming: Time and Complexity in the Physical Sciences* (New York: W.H. Freeman and Co., 1980).

3. Giorgio Careri, *Order and Disorder in Matter,* translated by K. Jarratt (Menlo Park, Calif.: The Benjamin/Cummings Publishing Co., Inc., 1984).

4. P. Glansdorff and I. Prigogine, *Thermodynamic Theory of Structure Stability and Fluctuations* (New York: John Wiley and Sons, 1971).

5. By contrast, in "near equilibrium" thermodynamic systems, also known as the linear "*Onsager regime,"* the physical state tends toward maximum disorder (i.e., minimum negative entropy), while maintaining the temporal symmetry of classical Newtonian mechanics.

6. G. Careri, 109.

7. For an interesting discussion on this phenomena, see David Ruelle,

Chance and Chaos (Princeton: Princeton University Press, 1991).

8. For example, analytic solutions of "linear" differential equations that describe simple harmonic motions are only found in dynamical systems with *small amplitudes,* where non- linear terms are assumed to be negligible. Similarly, inclusion of *interactive coupling terms* in "many-body" problems do not lead to exact "deterministic" solutions of the dynamical system.

9. T. Dobzhansky, F. Ayala, G. L. Stebbins and J.W. Valentine, *Evolution,* Chapter 16 (San Francisco: W.H. Freeman and Co., 1977).

10. Francisco Ayala, "Darwin and the Teleology of Nature," a paper presented at the GCSSR -- AAAS Symposium on *Science, Cosmology and Teleology. Intercultural and Interdisciplinary Perspectives* (Seattle, Wash., February 12, 1997).

11. To Whitehead. "actual occasions" are shaped not only by logical reasoning, but includes all aspects of one's subjective experiences, including the use of ones imagination, aesthetic feelings, and other forms of non-cognitive and unconscious influences.

12. This is true particularly with the appearance of computational devices of extraordinary power and refinement today. Thus, numerical (if not analytical) solutions to many complex, non-linear systems can be carried out with relative ease.

13. See for example, Thomas E. Hosinski, *Stubborn Fact and Creative Advance: An Introduction to the Metaphysics of Alfred North Whitehead,* 46 -128 (Lanham, Md.: Rowman and Littlefield Publishers, Inc., 1993).

14. Such a point of view may appear to extend the so-called weak versions of the "anthropic principle," which asserts the primacy of the appearance of life (as we know it) in the universe. However, it would be misleading to believe that biological life, as we observe it on earth, are the only forms in which living systems may exist in the universe.