GREGORY BATESON, CYBERNETICS, AND THE SOCIAL/BEHAVIORAL SCIENCES

ABSTRACT

Gregory Bateson's interdisciplinary work in Anthropology, Psychiatry, Evolution, and Epistemology was profoundly influenced by the ideas set forth in systems theory, communication theory, information theory and cybernetics. As is now quite common, Bateson used the single term *cybernetics* in reference to an aggregate of these ideas that grew together shortly after World War II. For him, cybernetics, or communication theory, or information theory, or systems theory, together constituted a unified set of ideas, and he was among the first to appreciate the fact that the patterns of organization and relational symmetry evident in all living systems are indicative of *mind*.

Here, we must not forget that due to the nineteenth century polemic between science and religion, any consideration of purpose and plan, *e.g.*, mental process, had been *a priori* excluded from science as non-empirical, or immeasurable. Any reference to *mind* as an explanatory or causal principle had been banned from biology. Even in the social/behavioral sciences, references to mind remained suspect. Building on the work of Norbert Wiener, Warren McCulloch, and W. Ross Ashby, Bateson realized that it is precisely mental process or *mind* which must be investigated.

Thus, he formulated the *criteria of mind* and the *cybernetic epistemology* that are pivotal elements in his "ecological philosophy." In fact, he referred to cybernetics as an epistemology: *e.g.,* the model, itself, is a means of knowing what sort of world this is, and also the limitations that exist concerning our ability to know something (or perhaps nothing) of such matters. As his work progressed, Bateson proposed that we consider *Epistemology* as an overarching discipline of the natural sciences, including the social/behavioral sciences: a meta-science whose parameters extend to include the science of mind in the widest sense of the word. Apparently, many scholars and practitioners of the social/behavioral sciences, as well as the humanities, were first introduced to the cybernetic paradigm through Bateson's work. Yet, he seldom offered his audience more than a cursory reference to the key principles underlying cybernetics. Hence, the aim of this essay is to incrementally and historically delineate the fundamental principles underlying what is now often referred to as the 'first' cybernetics.

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> The ideas were generated in many places: in Vienna by Bertalanffy, in Harvard by Wiener, in Princeton by von Neumann, in Bell Telephone labs by Shannon, in Cambridge by Craik, and so on. All these separate developments dealt with *communicational problems, especially with the problem of what sort of thing is an organized system*.[1] [emphasis mine]
>
> —Gregory Bateson

Gregory Bateson was among the first to appreciate the fact that the patterns of organization and relational symmetry evident in all living systems are indicative of mind. Here, we must not forget that due to the nineteenth century polemic between science and religion, any consideration of purpose and plan, *e.g.*, mental process, had been *a priori* excluded from science as non-empirical, or immeasurable. Any reference to *mind* as an explanatory or causal principle had been banned from biology. Even in the social/behavioral sciences, references to mind remained suspect. Building on the work of Norbert Wiener, W. Ross Ashby and Warren McCulloch,[2] Bateson realized that it is precisely mental process or *mind* which must be investigated. Thus, he formulated the *criteria of mind* and the *cybernetic epistemology* that are pivotal elements in his "ecological philosophy." In fact, he referred to cybernetics as an epistemology: *e.g.,* the model, itself, is a means of knowing what sort of world this is, and also the limitations that exist concerning our ability to know something (or perhaps nothing) of such matters. As his work progressed, he proposed that we consider *Epistemology* as an overarching discipline of the natural sciences, including the social/behavioral sciences: a meta-science whose parameters extend to include the science of mind in the widest sense of the word.

With its focus on communication and information as the key elements of the self-regulation and self-organization in cybernetic systems, the cybernetic paradigm exemplifies the hierarchical patterns of organization evident in living systems. The elaborate differences of pattern, organization and symmetry embodied in living systems are also indicative of mental process. Thus, Bateson employed the aggregate of ideas referred to under the rubric of cybernetics as a unifying model of mental phenomena, and as a tool for "mapping" and explaining the previously inaccessible "territory" of mind. Taking his lead particularly from

Warren McCulloch,[3] Bateson's work led to the conclusion that epistemology is, in fact, a normative branch of natural history. For Bateson, McCulloch's work had "pulled epistemology down out of the realms of abstract philosophy into the much more simple realm of natural history," and established "that, to understand human beings, even at a very elementary level, you had to know the limitations of their sensory input."[4]

Apparently, many scholars and practitioners of the social/behavioral sciences, as well as the humanities (myself included), were first introduced to the cybernetic paradigm through Bateson's work. Yet, he seldom offered his audience more than a cursory reference to the key principles underlying cybernetics. Hence, the aim of this essay is to delineate the fundamental principles underlying what is now often referred to as the 'first' cybernetics. Clearly, Bateson's interdisciplinary work in Anthropology, Psychiatry, Evolution, and Epistemology was profoundly influenced by the ideas set forth in systems theory, communication theory, information theory and cybernetics. As is now quite common, Bateson used the single term *cybernetics* in reference to an aggregate of these ideas that grew together shortly after World War II, and for him, cybernetics, or communication theory, or information theory, or systems theory, together constituted a unified set of ideas. The quotation headlining this essay is intended to indicate that our topic deals with essentially *communicational problems*, "especially with the problem of what sort of 'thing' is an organized system," *i.e.*, a mind system, a communications system, a social system, and an ecosystem. Since we will be considering an aggregate of disciplines, I proceed chronologically, with the first of these disciplines to emerge, *i.e.*, general systems theory, and then move to consider how the recursive regularities of negative and positive feedback mechanisms, and circular causal systems (principles established first in mathematics, communication theory, and information theory)[5] led Norbert Wiener to coin the term cybernetics, and serendipitously offered a firmer theoretical foundation for systems theory.

The Classical Paradigm of Science, and the Emergence of General Systems Theory

General systems theory emerged out of the need to map and explain biological phenomena that cannot be suitably understood using the classical mechanistic model of reality. "The analytic, mechanistic, one-way causal paradigm of classical science," as the Austrian biologist Ludwig von Bertalanffy describes it, assumes that reality can be quantifiably analyzed; that a whole can be understood in terms of its parts; and that the nature and function of a substance or an organism can be comprehended by reducing it to its material, externally observable components.[6]

Systems analysis acknowledges the impressive gains in scientific inquiry, and the subsequent technological advances, afforded by the classical scientific paradigm. Granted, highly sophisticated methods of dissecting and quantifiably analyzing natural phenomena have provided important insights into the construction of our world. Such insights have also afforded a considerable, though limited, capacity to predict and control small pieces of reality, at a given moment in time. Yet, these gains have been achieved at considerable costs, costs that notably include: overspecialization and narrow professionalism in scientific research; the fracturing and fragmentation of science's vision of nature; and a subsequent sense of alienation from the beauty of nature's underlying unity.

Systems analysis observes that with the classical paradigm of reality, wider more inclusive patterns interaction are disregarded as immeasurable. Also, virtually all considerations of purpose and plan, *e.g.*, mental process, and final causes, are *a priori* excluded as non-empirical, or again, immeasurable. Coupled with Cartesian mind-body duality, the one-way causal paradigm of classical science assumes the nature of a substance—and this includes organisms—is reducible to forces, impacts and regularities that are inevitably subject to the second law of thermodynamics. It also assumes that all causes, effects and potentialities can be traced back, in linear fashion, to initial conditions.

While these assumptions are adequate for explaining carefully isolated phenomena, and the causal relationships between one "thing" and another "thing," science has found it difficult to apply this model of reality in situations displaying more than two variables.[7] Mapping multivariable complexes in terms of linear relations involves a piecemeal, fragmented analysis, in which the units involved are reduced to sequences of interacting pairs. Any process that is more complex than a hydrogen atom, with one electron orbiting its nucleus, embodies a complexity that escapes sufficient explanation. This method affords useful information, but it cannot sufficiently map the flow of an interactive complex.

Moreover, the successes garnered by the classical scientific paradigm revealed its inadequacies. As refined tools have opened wider panoramas of research, exhibiting data of increasing complexity, science has been driven to search for new ways of conceptualizing reality. In short, the classical paradigm of science has proven inadequate to the task of mapping the natural world. It is particularly inadequate when applied to describing and explaining the multivariable processes of human interaction, *e.g.*, communication, and humankind's intricate interrelationship with local and global ecological systems.

Under closer observation, it has become evident that natural phenomena do not behave as they are though subject to the narrow determinism postulated by the paradigm of classical science. This has led to a tangential or corollary view, a view that completely abandons causality and envisions the cosmos as random. As Joanna Rogers Macy has noted, the unidirectional paradigm of classical science has culminated in two distinct alternatives: "either we live in a clockwork universe, wholly predetermined by initial conditions, with no scope for genuine novelty, or the cosmos is a blind and purposeless play of atoms, and determinable only statistically, by the laws of chance."[8] Macy, identifies these dismal alternatives as a major contributing factor in the spiritual and psychic dislocation, or the sense of alienation experienced by contemporary humankind. These limited alternatives also serve as key barriers, blocking meaningful dialogue between science and religion.

I should also note that while the assumptions of the classical scientific paradigm have provided a capacity to predict and control the natural world, the impressive technological gains they afford are largely responsible for a familiar litany of alarming environmental crises: overpopulation, pollution and degradation of the environment, global warming and ozone depletion, *etc.*[9] We must recognize the role played by religion, as well as economics and other cultural factors, in shaping the attitudes that have fostered the ecological crisis we now face. Still, the now commonly held mistaken notions (concerning humankind's relationship with the biosphere, as well as what constitutes an appropriate and thoughtful application of scientific knowledge) are directly attributable to the myopic excesses of the classical scientific paradigm.

It is one thing to fantasize that we have the right to dominate nature. It is quite another thing, when techniques developed by science actually give us the ability to play out our dominant fantasies: altering and destroying vast sections of the natural order evident in the biosphere. Humankind's successes in scientific exploration have allowed for, and apparently encouraged, unwise intervention in natural systems that we do not fully understand. Our overconfidence in the veracity and reliability of a limited scientific paradigm, and our haste in applying techniques borrowed from this model—notably prediction and control—have fostered a pseudo-scientific and overly technological culture of consumerism. Such have been the costs of our over-reliance on the reductionist, mechanistic, one-way causal paradigm of classical science.

The perspective offered by advocates of general systems analysis identifies at least four areas where the inadequacy of the classical scientific paradigm is most apparently manifest, areas where its failings have stimulated the development and acceptance of systems analysis and subsequently cybernetics:

1. As previously noted, natural phenomena displaying a multiplicity of variables cannot be adequately understood through an analysis of their variables as separate entities. While analysis of the physical nature of differentiated "parts" comprising a whole may be useful, it is limited in what it reveals about the whole. Since focusing on isolated traits obscures or eclipses attributes characteristic of the whole, our focus should move to examining the *combined interaction* of these variables.

2. A linear concept of causality cannot adequately explain the interactions of a complex system or *Gestalt*. The classical scientific paradigm is sufficient only for understanding carefully isolated phenomena, where unidirectional cause and effect relationships occur between interacting pairs, *e.g.*, between one thing and another thing.

3. Entropy, or evidence of negentropic processes in the growth and evolution of living organisms, is also a realm of explanation where the classical paradigm of science has proven

to be inadequate. While not eluding the laws of physics, the complex interactions of biological systems involve regularities other than the second law of thermodynamics. According to the second law of thermodynamics, entropy always increases: with every transformation of energy there is a measure of that energy which is lost; therefore differences in heat become gradually equalized and the universe is seen as ultimately tending toward sameness, randomness and disorganization. In the physical sciences, this law has never been contradicted or disproved, and it is generally regarded as holding a "supreme position among the laws of Nature."[10] Yet, the second law of thermodynamics cannot adequately explain the evidence of continued biological negentropy. In their forms of life and patterns of interaction living organisms have not tended toward sameness, randomness and disorganization. Living systems differentiate, evolve and maintain increasingly complex forms of social and self-organization. Such self-organization in biological phenomena has been studied since the 1920's, and the anti-entropic evidence in the evolution of order and increased complexity within biological systems simply cannot be explained with traditional linear concepts such as the second law of thermodynamics, where effect is understood to pre-exist in cause.

4. The classical paradigm of science has led to overspecialization and departmentalization, blocking the perception and investigation of interdependence in natural phenomena. The shared presuppositions: that reality can be quantifiably analyzed; that a whole can be understood in terms of its parts; and that the nature and function of a substance or organism can be ascertained by dissecting it into smaller and smaller components, has bred acute specialization. As specialists have learned "more and more about less and less," the separations between their disciplines become virtually impenetrable. A specificity of disciplines and terminology impedes communication among scientists, limiting understanding of scientific inquiry to a limited class of experts. Perhaps the most damaging result of over-specialization in scientific inquiry is that it has obstructed the perception and study of the non-substantial phenomena intrinsically manifest in relationships. As Ervin Laszlo notes,

> We are drilling holes in the wall of mystery that we call nature and reality on many locations, and we carry out delicate analyses on each of these sites. But it is only now that we are beginning to realize the need for connecting the probes with one another and gaining some coherent insight into what is there.[11]

General Systems Analysis:
Homeostatic and Self-Organizing
Open Systems in the Phenomena of Life

General systems theory first originated in biology, a science where the need to move beyond a reductionist and atomistic approach is perhaps most evident. In the 1920's, Austrian scientist Ludwig von Bertalanffy directed his attention to the organization of organisms, rather than their substance—focusing on wholes, and the manner in which wholes function, rather than on parts. Concerning the early stages of his work von Bertalanffy wrote:

> [I] became puzzled about obvious lacunae in the research and theory of biology. The then prevalent mechanistic approach . . . appeared to neglect or actively deny just what is essential in the phenomena of life. [I] advocated an organismic conception of biology which emphasizes consideration of the organism as a whole or system, and see the main objective of biological sciences in the discovery of the principles of organization at its various levels.[12]

Of course, von Bertalanffy's thinking was not entirely isolated. Process-oriented, holistic approaches were being considered in many places. Whitehead's process philosophy, Jung's *Gestalt* therapy, and more to the point, Cannon's work on homeostasis (an integral element of systems thought) first appeared at this time.[13]

Von Bertalanffy's work established that the behavior of living phenomena is best comprehended in terms of wholes, rather than parts. He also discerned that biological wholes—animal or vegetable; cell, organ, or organism—are best described as systems. The system, as described by von Bertalanffy, is less a "thing" than a pattern of organization. Systems are comprised of a unified pattern of events, and their existence, as well as their character are derived more from the nature of their organization, than from the nature of their components. As such, a system consists of a dynamic flow of interactions that cannot themselves be quantified, weighed or measured. The pattern of the whole is "non-summative" and irreducible. Hence, as a pattern of organization, the character of a system is altered with any addition, subtraction or other form of perturbation in any of its constitutive elements.

Doubtless, a living system is more than simply the sum of its parts. However, this *more* is not something *extra*, such as an *elan vital* or a vitalist principle. Even after significant disruption, an organism in nature can continue to develop in a manner normal for its species—evidence the fact that organisms can heal themselves. Since this sort of phenomenon seems to contradict the classical laws of physics, giving organisms an aspect of independence from the external operation of cause and effect earlier biologists attributed it to a soul-like vitalist factor.

Having found this sort of explanation inadequate and unwarranted, von Bertalanffy attributed the phenomenon to a function of the dynamic organization of the system as a whole.[14] That is, through the combined interaction of the differentiated elements that comprise the system, a new level of operation is formed. Namely, a unique status of existence is facilitated by the fully integrated interdependence of its "parts." Thus, the very nature of a system is immanent in the combined interaction of the system as a whole, and hence, the system's true character is lost from view when its distinguishable components are investigated independently of each other. Von Bertalanffy came to understand that the organic interdependence which governs the internal functioning of a living system also exemplifies its relations with its environment. Whether an organism or an organ, a cell or an organelle, a living system functions and evolves within a larger system—linked in relationships which embody both dependence and indispensability. Living systems both envelop, and are enveloped by, other living systems with which they are in steady communication, thus forming a natural hierarchical order.

Thus, the diverse morphogenesis apparent in the discernable wholes studied by the biological sciences—organelle or cell, organ or organism, vegetable or animal, species or genus, *etc*.—are not only systems, they are *open* systems.[15] They organize and sustain themselves by exchanging matter, energy and information with their environment. Moreover, it is precisely the processes involved in these exchanges which constitute the life and continuity of such living systems. For although a living system may replicate itself, no single component of the system is permanent.

The manner in which these exchanges and transformations take place, the principles by which an incessantly changing pattern both retains its configuration or identity *and* evolves its order, have been a central focus of systems inquiry. As for *what* exactly is exchanged, since the distinctions between matter, energy, and information have become blurred, answers to this question are not entirely clear. Yet, it is clear that all three flow through the system and are subsequently transformed by it. Von Bertalanffy's major discovery was that regardless of a system's material ingredients or external appearance, in their relational patterns and processes, the regularities or invariances which govern these operations are essentially the same. Furthermore, in maintaining and organizing itself, an open system is distinguished by what von Bertalanffy identified as *Fließ-Gleichgewicht* (literally, "flux-balance"), or *steady state*. Because a living system is incessantly involved in processes of exchange and transformation—in states of inflow and outflow—the system is recognized as maintaining a continual state of flux. Never stationary or fixed in chemical or thermodynamic equilibrium, its components are constantly altered by metabolic events.

The terms balance and steady are here most significant. These terms underscore the fact that the system maintains itself in tension between opposing forces—between the formation and the dissolution of its constitutive components, *i.e.*, its "substance." A system compensates for its deterioration by importing and processing energy. Thus, it attains and sustains a steady balance—a *dynamic* equilibrium—between its own improbable state and the surrounding environment.[16] While its elements dissipate, its pattern endures and can even evolve in complexity. The morphogenesis embodied in living systems exemplifies negen-tropic or anti-entropic qualities that apparently defy the physical laws of nature. Living systems represent a successful maintenance and increase of order within the prevailing thermodynamic drift toward randomness and disorganization. Their orderliness persists, not only in spite of disintegrative forces, but actually by means of utilizing them.

The processes through which living systems generate and sustain order are two-fold. One is self-stabilizing or homeostatic, where the continuity of the system's pattern or configuration is maintained. The other is self-organizing, where the overall pattern of the system itself is modified, and its organization increased. Increased complexity fosters a decrease in structural stability, and complexification moves the system toward greater variety, improbability, and possible inviability. The more complex and intricately refined system is more vulnerable to physical disorganization. Yet, this tendency is also counter-balanced by subsequent increases in the system's flexibility, and its heightened capacity to process information and adapt.

Systems theorists observe that it is within closed systems, like a machine without an outside source of energy, that entropy inevitably increases. This highlights the fact that while open systems do manifest entropy, they can also import energy from their environment, and through orderly differentiation they can increase in complexity. Unless the universe as a whole is taken as one, the concept of a closed system is an abstraction that does not exist in nature.[17]

The self-organizing and homeostatic (self-stabilizing) processes exhibited by open systems constitute evidence of persistent phenomena which are contrary to the mechanically and statistically demonstrable dissolution of the universe, postulated by the second law of thermodynamics. Also, open systems provide evidence that demonstrates the existence of anti-entropic (negentropic) tendencies within our perceived universe—negentropic tendencies in which order, complexity, and improbability are sustained and increased. Hence, we may safely assume that the existence of open systems resolves the apparent contradiction between data from physics which supports dissipation, disorganization and randomness, on the one hand, and ample documentation of increased order and complexity in biological evolution, on the other.

Cybernetics: Circular Causal Systems in Biological and Social Systems

Gregory Bateson embraced the concepts and vocabulary of cybernetics because this interdisciplinary field offered a more rigorous formulation of theoretical concerns with which his work had already been dealing. In fact, Bateson's biography offers ample evidence that long before he first encountered cybernetic theory, a systems approach to the biology and the behavioral sciences were for him not a foreign concept.[18] His father William Bateson was a preeminent British biologist and a pioneer in the study of genetics (he introduced the term to the English speaking world). Of his father, Bateson has written that he, "was certainly ready in 1894 to receive the cybernetic ideas."[19] It is also interesting to note that as early as 1906, the elder Bateson had written:

> We commonly think of animals and plants as matter, but *they are really systems* through which matter is continually passing. *The orderly relations of their parts* are as much under geometrical control as the concentric waves spreading from a splash in a pool. If we could in any real way identify or analyze *the causation* of growth, biology would become a branch of physics.[20] [emphasis mine]

Judging from the above, it does appear that Bateson was raised in an atmosphere where the concerns and ideas central to systems analysis, and later cybernetics, were familiar topics. Moreover, at Cambridge University in the 1920's, the pattern of his education in science had encouraged broad, general, interdisciplinary interests.[21] No doubt, having been raised and educated in such an environment favorably prepared Bateson for the advent of cybernetic ideas.

Well before 1946, when he was invited to attend the first formal conference on cybernetics sponsored by the Macy foundation, Bateson's work in cultural anthropology dealt with the processes by which social systems organize and stabilize themselves. However, he was not satisfied with his interpretations of his own social anthropological fieldwork.[22] It was not until cybernetics offered the possibility of extending the precision of mathematics to these processes, that he became actively involved in the movement to apply a variety of concepts originating in mathematics and engineering to biology and the behavioral sciences.[23] Still, Bateson was by no means a mathematician. He understood relatively little mathematics and his distaste for engineering is well documented:[24]

> . . . his interest was in the concepts from logical and mathematical theories which he could use, as metaphors or in an heuristic way, to formulate conceptual schemes in the behavioral and social sciences. His tool was and is the English language, and he tried to achieve clarity and precision in its use, as far as was possible, but never mathematical rigor.[25]

Bateson not only assimilated the conceptual schemes of cybernetics into his work, during the remainder of his career he refined the newly developed lexicon of cybernetics, so that it could be used with both scientific rigor and poetic imagination,[26] and cybernetic principles became the central metaphor in his proposed meta-science of *Epistemology*.

James Watt's invention of the governor on a steam engine (given precise mathematical analysis by Clerk Maxwell in 1868) and Cannon's discovery of homeostasis in the maintenance of the chemical balance of the blood, had already revealed the principles underlying the processes of self-regulation.[27] These principles were more rigorously clarified through research initially carried out on the improvement of anti-aircraft artillery during World War II. To delineate further the operation of self-corrective or "Teleological Mechanisms," research was directed to the ways in which such devices receive, exchange and use information to adjust to multivariable contingencies in the environment. Devices were built that could monitor their own performance, correct for deviations and changing conditions, and within set parameters, alter their goals. The method used to accomplish all of this utilized the properties of closed self-corrective circuits, referred to as feedback mechanisms, and in time as cybernetics.

The term *Cybernetics* was coined by Norbert Wiener, at the end of World War Two, in reference to the, "entire field of control and communication theory, whether in the machine or in the animal."[28] He was, of course, referring to a remarkable set of discoveries concerning the nature of self-corrective machines that he and many others had made while working on defense projects. During the war Wiener had been part of an interdisciplinary team at the Massachusetts Institute of Technology who had worked on the mathematical aspects of guidance and control systems for anti-aircraft fire. His earliest public use of the term *Cybernetics was* in March 1946,[29] at the first of the Macy conferences, entitled, "Feedback Mechanisms and Circular Causal Systems in Biological and Social Systems."[30] Ironically, it was their consideration of guided ("purposeful") anti-aircraft projectiles, and other weapons being developed for the war, which had alerted Wiener and his associates to the similarity of organisms and machines:

> Rosenblueth, Wiener, and Bigelow had, in effect, announced a new paradigm in science, according to which one seeks an overarching theory to include machines and organisms; the theory would clearly involve ideas of information, control, and feedback.[31]

The introduction of cybernetics as an interdisciplinary field led to considerable enthusiasm among the scientists who attended the Macy conferences. Many, including

Bateson, believed the ideas offered were sufficiently deep, yet acceptably overarching, that out of them might come a vocabulary suitable as a unifying conceptual framework for the biological and social sciences. Norbert Wiener perhaps best captured the mood of enthusiasm when he wrote:

> If the seventeenth and early eighteenth centuries are the age of clocks, and the later eighteenth and the nineteenth centuries constitute the age of steam engines, *the present time is the age of communication and control*. There is in electrical engineering a split . . . between the technique of strong currents and the technique of weak currents, and which we know as the distinction between power and communication engineering. *It is this split which separates the age just past from that in which we are now living*. Actually, communication engineering can deal with currents of any size whatever . . . *what distinguishes it from power engineering is that its main interest is not economy of energy but the accurate reproduction of a signal*.[32] [emphasis mine]

Here, I want to call particular attention to the fact that in this quotation Wiener emphasizes the accurate reproduction of a signal, *i.e.*, communication, as the separation which distinguishes cybernetics from the laws of thermodynamics. Later, when he stated that "the study of messages, and in particular effective messages of control, constitutes the science of *Cybernetics*,"[33] Wiener was referring to the principles exhibited in the recursive processes of feedback.

Clearly, the fundamental concepts of cybernetic theory include the closely related phenomena of communication, information, and feedback. Simply put, "the feedback principle means that behavior is scanned for its result, and that the success or failure of this result modifies future behavior."[34] As straight forward as this may seem, the actual processes involved in feedback are considerably more complex. Consider the following observation from von Bertalanffy,

> The minimum elements of a cybernetic system are a "receptor" accepting stimuli (or information) from outside as input; from this information a message is led to a "center" which in some way reacts to the message . . . ; the center, in its turn, transmits the messages to an "effector" which eventually reacts to the stimulus with a response as output. The output, however, is monitored back, by a "feedback" loop, to the receptor which so senses the preliminary response and steers the subsequent action of the

system so that eventually the desired result is obtained. In this way, the system is self-regulating or self-directing.[35]

If we consider the tangible instances of cybernetic systems, found both in technology and biology, the configurations outlined above are usually of extraordinary complexity. Yet, cybernetic and systems theorists have discovered that they can always be analyzed into feedback circuits.[36]

According to Wiener, the operations of biological and technological systems are precisely *parallel*. "Feedback" indicates the operation of a system whereby its actions are scanned by sensory receptors as one state in its cycle of operation. The system can monitor itself and direct its behavior: that is, the system must have a special apparatus for collecting information at low energy levels, and for making this information available in the operation of the system. These messages are not selected and conveyed in an unaltered state. Rather, through transforming operations which are integral to the system, the information is translated and encoded into a new form that is available for further stages of the system's performance. Thus, the system can modify its future behavior. "In both the animal and the machine this performance is made to be effective on the outer world. In both, their *performed* action on the outer world, not merely their *intended* action, is reported back to the central regulatory apparatus."[37]

The above description of feedback again indicates the extent to which the cybernetic paradigm employed Shannon and Weaver's information and communication theory, in which the pivotal concept is codification, *i.e.*, *the transformation of perceived events into symbolic information.*[38] The degree to which the principles of communication theory are integral to the cybernetic model are evidenced above, in that: (a) the entire process hinges upon the communication of *messages*, *e.g.*, information, (b) emphasis is placed upon *information* collected at low energy levels, (c) information from outside the system is not selected and conveyed in an unaltered state, (d) if such information is to be available to the system, it must be transformed, *i.e.*, translated and encoded into a new form. At this juncture, a quotation from Bateson's work may help to illustrate the significance that Shannon and

Weavers theories hold for cybernetic theory, and also to indicate the radical shift in perspective that information and communication theory require:

> This world, of communication, is a Berkeleyan world, but the good bishop was guilty of understatement. Relevance or reality must be denied not only to the sound of the tree which falls unheard in the forest but also to this chair which I can see and on which I am sitting. My perception of the chair is *communicationally* real, and that on which I sit is, for me, only an idea, *a message* in which I put my trust.[39] [emphasis mine]

Positive Feedback, Negative Feedback and Mutual Causal Loops

As we have seen, feedback is a recursive process whereby a system's behavior is scanned and fed back through its sensory receptors. Data about the system's previous actions, as a part of the input it receives, is *monitored*, allowing the system to "watch" itself, and thus signal the degree of attainment or non-attainment of a given operation *relative to pre-established goals*. This process allows a system to alter its output and thereby regulate or steer its behavior in relation to its pre-encoded goals. Thus, two forms of feedback are recognized, negative and positive.

Negative feedback signals the absence of deviation, or the absence of any perceived mismatch, between the system's actual behavior and its targeted goal(s). In effect, the negative message of "no problem" is reported back to the systems central regulatory apparatus (servomechanism, computer, autonomic nervous system, brain, etc.,) signaling that no change in the system's output is necessary. Thus, *negative feedback* stabilizes the system, allowing it to remain steady or constant within its prevailing course of trajectory. Conversely, *positive feedback* signals a mismatch between the system's actual behavior and its intended performance.[40] Positive feedback messages initiate modifications in the system's operation, until the feedback is again negative and the system is on target. In fact, within highly complex systems, positive feedback can actually modify the goal(s), and hence the aim(s), of the overall system, itself.

Before further considering the properties of negative and positive feedback, we again underscore the fact that cybernetics has opened new horizons for the examination and explanation of living systems. Charting the traits of negative and positive feedback loops has unveiled pattern-building, or isomorphisms and invariances unlike any accepted by the *linear*, or *lineal* paradigm that continues to dominate Western culture.[41] Hence, phenomena such as circular and mutual causality, dynamic stability, and complexly interrelated systemic hierarchies are now open to more rigorous investigation.

For many people, the analogy of feedback as a "loop" or circle may tend to suggest a "vicious circle," or reversion to a pre-existing state—an incessant return to the same point, and the exclusion of novelty. However, as we will discover, feedback generates information and innovates novelty. Through the recursive operation of negative and positive feedback, elements within a system, be they cells in a body or members of a society, become informed and differentiated. Hence, they are able to grow and evolve.

An accessible example of the cybernetic model is the thermostatically controlled heating system. The entire unit, weather-house-heater-thermostat-homeowner, is here understood as *a system of communication*. The thermostat contains a thermometer (a receptor or a sort of sense organ), which responds to messages or transforms of difference (*e.g.*, *information*) between a specified ideal temperature and actual changes in room temperature. Note that it is the homeowner who specifies, sets or encodes, the thermostat's ideal temperature. Hence, as the following observation from Bateson indicates, from one perspective the system's circuitry is closed; but, the system is also open to changes in both weather patterns and the homeowner's personal preferences.

> When the phenomena of the universe are seen as linked together by cause-and-effect and energy transfer, the resulting picture is of complexly branching and interconnecting chains of causation. In certain regions of this universe (notably organisms in environments, ecosystems, thermostats, steam engines with governors, societies, computers, and the like), these chains of causation form circuits which are *closed* in the sense that causal interconnection can be traced around the circuit and back through whatever position was (arbitrarily) chosen as the starting point of the description. In such a circuit, evidently, events at any position in the circuit may be expected to have effect at *all* positions on the circuit at later times.
>
> Such systems are, however, always *open*: (*a*) in the sense that the circuit is energized from some external source and loses energy usually in the form of heat to the outside; and (*b*) in the sense that events within the circuit may be influenced from outside or may influence outside events.[42]

In our example of a cybernetic system (weather-house-heater-thermostat-homeowner), when the temperature of the house is too warm or too cold, the thermostat will respond to its own codification of the change—not to a physical energy transfer—and will signal the heater to turn off or on, thereby equilibrating to conserve the system's ideal temperature. This typifies the *interactive oscillation* between messages communicating the real to the ideal *and* the ideal to the real within the comprehensive circuitry of a cybernetic system—exemplified in steady state, homeostasis or *morphostasis*. In this system the messages of temperature change, *i.e.*, deviation from the ideal, represent *positive feedback*, and are counteracted through self-stabilizing messages of control, *e.g.*, *negative feedback*, which activate or deactivate the heating element so as to maintain a balanced approximation of the system's encoded ideal.

Feedback "mechanisms" are circular and self-referential by nature. In the closed "circuitry" of a feedback loop, "cause" and "effect" cannot be categorically isolated. They modify each other in a continuous process whereby input and output, percepts and performance, interact. This complex interaction between perception and action, evident in exploratory and learning behaviors, is the means by which a system—animal or machine—has the capacity to adapt, organize and increase its complexity. It is the key to a system's self-organization and its self-stabilization. Thus, cybernetic models mandate explanation in terms of serial and reciprocal sequences of cause and effect:

> All that is required is that we ask not about the characteristics of lineal chains of cause and effect but about the characteristics of systems in which the chains of cause and effect are circular or more complex than circular. If, for example, we consider a circular system containing elements *A*, *B*, *C*, and *D*—so related that an activity of *A* affects an activity of *B*, *B* affects *C*, *C* affects *D*, and *D* has an effect back upon *A*—we find that such a system has properties totally different from anything which can occur in lineal chains.[43]

Precisely because lineal one-way causal premises—with categorical distinctions between cause and effect—can only be applied piecemeal to two variables at a time, they have proven inadequate for explaining the properties of circular or more complex than circular systems. The interactions of cybernetic pattern-building disclose a different kind of causality, one involving interdependence and reciprocal relationships between causes and effects. The recursive processes involved in feedback serve to link causal variables in a continuous flow of information and energy. Not unlike an electrical circuit, feedback loops connect output with input, and the information they communicate sustains an interactive oscillation between the systems targeted ideal(s) and the success or failure of its behavior(s).

Consequently, the circular or more complex than circular processes of feedback exhibit properties that far exceed the general notion of interaction, or the mere presence of influences in two directions. They function in terms of *mutual causal loops*, and as such, these influences actively influence each other—both within a given system, or a subsystem, and between systems. *A* may affect *B* in a way that is unrelated to *B's* influence on *A*. Yet, only where *A's* effect on *B* is qualified by *B's* effect on *A* (or, where *A* is modified by its effect on *B*), is there a feedback loop and mutual causality in a strict sense.[44]

Regenerative Feedback,
Deviation Amplification,
and Cybernetic Stability

Although developed from work with self-corrective, purposive or "teleological" machines, the application of feedback principles was quickly recognized as a valuable tool for describing the function of living open systems.[45] In an organism, sensory signals, such as the pain which results from touching a hot object, constitute feedback. In social relations, feedback reports the result—or the perceived result—of our behavior on other persons, such as our perception of a smile or frown in return for our own.[46] Particularly in relation to the *self-stabilizing* and *self-organizing* nature of a system (*i.e.*, cybernetic stability), the mutual causal effects of feedback have been recognized as invaluable tools for appropriately explaining the interaction observed in the relationship of a system with its environment. They also offer concepts with which the extraordinary self-regulative capacities of living systems can be comprehended and investigated. Hence, cybernetics serendipitously provided a firmer theoretical foundation for general systems theory.

Nevertheless, it should be noted that some general systems theorists adopted cybernetic principles with firm reservations. For example, von Bertalanffy asserted that:

> Cybernetic systems are "closed" with respect to exchange of matter with environment, and open only to information. For this reason the cybernetic

> model does not provide for an essential characteristic of living systems whose components are continually destroyed in catabolic and replaced in anabolic processes, with corollaries such as growth, development, differentiation, *etc*.[47]

According to von Bertalanffy, the cybernetic model introduced *circular causality* by way of the feedback loop, which accounts for the self-regulation, goal directedness, *etc*., of the system. Yet, the feedback model is only one, "rather special," type of self-regulating system; and it is too "mechanistic" in the sense that it presupposes structural arrangements (receptors, effectors, control center, etc.). In contrast, he maintained that the concept of general systems is broader and non-mechanistic, in that regulative behavior is not determined by structural or "machine" conditions, but a *dynamic interaction* between *many* variables. John Milsum and others seem to have resolved these issues, but von Bertalanffy's resistance persisted.[48]

Be that as is may, Von Bertalanffy's remarks do highlight some of the key objections voiced when the cybernetic model is applied to living systems. Once again, the general confusion regarding information, matter, and energy is apparent, and although von Bertalanffy neglects the crucial point that matter may serve as information, his objections underscore the fact that a sharp distinction must be drawn between matter and energy, and information.[49] As for his claims that the cybernetic model does not provide for growth, development or differentiation, and that regulative behavior in the feedback model is too structural and mechanistic, they are simply overdrawn.[50]

Von Bertalanffy made use of the cybernetic model, and he was well aware that it is intended as an analogy. His objections cannot have been an instance of mistaking map for territory. Yet, as the founder of general systems analysis, he was inclined toward maintaining its uniqueness and superior comprehensiveness. In his favor, we should recognize that as a conscientious pioneer of scientific thought he was also concerned with avoiding overly ambitious applications of both general systems analysis and cybernetics.[51] It is interesting to note that Bateson chose to avoid this particular mode of systems/cybernetics controversy, and was among those who integrated the elements shared in common by these "related disciplines." Von Bertalanffy's objections are echoed in the criticisms leveled at employing a cybernetic model in the social/behavioral sciences. However, at this point my aim is to delineate the premises upon which cybernetics is based, and attempting to resolve these issues moves beyond our present topic.

As systems theory assimilated cybernetic principles, the *self-stabilization* of a system came to be understood as an operation of the *deviation-counteracting* processes of negative feedback.[52] Natural systems respond to change in the environment in much the same way as a thermostat. Both adjust their behavior so as to minimize deviations between their perceptions or measurements of the environment (the input) and their internal requirements encoded in a control center (brain, servomechanism, *etc*.). Thus, they maintain a steady state of morphostasis in the ongoing relationship of their systems' mutually affecting variables, the continuity of their pattern is ensured, and their systemic integrity is *actively* "stabilized."

Yet, cybernetic systems exhibit a capacity for pathology and self-destruction. In the example of a home thermostat, if the polarity of the system's codifier is reversed so it responds to positive feedback with positive feedback—increased room temperature triggers the heating element, which raises room temperature and triggers the thermostat, *etc;* the system will shift into a state of runaway, like a steam engine without a governor, and exponentially self-destruct. This attribute of positive feedback is termed *regenerative feedback*. If left uncorrected, it leads to pathology and ultimately self-destruction. Mapping and explaining the capacity for systemic pathology is a recognized contribution of cybernetics. Indeed, it seems Wiener focused on the study of *effective messages of control*, as constituting the science of cybernetics, precisely because he assumed that self-regulating systems tend toward entropy. Thus, in cybernetic explanation questions are framed in terms of what *restraints* are activated in order to maintain a system in steady state.[53]

Although degrees of pathology are a potential consequence of positive feedback, a related phenomenon, oddly enough, is the system's capacity for *self-organization*. This particular aspect of positive feedback is a result of the *deviation-amplifying* processes of regenerative feedback. Recognized in growth, learning, and evolution, it is perhaps the most significant consequence of positive feedback. If there is a persistent mismatch in the mutual causal relationship between the environment and a system's configuration (between a system's input and its code), such perturbations may trigger modifications in the code and the overall "structure" of the system, itself. Messages of deviation may be "interpreted" by a system to require increased deviation. Consequently, the deviation-amplifying process of positive feedback, through which a system may destroy itself, may also trigger *morphogenesis* —changes that reorganize and complexify the system's overall pattern of operation, transforming it to a thermodynamically less probable, but a contextually more viable order of configuration and interaction.[54]

Cybernetic research has convincingly demonstrated that through the deviation-amplifying mutual causal process of positive feedback, starting anywhere except the thermodynamically most probable equilibrium, open systems will complexify in response to *enduring* perturbations from the environment. In short, "whenever a *lasting* deviation from uniformity (thermodynamic equilibrium) develops," a system will move toward increased differentiation and complexification, and therefore, a more tenuous steady state.[55] It will adapt itself to environmental conditions by altering and complexifying its organization, and increased complexification in all natural systems represents movement away from systemic stability. That is, as a system's configuration becomes more intricately organized *and* more intimately interrelated with increased external variables, it becomes more sensitive and responsive to change, and thereby less stable. However, the emergence of increased differentiation and complexification also manifests a corresponding increase in the system's array of available responses, or what Ervin Laszlo terms *cybernetic stability*—the system's capacity for effective adaptation.[56]

Note how the cybernetic paradigm shifts the focus of our discourse away from: discreet material substances, oneway causality, structure, and summativity. Rather, a cybernetic explanation focuses on: process and behavior, dynamic or animated organization, circular or more complex than circular causality, the mutual causal loops of feedback cycles, interaction between multiple variables, and emergent morphogenesis. Hence, the cybernetic stability of a system must be understood not as an inactive structure, but as a pattern of events—an animated organization of exchanges and transformations within the system's parameters. Hence, it is not the characteristics of the "parts" alone that are basic to any whole. Rather, it is the manner in which the system's differentiated components are interrelated that gives them their distinctive properties. Furthermore, within more complex systems the "differentiated parts" exhibit properties which they owe specifically to being components of a larger whole.

Through its receptors, a cybernetic system acquires and processes information and energy according to its needs or code. Information, energy and matter may spread through the system following a fixed pathway, but they do not trigger responses and produce systemic behavior (output) directly. Rather, they are subject to the dynamics of the system's configuration, and in the circular or more complex than circular operations of a cybernetic circuit or network, events at any position in the circuit may be expected to have effect at *all* positions on the circuit at later times. Incoming messages are received as encoded transforms of perceived events, and such information is translated or "interpreted" (sifted, sorted, evaluated and recombined) before it is conveyed to effectors and translated into action. Thus, the cybernetic system does not passively undergo the effects of external causes, but actively transforms them. It is not simply input that determines a system's behavior, but what happens to the input within the system, how the input is interpreted and used in terms of the system's organization. As Laszlo insists, "this is directly contrary to linear-causality input-output systems."[57]

Indeed, the cybernetic model does contradict the linear concept of causality, undermining the axiom that, "similar conditions produce similar results and that different conditions will produce different results." Maruyama observes that this "sacred law of causality in classical philosophy" has guided much research, leading scientists to seek explanations for differences between phenomena in their initial conditions, rather than in ongoing mutual causal interactions.[58] However, deviation-counteracting and deviation-amplifying mutual causal interactions influence and shape events in accordance with a system's codes and goals. Accordingly, they can produce different results from the same initial inputs or similar results from differing inputs.

Focusing on the deviation-counteracting aspects of a system's mutual causal process discloses negative feedback, through which a system maintains morphostasis, or steady state.

Still, although a system's overall configuration (including its code) must remain "stable," it is not static. In the fluctuating context of a changing environment, a system's code must determine how it uses or "interprets" its input, and through the deviation-amplifying messages of positive feedback, morphogenesis may emerge. Triggered by perturbations of a persistent mismatch in the mutual causal relationship between a changing environment and a system's overall configuration, a system may transform itself. Thus, a system has the capacity to maintain cybernetic stability precisely by altering its code and reorganizing its overall operation into a more complex order of configuration and performance.

Here, I should also underscore the fact that in cybernetic explanation the ongoing relationship between a system and its environment is discerned as essentially nonsubstantial, communicational, and stochastic.[59] Cybernetic systems aim at sustaining a viable steady state of interaction within changing contexts through the stochastic process of trial and error. Bear in mind that such a system must respond to the effects of its own output, as well as other alterations in its environment. This process includes exchanges of energy, and generally, exchanges of matter as well. Still, it is exchanges of information, messages of effective control, which restrain and govern systems. Thus, the processes that together comprise the pattern of events discernable in whole systems, and within the continuing relationship between a system and its environment, exhibit regularities that are not primarily subject to the physical laws of energy transfer and the second law of thermodynamics. Rather, they proceed according to regularities discovered in the transformation of perceived events into symbolic information. This is the realm of existence, the universe of discourse, that Bateson referred to as "the Berkeleyan world of communication."

Negative feedback messages communicate information which allow a system to delimit or restrain its array of available responses, and thus maintain the system's steady state. Positive feedback messages communicate information which may trigger emergent (*e.g.*, delimited by previously successful patterns) morphogenesis. A living system does not initially contain coded within it all the information required for it to evolve into what it has or will become. However, morphogenesis can "employ" the deviation-amplifying processes of positive feedback to produce variations of previously encoded information. As a consequence, the process of morphogenesis can generate messages that determine the innovative "direction" in which a system's overall pattern of operation will change. Through such stochastic exchanges of signals or messages, restraints and transformations, a cybernetic system maintains and evolves its pattern of organization in mutual interaction with its environment.

Systemic Invariance and Isomorphisms: Whole Systems and the Hierarchy of the Observable Cosmos

As we have seen, Norbert Wiener proposed *Cybernetics* as a general study of control and communication theory in both the machine and the animal. As such, cybernetics became a master concept which assimilated a number of analytic methods, including computerization and simulation, set theory, graph theory, net theory, automata theory, decision theory, queuing theory, game theory, and general systems theory, as well. Indeed, with the introduction of the cybernetic paradigm, systems theory was more readily accepted and applied to numerous fields of research. Hence, as is apparent in the wealth of available literature, cybernetic processes became discernible to many theorists, not only in biological systems, but also in the sub-organic and supra-organic world—from microphysics to organic life, through social groups, to the biosphere of our planet, and beyond.

In short, the introduction of cybernetic principles led to the identification of *systemic invariance* or *isomorphisms* throughout the observable cosmos. Still, whether or not employment of the cybernetic paradigm has been appropriate in each instance remains an area of dispute. Nevertheless, once perceived, the recognition of such isomorphisms has fostered a valuable epistemic shift: from consideration of "entities," to the discernment of whole systems. The recognition of systemic isomorphisms also initiated further disclosure of the logic evident in the behavior and interaction of systems, enabling theorists to frame the formal characteristics inherent in whole (cybernetic) systems.

The properties of such a system are identified as four-fold, three of which have been discussed in detail:

1. The system is a *holistic*/*non-summative* whole that cannot be reduced to its parts without altering its pattern. Artificially composed aggregates, wherein the constituent elements can be added or subtracted without altering the overall system are not included.

2. The system is *self-regulating*, *e.g.*, homeostatic, stabilizing itself through negative feedback. If input matches a system's coded requirements, the system maintains its output in order to maintain its match.

3. The system is *self-organizing*. If mismatch between input and internal code persists, the system searches for, and encodes a new pattern with which to operate. Thus, in the passage of time, differentiation and complexification of the overall system may emerge through positive feedback.

4. Moreover, the system is understood as a differentiated sub-whole within a *systemic hierarchy*. The "environment" in which a system exists is also a whole system, a meta-system. Whether ecosystem, animal, organ or cell, systems consist of subsystems that operate within a hierarchy of progressively inclusive meta-systems. As a subsystem, the system's characteristics and operations are co-determinative components of the larger system within which it is an integral component. Thus, a system may be understood as Janus-faced. As a whole, it faces inward, *i.e.*, the system is concerned with maintaining its internal steady state; as a sub-whole, the system faces outward, responding to its environment (a meta-system) in a potentially infinite regression of relevant contexts.

Spurred by the enthusiasm with which cybernetics was received, systems research has been applied to many fields of scientific enquiry. Such research supports the evolutionary view that over time, through self-organization and mutual adaptation, systems tend to form structural hierarchies, *i.e.*, they fashion progressively larger, more inclusive systems out of preexisting sub-systems or microhierarchies. Notably, such research has also revealed that this phenomenon is delimited by *hierarchical restraints* of a morphic nature.[60] In the patterns they exhibit, these new systems generate unique qualities, including more complex organization and inherently novel forms of operation.

The view which subsequently emerged, discerns a complementary relationship between the morphic nature of systemic integration and systemic differentiation within a hierarchical universe. Systemic differentiation and integration are *conventionally* understood as delimited by the channeling of energy, matter *and* information to maintain and generate form. Also, through the cybernetic interaction of their patterns of operation, systems tend to complexify and form hierarchies. Hence, in the realm of astronomy, hierarchical restraints are understood as gravitational; in the hierarchy from microphysics to organic life, these cybernetic restraints are understood as electrochemical forces; and in social and cognitive hierarchies, such constraints are understood as operating in the communication of symbols.[61]

Bateson rejected the use of *energy* and *matter* in this context—except in those instances where they act as *information* and thus have *communicational* value. As is well known, Bateson's work aimed at clearly drawing the distinction between energy and matter, on the one hand, and *information*, on the other, by pointing out that information represents a difference, and unlike energy or matter, difference is a non-substantial phenomenon that cannot be located in space or time. Hence, he maintained that cybernetic models and metaphors are most appropriately applied to the mental realm of cognitive systems, *i.e.*, mind systems—both artificial and natural. Given the unique status of information and communication, as *nonsubstantial* phenomena which nevertheless govern and control cybernetic systems, he maintained that cybernetic systems best exemplify *mental* process.

In this context the use of *energy* and *matter* as explanatory principles is clearly inappropriate—except in those instances where they function as *information* and thus have *communicational* value. Recall that in cybernetics, zero has a "causal" value because zero represents a difference, it is different from one, and zero (quite literally, no thing) may thus be used to explain a response in this realm of mental process. As a consequence, the holistic systems under discussion cannot be effectively measured or studied in quantitative terms. Quantifiable concepts such as power, gravity, and energy, *etc.* are applicable only in what Bateson referred to as the *Pleromic* realms of explanation, *i.e.*, the physical sciences.[62] Atoms, molecules and stones do not respond to *information*. They do not scan their behavior for its result, nor do they modify future behavior on the success or failure of such information. Thus, in contrast to Laszlo and others, Bateson rejects the application of cybernetic principles in describing and explaining atomic, subatomic and electrochemical realms of physical existence.

In Bateson's *cybernetic epistemology*, mental process emerges out of certain types of organization of matter, and the mental properties of the system are understood as *immanent*, not in any one part, but within *the system as a whole*. Mental process (*e.g.*, mind) is understood as immanent in the circuits of the brain which are *complete within* the brain; mental processes are similarly immanent *in the circuits* which are complete *within the system*, brain-plus-body; and mind is immanent in *the larger system*—person-*plus*-environment.[63] The resulting image requires that we eliminate the commonly held notion that mind is to be identified as residing only within the boundary of our physical body, and is somehow radically separate from others.

> . . . there is no requirement of a clear boundary, like a surrounding envelope of skin or membrane, and you can recognize that this definition [of mind] includes only some of the characteristics of what we call "life." As a result it applies to a much wider range of those complex phenomena called "systems," including systems consisting of multiple organisms or systems in which some of the parts are living and some are not, or even to systems in which there are no living parts.[64]

To be sure, mental process requires collateral energy. However, the interactions of mental process are *triggered* by difference, and "difference is *not* energy and usually contains no energy."[65] Mental process requires some amount of energy (apparently very little), but as a stimulus the nonsubstantial phenomenon of *difference* does not provide energy. The respondent mind system has collateral energy, usually provided by metabolism. If we kick a stone, it receives energy and it moves with that energy. However, if we kick a cat or a dog, our kick may transfer enough energy to move the animal. We may even imagine placing the animal into a Newtonian orbit. However, a living organism responds with energy from its metabolism. In the control of animation by information, energy is already present in the respondent, the energy is available in advance of the "impact" of events.

Moreover, the phenomena of coding, an integral element of feedback in cybernetic systems, is centrally incorporated into Bateson's epistemic model; and here we should note that his *cybernetic epistemology* assigns unequivocal limitations as to what mind systems are capable of knowing, largely due to this phenomena. That is, the process in which information is translated and encoded into a new form—for only then is information available for further stages of a system's performance—limits the perception of mental systems to *images* that are reminiscent of the shadows in Plato's allegory of the cave.

The perspective which is thus added to Bateson's work emerges out of the information theory and communication theory developed by Shannon and Weaver, and it effectively places his epistemic model in what Bateson refers to as "the world of communication." This world of communication is to be understood as a realm of explanation wherein the only relevant entities or "realities" are messages. And for Bateson, this is the realm of mind, in which relationships and metarelationships, context, and the context of context—all of which are complex aggregates of information or *differences which make a difference*—may be identified in a potentially infinite regress of relevant contexts. Consider Bateson's comparison of the Newtonian world and the world of communication:

> The difference between the Newtonian world and the world of communication is simply this: that the Newtonian world ascribes reality to objects and achieves its simplicity by excluding the context of the context—indeed excluding all metarelationships—a fortiori excluding an infinite regress of such relations. In contrast, the theorist of communication insists upon examining the metarelationships while achieving its simplicity by excluding all objects.[66]

As previously noted, Bateson goes on to suggest that the world of communication is a Berkeleyan world, but the good bishop was guilty of understatement, "relevance or reality must be denied not only to the sound of the tree which falls unheard in the forest but also to the chair that I can see and on which I may sit." Our perception of a chair is *communicationally* real, but in the realm of mental process—the world of communication—the chair on which we sit is only an idea, a *message* in which we put our trust. There are in fact no chairs or tables, no birds or cats, no students or professors *in* the working circuitry of the mind, except in the form of "ideas." *Dinge an Sich* or things-in-themselves are inaccessible to direct inquiry. Only ideas (difference, news of difference, images or maps) and information (*differences which make a difference*) about "things" are accessible to mind:

> Ideas (in some very wide sense of that word) have a cogency and reality. They are what we can know, and we can know nothing else. The regularities or *laws* that bind ideas together—these are the (eternal) *verities*. These are as close as we can get to ultimate truth.[67]

Be that as it may, in each of the above examples (astronomy, microphysics, organic life, and social and cognitive hierarchies), the hierarchical constraints are of a morphic nature, *e.g.*, they deal with pattern, not substance. Each step between the hierarchies may be recognized as an advance the development of form toward increasingly complex organization. Furthermore, as cybernetic/systems proponents point out, in asserting the irreducibility of levels, the hierarchical view of cybernetic theory conflicts with traditional monism, as well as with dualism and pluralism.[68] Since hierarchical constraints produce both novelty and organization, causal or generative relations necessarily exist *between* the levels.

Hence, the cybernetic view of observed reality is hierarchical: the universe is understood as a hierarchy of systems, wherein each higher level of system is composed of systems of lower levels. Yet, as Joanna Macy notes, this is not the hierarchy of rank and authority associated with organized religions or an army, nor is it the hierarchy of being and value found in the thought of Plato and Plotinus.[69] It is more like a set of self-organizing Chinese boxes, each one neatly fashioned to fit inside the other, *ad infinitum*. The hierarchy of observed reality is thus maintained through structured interaction, with self-organization and mutual adaptation acting as hierarchical restraints; regulating an "osmotic" flow of energy, matter, and information exchanged between its differentiated levels. Or, to use the metaphor offered by Macy, it is more like an inverted tree, as the ancient verses of the *Katha Upanisad* imaged, where systems branch downward into subsystems, seemingly *ad infinitum*:

> In this tree, however, the movement of growth and organization is in the reverse direction. Like the shape of the inverted tree, or like pyramids, these natural systemic hierarchies narrow as they go up, in the sense that the higher levels, since they enclose the lower, are fewer in number. Yet they represent a vastly greater variety. While there are, for example, more atoms in the world than forms of plant and animal life, atoms come in only 82 kinds, whereas types of organic species number some million.[70]

In this view, each level of the hierarchy cybernetically builds on more basic levels of organization: integrating pre-existing subsystems and micro-hierarchies into novel patterns; and fashioning new, more inclusive systems. As observed in embryology (*e.g.*, *epigenesis*), evolution and child development, growth and learning occur incrementally or step-wise. Whole systems never begin from scratch. Their growth is inevitably based upon the organization of pre-organized components. They are both delimited and enabled by hierarchal constraints that permit stability, economy, and speed in the unfolding of new forms of life *and* more inclusive hierarchical levels.[71]

Since their introduction, investigation of the holistic/non-summative, self-stabilizing, self-organizing and hierarchical traits formally identified in cybernetic systems has spread into the social/behavioral sciences. Thus, the *informational* nature of cybernetic processes: including the concepts of feedback, mutual causality, and self-regulating systems—*i.e.*, that cybernetic systems adapt to *and* alter their environments through *sequences* of self-stabilization around steady states—have been adopted and fruitfully employed in these universes of discourse. In closing, we may note that this shift in methodology and theory is more than a mere attempt to take the common sense notion of communication as having something basic to do with the social/behavioral sciences and give it a firm scientific status.

Following Bateson, *et al.*, we may safely assert that cybernetics discloses a new paradigm of science, a paradigm that Bateson used with rigor and imagination, and which, as he often asserted, initiates four theoretical advancements that redefine the social/behavioral sciences:[72]

1. Rather than focusing on the substance and content of isolated phenomena, as in the reductionist, mechanistic, one-way causal paradigm of classical science, cybernetics focuses on form, pattern and redundancy in whole systems.

2. The cybernetic paradigm clarifies the operational significance of information and communication—*i.e.*, mental process—in biological, social and behavioral phenomena.

3. With its focus on communication and information, the cybernetic paradigm illuminates the negentropic realm of living systems. This is realm of *mind* in the widest sense of the word, and this realm must be approached through its own set of preconceptions and

premises. When we wish to describe and explain the negentropic processes evident in living systems, physical analogies are inadequate, and the analogies of method taken from the "hard sciences" are inappropriate.

4. The cybernetic paradigm provides a rigorous model of mental process with a unified vocabulary and a unified methodology which serve as an effective counterbalance to the charge of subjectivism aimed at the methodologies used in the social/behavioral sciences, as well as the currently fashionable assortment of "vicious criticisms" aimed at all forms of linguistic discourse.[73]

These four points suggest the problem solving values claimed for cybernetics by its proponents in the social/behavioral sciences. Although not without reservations concerning uncritical applications of the cybernetic paradigm, I believe the characteristics formally identified in cybernetic systems offer profoundly significant advances for studies in the human sciences, including my own field of specialization, religious studies and interreligious dialogue. Consequently, in continuing the line of inquiry presented in this essay, I have written an essay that further details the problem-solving values claimed for cybernetics by its advocates in the social/behavioral sciences. Inasmuch as the utilization of cybernetics principles in these realms of discourse has not gone without its critics, this companion piece focuses on the major criticisms leveled at employing cybernetics in the social/behavioral sciences, while exploring the manner in which insights from the work of Gregory Bateson confront and resolve these often valid criticisms.

Notes

[1]Gregory Bateson, "From Versailles to Cybernetics," in *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* (San Francisco: Chandler Publishing Company, 1972), pp. 482-83. (hereafter — *STEPS*)

[2]Warren S. McCulloch, *Embodiments of Mind* (Cambridge, Massachusetts: M.I.T. Press, 1965). McCulloch was a key member of the group that did the original work in cybernetics. He is referred to by Bateson more often than any other modern scientist.

[3]In this context, Bateson was notably influenced by a paper that McCulloch coauthored. See, J. Y. Lettvin, W. S. McCulloch, H. R. Maturana, and W. H. Pitts, "What the Frog's Eye Tells the Frog's Brain," *Proceedings of the Institute of Radio Engineers* 47 (1959): 1940-52; reprinted in Warren S. McCulloch, *Embodiments of Mind*, Chapter 14, pp. 230-255.

[4]Gregory Bateson, "This Normative Natural History Called Epistemology," reprint of Bateson's, "Afterword," in *About Bateson*, edited, with a new title taken from the body of the text; reprinted in *Sacred Unity: Further Steps to an Ecology of Mind*, Part III: Epistemology and Ecology, pp. 215-224, edited by Rodney E. Donaldson; see, p. 216.

[5]Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press, 1949; 6th ed., Urbana: University of Illinois Press, 1964), p. 1, n 1. (hereafter — *Shannon & Weaver*)

[6]Ludwig von Bertalanffy, *General Systems Theory* (New York: George Braziller, 1968), p. xxi.

[7]Ervin Laszlo, *Systems View of the World* (New York: George Braziller, 1972), pp. 5, 6.

[8]Joanna Rogers Macy, "Interdependence:" (Ph.D. dissertation, Syracuse University, 1978), p. 58.

[9]Lester R. Brown, *et al.*, *State of the World 1989: A Worldwatch Institute Report on Progress Toward a Sustainable Society* (New York: W.W. Norton & Co., 1989).

[10]*Shannon & Weaver*, pp. 12-28; also, Spyros Makridakis, "The Second Law of Systems," *International Journal of General Systems*, 4 (September 1977): 2-4. (hereafter — IJGS)

[11]Ervin Laszlo, *Systems View of the World*, p. 4.

[12]Von Bertalanffy, *General Systems Theory*, p. 12.

[13]Gordon Allport, "The Open System in Personality Theory," in *Modern Systems Research for the Behavioral Scientist*, pp. 343-350, edited by Walter F. Buckley (Chicago: Aldine Publishing Co., 1968), p. 344.

[14]Von Bertalanffy, *General Systems Theory*, p. 40.

[15]Ludwig von Bertalanffy, *Organismic Psychology and Systems Theory* (Barre, Massachusetts: Clark University Press, 1968), pp. 44-47.

[16]Von Bertalanffy, *Organismic Psychology and Systems Theory*, pp. 46-48.

[17]Kenneth Sayre has remarked that, "the universe cannot coherently be conceived as a closed system, since there is no coherent concept of what it could be closed to." Kenneth Sayre, *Cybernetics and the Philosophy of Mind* (Atlantic Highlands, New Jersey: Humanities Press, 1976), p. 46.

[18]David Lipset, *Gregory Bateson: The Legacy of a Scientist* (Boston: Beacon Press, 1982), pp. 142-159.

[19]"Introduction" in *STEPS*, p. xvi.

[20]William Bateson, "Gamete and Zygote," in *William Bateson, F.R.S.: Naturalist, His Essays and Addresses Together with a Short Account of His Life*, Caroline Beatrice Bateson (Cambridge: Cambridge University Press, 1928), p. 209.

[21]Steve P. Heims, "Gregory Bateson and the Mathematicians: from interdisciplinary interaction to societal functions," *Journal of the History of the Behavioral Sciences* 13 (April 1977): 141. (hereafter - JHBS)

[22]Gregory Bateson, *Naven* (Stanford: Stanford University Press, 1965, reprint of 2nd. ed., with "Preface to the Second Edition," and "Epilogue 1958,"), pp. 1-5. (hereafter — *Naven*)

[23]Steve P. Heims, "Gregory Bateson and the Mathematicians," JHBS 13 (April 1977): 142-44; also see, Steve P. Heims, "Encounter of Behavioral Sciences with New Machine-Organism Analogies in the 1940s," JHBS 11 (October 1975): 368-373.

[24]*E.g.*, see, Gregory Bateson, *Mind & Nature: A Necessary Unity* (New York: E. P. Dutton, 1979), p. 207. (hereafter — *Mind & Nature*)

[25]Steve P. Heims, "Gregory Bateson and the Mathematicians," JHBS 13 (April 1977): 146.

[26]Catherine Wilder-Mott and John H. Weakland, editors, *Rigor & Imagination: Essays from the Legacy of Gregory Bateson* (New York: Praeger Publishers, 1981).

[27]*Mind & Nature*, p. 106.

[28]Norbert Wiener, *Cybernetics—or Control and Communication in the Animal and the Machine* (New York: John Wiley & Sons, Inc., 1948), p. 11. This work's introduction details the major contributors and developments which led to the formation of cybernetics as a single field of research.

[29]"Historically, the word [cybernetics] had three diverse sets of reference: to automated

control mechanisms, to men controlling vehicles such as ships, and to political control in Society. Writing in 1948, as if he was widening the implication of the word, Wiener attributed his use of the term solely to the Greek, κυ_ερνήτης for 'steersman.' Yet in Plato, this word was already used to refer both to nautical and to social control." David Lipset, *Gregory Bateson: Legacy of a Scientist*, p. 180.

[30]*Ibid.,* pp. 179-181; *Cf.*, Steve P. Heims, "Gregory Bateson and the Mathematicians," JHBS 13 (April 1977): 141-42; The conferences continued through 1953, and except for the second conference, entitled "Teleological Mechanisms and Circular Causal Systems," they all retained the original name. The first conference dealt with a variety of concepts that originated in mathematics and engineering, with John von Neumann and Norbert Wiener leading discussions on: servomechanisms, analogical and digital coding, negative and positive feedback, the measurement of information and its relation to the idea of entropy, binary systems, von Neumann's theory of games, Bertrand Russell's theory of logical types, "pathological" oscillations (yes-no-yes-no-yes, *etc*.) in a computer confronted by Russellian paradox, and the concept that communication systems depend upon *information* and not *energy*. Bateson unequivocally stated that membership in these conferences was "one of the great events of my life." See, John Brockman, *et al.*, *About Bateson*, edited by John Brockman (New York: E. P. Dutton, 1977), pp. 9-10. (hereafter — *About Bateson*)

[31]Steve P. Heims, "Gregory Bateson and the Mathematicians," JHBS 13 (April 1977): 142-143; also see, Arturo Rosenblueth, Norbert Wiener and Julian Bigelow, "Behavior, Purpose and Teleology," *Philosophy of Science* 10 (January 1943): 18-24.

[32]Norbert Wiener, *Cybernetics*, p. 50.

[33]Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (Cambridge, Massachusetts: Riverside Press, 1950), pp. 8-9.

[34]*Ibid*., p. 69.

[35]Von Bertalanffy, *Organismic Psychology and Systems Theory*, pp. 40-41.

[36]William Ross Ashby, *Design For A Brain* (New York: John Wiley & Sons Inc., 1952), pp. 36-52.

[37]Norbert Wiener, *The Human Use of Human Beings*, p. 15.

[38]*Shannon & Weaver*, pp. 1-12; regarding the close relationship between Shannon's work and Norbert Wiener, see p. 1, n 1.

[39]Gregory Bateson, "Minimal Requirements for a Theory of Schizophrenia," *A.M.A. Archives of General Psychiatry* 2 (May 1960): 477-491; reprinted in *STEPS*, Part III: Form and Pathology in Relationship, pp. 244-270; see, p. 250.

[40]Note how a rigorous use of these terms conflicts with common parlance, where *negative feedback* signifies criticism and *positive feedback* denotes encouragement.

[41]"Linear and lineal. Linear is a technical term in mathematics describing a relationship between variables such that when they are plotted against each other on orthogonal Cartesian coordinates, the result will be a straight line. Lineal describes a relation among a series of causes or arguments such that the sequence does not come back to the starting point. The opposite of linear is nonlinear. The opposite of lineal is recursive." See, "Glossary," in *Mind & Nature*, p. 228.

[42]Gregory Bateson, "Cybernetic Explanation," *American Behavioral Scientist* 10 (April 1967): 29-32; reprinted in *STEPS*, Part V: Epistemology and Ecology, pp. 405-416; see, pp. 409-10.

[43]"Epilogue 1958," in *Naven*, p. 288.

[44]Magoroh Maruyama, "Mutual Causality in General Systems," in *Positive Feedback*, edited by John H. Milsum (London: Pergamon Press, 1968), pp. 80-81.

[45]Evident in the title of the Macy conferences on Cybernetics, *e.g.*, ". . . *in Biological and Social Systems*."

[46]Ernest Kramer, "Man's Behavior Patterns," in *Positive Feedback*, pp. 139-148, edited by John H. Milsum (London: Pergamon Press, 1968), p. 140.

[47]Von Bertalanffy, *Organismic Psychology and Systems Theory*, pp. 42-43.

[48]John H. Milsum, ed., Preface to *Positive Feedback*, p. viii. Milsum's preface to this volume notes that: (a) "semantic and conceptual problems have arisen between control specialists and life scientists over use of the term *feedback* for living systems," (b) that "Magoroh Maruyama advocates the term *mutual causality* as more appropriate than *purposeful* for positive and negative feedback processes in living systems," and (c) "the synthesis attempted in this volume should help clear up confusion on this matter." Also consider Ernest Kramer's remarks in the same work, p. 140, "It is only recently that the feedback principle has been isolated in mechanics and extensively made use of: in organisms the corresponding principle has long been recognized; it is only the term which is new. And being new, its exact usage is not stabilized."

[49]Clarification of the concept "information" is one of Bateson's major contributions to this field of enquiry. Drawing an unobstructed distinction between matter, energy, and information is a key element of Bateson's epistemology, and thus, his vision of a sacred unity of the biosphere.

[50]William Ross Ashby, *An Introduction to Cybernetics* (New York: Chapman & Hall, 1956; Science Editions, New York: John Wiley & Sons, Inc., 1963), pp. v-vii, indicates that early cybernetic theory provided for adaptive behavior, differentiation and growth; also, A. Rosenblueth; N. Wiener; and J. Bigelow, "Behavior, Purpose and Teleology." *Philosophy of Science* 10 (January 1943): 22-23, clearly acknowledge the distinctions between animal and machine.

[51]Ludwig von Bertalanffy, "General Systems Theory—A Critical Review," in *Modern Systems Research for the Behavioral Scientist*, pp. 11-30, edited by Walter F. Buckley, (Chicago: Aldine Publishing Co., 1968), p. 22.

[52]*Ibid.*, p. 17. Consider the example of homeothermy, the maintenance of body temperature in the homeostasis of warm-blooded animals. Contrary to the rules of physical chemistry, where a decrease in temperature leads to a slower rate of chemical reaction, body cooling stimulates thermogenic centers in the brain which "turn on" the heat-producing mechanisms of the body. Cold is offset by an increased metabolic rate. Similarly, in the thermostat, *a relationship between* a minimum of three variables—the temperature readings, the control center, and the furnace switch—maintains a systemic balance; the lower the heat in the house, the more the fuel is used. In both cases, *mutually affecting variables* work to counteract or balance each other.

[53]Gregory Bateson, "Cybernetic Explanation," *American Behavioral Scientist* 10 (April 1967): 29-32; reprinted in *STEPS*, Part V: Epistemology and Ecology, pp. 405-416; see, pp. 410-411. Bateson observes that, "For purposes of cybernetic explanation, when a machine is observed to be (improbably) moving at a constant rate, even under varying load, we shall look for restraints—*e.g.*, for a circuit which will be activated by changes in rate and which, when activated, will operate upon some variable (*e.g.*, the fuel supply) in such a way as to diminish the change in rate."

[54]Magoroh Maruyama, "The Second Cybernetics: deviation-amplifying mutual causal process," *American Scientist* 51 (June 1963): 164-79; also see, Magoroh Maruyama, "Morphogenesis and morphostasis," *Methodos* 12-48 (1960): 251-96.

[55]Spyros Makridakis, "The Second Law of Systems," IJGS 4 (September 1977): 3, "Organization starts whenever a *lasting* deviation from uniformity (thermodynamic equilibrium) develops." Makridakis generalizes this principle as the "Second Law of Systems," which he submits as an antithetical complement to the Second Law of Thermodynamics, the employment of which is restricted to closed systems. His "First Law of Systems" is that the relation between organization and energy is non-linear; more complex systems do not require more energy to self-organize and often much less.

[56]Ervin Laszlo, *Introduction to Systems Philosophy* (New York: Harper Torchbook, 1973), p. 269.

[57]*Ibid*., p. 25.

[58]Magoroh Maruyama, "The Second Cybernetics: deviation-amplifying mutual causal process," *American Scientist* 51 (June 1963): 167.

[59]"*Stochastic*. (Greek *stochazein*, to shoot with a bow at a target; that is to scatter events in a partially random manner, some of which achieve a preferred outcome) If a sequence of events combines a random component with a selective process so that only certain outcomes of the random are allowed to endure, that sequence is said to be *stochastic*." See, "Glossary," in *Mind and Nature*, p. 230.

[60]Lancelot L. Whyte, "The Structural Hierarchy in Organisms," in *Unity in Diversity: A Festschrift for Ludwig von Bertalanffy*, pp. 271-285; Vol. 1 of 2 vols, edited by William Gray and Nicholas D. Rizzo (New York: Gordon and Breach, 1973), p. 275.

[61]Ervin Laszlo, *Introduction to Systems Philosophy*, pp. 57-117; also, pp. 177-180.

[62]See, *Mind and Nature*, pp. 91-94.

[63]*Ibid.*, p. 317.

[64]Gregory Bateson and Mary Catherine Bateson, *Angels Fear: Towards an Epistemology of the Sacred* (New York: Macmillan Publishing Co., 1987); posthumously reconstructed and edited by Bateson's daughter, Mary Catherine Bateson, see p. 19. (hereafter — *Angels Fear*)

[65]*Mind & Nature*, p. 100. Qualifying the word *triggered*, Bateson notes that, "Firearms are a somewhat inappropriate metaphor because in most simple [*nonrepeating*] firearms there is only a lineal sequence of energetic dependencies. . . In biological systems, the end of the lineal sequence sets up conditions for a future repetition," p. 101*n*.

[66]"Minimal Requirements for a Theory of Schizophrenia," in *STEPS*, p. 250.

[67]*Mind & Nature*, p. 191.

[68]*Ibid.*, p. 175.

[69]Joanna Rogers Macy, "Interdependence:" (Ph.D. dissertation, Syracuse University, 1978), p. 69.

[70]*Katha Upanisad* II, iii.1., quoted in Joanna Rogers Macy, "Interdependence:" (Ph.D. dissertation, Syracuse University, 1978), p. 69-70. In n 2, Macy observes that, "these systemic pyramids or tree-forms narrow as they ascend only by virtue of the fact that lower or previous levels channel into them—in that sense they are like a company's table of organization. On the other hand, if we take as our measure the variety they display, they widen. This calls to mind the two reversed and intersecting gyres which W. B. Yeats beheld in his vision (1937)."

[71]Herbert A. Simon, "The Organization of Complex Systems," in *Hierarchy Theory*, edited by Howard Pattee (New York: George Braziller, 1973), p. 7.

[72]Gregory Bateson, "Epilogue: The Growth of Paradigms for Psychiatry," in *Communication and Social Interaction: Clinical and Therapeutic Aspects of Human Behavior*, pp. 331-337, edited by Peter F. Ostwald (New York: Grune & Stratton, 1977), pp. 336-37.

[73]Richard J. Bernstein, *Beyond Objectivism and Relativism: Science, Hermeneutics, and Praxis* (Philadelphia: University of Pennsylvania Press, 1983), p. 16.

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