TRANSDISCIPLINARY PRINCIPLES AND PROCESSES INHERENT IN THE EVOLUTION OF COMPLEX SYSTEMS

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Transdisciplinary Principles

This paper was initially inspired by Robert W. Winquist's article "What Are Transdisciplinary Principles?" which appeared in the 1982 *Issues in Integrative Studies*. "Transdisciplinarity," Dr. Winquist says, "is built on the premise that there are discernible principles and purposes which underlie the entire knowledge/knower system." He goes on to amplify this definition by citing Kirtley Mather's "rationale for a transdisciplinary approach to the integration of the liberal arts curriculum." In Mather's words,

> … important is the search for basic concepts and underlying principles that may be valid throughout the entire body of knowledge, that serve as the common roots from which the various branches draw their vitality .... integrative studies for general education must involve the quest for basic concepts and underlying principles. Such studies must go down to the very roots of the tree of knowledge; they must deal with the structures of the universe and its fundamental directives.[1]

Mather's mandate, of course, has been echoed by a vast number of scientists and teachers during the last twenty years. Ludwig Bertalanffy, for example, envisioned General System Theory as a paradigm that might successfully develop "unifying principles running 'vertically' through the universe of the individual sciences." "This," Bertalanffy asserted, "can lead to a much-needed integration in scientific education."[2]

Eric Janisch, a system theorist associated for many years with the Center for Research in Management at UC Berkeley, was also deeply committed to a lifelong exploration of the meaning and relevance of "general laws of the dynamics of nature." As Dr. Jantsch wrote most movingly in his introduction to *The Self-Organizing Universe*:

> [The] new type of science which orients itself primarily at models of life, and not mechanical models,... is thematically and epistemologically related to those events which [are] aspects of the metafluctuation which rocked the world. The

basic themes are always the same. They may be summarized by notions such as self-determination, self-organization and self-renewal; by the recognition of a systemic interconnectedness over space and time of all natural dynamics; by the logical supremacy of processes over spatial structures; by the role of fluctuations which render the law of large numbers invalid and give a chance to the individual and its creative imagination; by the openness and creativity of an evolution which is neither in its emerging and decaying structures, nor in the end result, predetermined. Science is about to recognize these principles as general laws of the dynamics of nature. Applied to humans and their systems of life, they appear therefore as principles of a profoundly natural way of life. The dualistic split into nature and culture may now be overcome.[3]

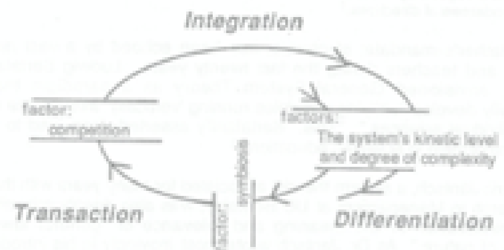
In the paper that follows, I attempt to describe the "systemic interconnectedness" of the "natural dynamics" that run vertically through the continuous evolution of biological and social systems.

The Process of Complexification

The evolution of both biological and social systems can be conceptualized as a perpetual sequence of three somewhat distinct processes: differentiation, transaction, and integration. These three processes reoccur as phases in an ever-widening gyre of system complexification so that, as Jantsch notes,"... evolution becomes a circular process in a four-dimensional space-time continuum."[4]

The process of complexification may be diagrammed as follows:

Figure 1
The Process of Complexification



Let's briefly follow the cycle around through its three phases, starting at three o'clock on the diagram. The rate and degree of differentiation in a living system are determined by the system's kinetic level (active energy level) and degree of complexity. These factors are best explained in terms of the physical chemist Ilya Prigogine's theory of dissipative structures, which runs somewhat as follows:

The "big bang" that gave birth to the universe as we now know it occurred approximately fifteen billion years ago.[5] Prior to this explosion the entire universe was compressed into an incredibly hot, dense mass no larger than a pinhead. Since the explosion, the universe has been expanding and cooling. If, as is likely, the universe is a finite, closed system, and if the total gravitational force within it is sufficient, at some point in the future the expansion may cease.

The Second Law of Thermodynamics stipulates that in any closed system–any system unable to import fresh usable energy from outside itself–a process of anti-differentiation gradually occurs: The system eventually becomes completely homogeneous and inactive throughout.

In cosmological terms this means that at some point in the far future our universe, if it is indeed closed, may reach a point of "heat death" at which, after all higher-order material structures have become undifferentiated, all tangible activity will cease.

In the terminology of thermodynamics, this gradual homogenization, loss of differentiation, and disintegration of tangible, usable energy is a process known as "entropy." The universe in its entirety is subject to this fatal process.

But to move backward in time: Approximately 10 1/2 billion years after the "big bang," or 4 1/2 billion years ago, our planet earth was formed. Less than a half billion years after that--very quickly in cosmological terms--the first elementary forms of life began to appear on this planet. Like every other material entity in the cosmos, these life forms, too, were subject to the entropy law: They were mortal. Over time they, too, were subject to disintegration, homogenization and death.

In a sense, though, the individual life forms were able to transcend death--to circumvent it, if you will--by generating approximate reproductions of themselves. They were able to do this because, unlike the universe in its totality, these living systems were neither finite nor closed. They were open systems. Through their permeable boundaries they were able to import fresh usable energy and basic chemical structures with which to replicate themselves, thereby counteracting the fatal mandate of the entropy law. It is for this reason that we say that living systems are negatively entropic, or "negentropic."

Ilya Prigogine referred to these negentropic structures as dissipative structures. That is, they consumed, or dissipated, external energy and structures in order to regenerate their own internal energy and structures.

But the regeneration was never an exact replication. The dissipative structures were constantly being slightly reordered, slightly changed, slightly differentiated, by the active or kinetic energy flowing through them. If the changes were minor, the living system suppressed them and retained its structural integrity.[6] If, however, the changes were major ones that were nevertheless still in line with the general direction of the system's evolution, then the dissipative structure could "escape" beyond its "threshold of stability" into a new and higher order, into a new level of meaningful complexity.

Being invested with new energy and order, often with an additional number of subsystems in themselves subject to change, the new, more complex system was even more unstable than the old one. Being more complex and yet more unstable, the new dissipative structure was increasingly subject to fluctuations that might become perpetually incorporated into the system if they were meaningful enough in terms of the system's long-range survival and growth.

As indicated at three o'clock in figure 1, the rate and degree of change, of differentiation, of negentropy, was proportionate to the system's kinetic level and degree of complexity. In other words, the more active the system, and the greater the number of subsystems within it that were subject to change through meaningful activity, the faster and more pronounced was the system's overall evolutionary metamorphosis.

Inherent in Prigogine's theory is an explanation of the reason why the rate of differentiation in complex biological and social systems seems to increase geometrically: "Complexity begets complexity."

During the second distinct phase of the complexification cycle, the transactional phase located at "six o'clock" in figure 1, the differentiated systems become complementary in their structures and functions. This state, known as symbiosis, provides the basis for mutually beneficial exchanges of the energy, matter and information (negentropy) which each living system "suck[s] … from its environment."[7]

As Bertrand Russell notes in *The Scientific Outlook*, "Every living thing is a sort of imperialist, seeking to transform as much as possible of its environment into itself and its seed."[8]

Imperialistic as living systems may be, however, they maintain a necessary, delicate balance of competition and cooperation in the context of organic and ecological suprasystems.

As indicated at "nine o'clock" in figure 1, this delicately balanced process of competition/cooperation is what stimulates effective long-term patterns of true integration in living systems. As I will explain in some detail later, these patterns of integration are governed by higher-order organizational principles known as "algorithms."

There is a question I have thought about over a period of many years. I regard it as the ultimate question in system theory:

Why do living systems complexify, defying the Second Law of Thermodynamics that dominates the overall long-term evolution of the physical universe? There is no denying that life on this planet is indeed a sort of small miracle that cannot be adequately explained by mere descriptions of structures or mechanisms.

Neither cybernetic, Darwinian, sociobiological nor theological explanations in themselves suffice to account for living systems' impetus toward complexification.

Prigogine's theory does however suggest a basis for this process--the idea that the evolution of living systems occurs through a relentless, eternal sequence of structural-functional differentiations and recombinations. These phenomena must be considered somewhat random in the sense that the astronomical number of possible recombinations, all adjusted through new forms of complementarity or symbiosis, are only somewhat predictable at this stage in the development of science.

We can say with some certainty, nevertheless, that a successful living system may be prone to pursue one of two evolutionary game plans: (1) An extremely high reproductive rate combined with a low level of internal complexification or structural-functional integration. (2) A lower reproductive rate balanced by the more expensive development of complex strategic subsystems that will aid the organism in the competition for natural resources.

Harvard's theoretical biologist John Tyler Bonner devoted much of his career to an exploration of the process of complexification in living systems. In his book *On Development: The Biology of Form* (1974), he discusses the reasons why a majority of living systems tend to complexify over a period of time:

> Those cells that find and process fuel most effectively will be more successful at reproduction. Any new quality the cell might acquire that will decrease its chances of destruction in the changing environment will increase its chances of success in producing offspring. Any new quality that simply gives the cell advantage in competition with other cells for food or for shelter will be favored by selection, and will eventually play a far more significant role than the speed of making copies.
>
> It is here, in fact, that we see the advantages of size appear for the first time. With an increase in size and concomitant increase in complexity, specialized structures appear. For instance, flagella arise which permit the cell to move; it can go toward food or away from adverse conditions. Spore formation appears which protects the cell against drought and other adverse environmental changes. Any increase in size and complexity will automatically mean a decrease in the rate of duplication or reproduction, but what is lost in duplication

speed is more than gained by successfully competing for limited resources and being less susceptible to environmental hazards.[9]

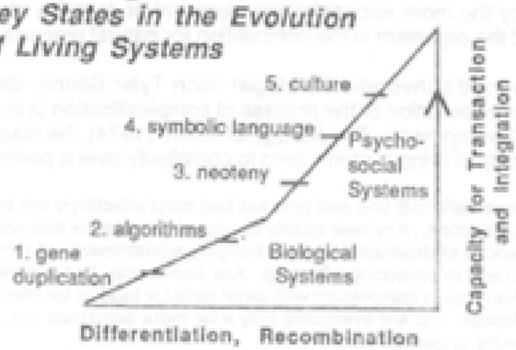
The basis of the impetus toward complexification is strikingly illustrated by the common slime mold, Dictyostelium discoideum. It consists of individual bacteria-eating amoebae which remain separate in periods when environmental conditions are favorable and food is plentiful, but which become temporarily integrated chemotactically under more adverse environmental conditions that threaten their survival as isolated individuals. As Eric Jantsch notes, it is the aggregate entity resulting from this integration that can move "along the earth in search of more favorable feeding places."[10]

Key Stages in the Evolution of Living Systems

There are five key stages in the evolution of complex living systems: (1) gene duplication, (2) algorithms, (3) neoteny, (4) symbolic language and (5) culture. Each is a stage in an unbroken continuum of increasing complexification in which higher rates and levels of differentiation/recombination become proportionate (in line with Prigogine's theory) to the capacity for transaction and integration, which increases markedly with the advent of psychosocial systems.

This continuum of complexification may be diagrammed as follows:

Figure 2
Key States in the Evolution of Living Systems



Sexuality, which began to develop well over a billion years ago, enhanced the genetic variety of living systems. Each act of sexual union doubled the number of development lines from which genetic variations were drawn, producing a reservoir of potentiality "so vast that only a part of it [was] used in a lifetime--the rest [serving as] the 'reserve' for epigenetic flexibility."[11] (Epigenetic flexibility is an organism's potential to evolve over time into a variety of forms adapted to a variety of environmental conditions.

The American geneticist Susumo Ohno has theorized that the foundation for rapid surges in mammalian and human evolution was laid at some point millions of years ago "when the forbears of man were still swimming in the sea or alternating between water and dry land."[12] At that point, in some "simple, generalized creature"[13] (most likely an amphibian of some sort), many exact, redundant, useless gene copies were produced which later mutated into genes with specific novel functions. Thus, over a period of time, "DNA was provided with redundancy in large quantities, and eventually the redundancy became useful information."[14]

In the terminology of information theory, the complexification of living systems is based on the combinational principle and algorithms. The combinational principle, in the words of Francis Crick, is the utilization of "only a small number of types of standard units, [such as the base pairs in the DNA molecule,] which are then combined in very many different ways. Writing is an excellent example of this principle."[15]

The rules, the "grammar," if you will, dictating the order of repeated combinations in a living system, constitute the algorithms predominant in that system. As Jeremy Campbell explains in *Grammatical Man: Information, Entropy, Language, and Life*:

> In its modern sense, an algorithm is some special method of manipulating symbols, especially one which uses a single basic procedure over and over again. It converts certain quantities into other quantities, using a finite number of transformation rules. Rules of language, for example, are of this kind. In the case of DNA, the rules may enable sets of genes to be copied over and over again and to be expressed as protein in various specific ways and not in others. The algorithm would be a kind of program, instructing certain combinations of genes to turn on or off at specific times, and it would be stored in the DNA text as information. It may be analogous to the grammar and syntax of English.[16]

The DNA text of mammals is 30 times as long as that of a sponge, yet only a little over one percent of this additional text "consist[s] of genes [coding] directly for proteins."[17]

These genes directly involved in the replication of proteins are known as structural genes. In Campbell's words, it was "one of the scandals of modern biology" when Emile Zuckerhandl reported in 1976 that the structural genes of chimpanzees and humans "are 99% identical." In fact, reported Zuckerhandl, the basic chemistry of chimpanzee and human brains is so similar that it may not really be asserted with any certainty that the more highly evolved human brain in fact contains a single new protein "with a genuinely novel function." "The uniqueness of the human brain," Zuckerhandl hypothesized, "must be due to structural and functional variants of pre-existing proteins and to variations in the quantity, timing, place and coordination of the action and interaction of these proteins."[18]

The key algorithm in the case of Homo sapiens, the algorithm which, in Campbell's eloquent words, made possible all "the fruits of the contemplative mind: myth, religion, art, literature, and philosophy,"[19] is the organizational principle known as neoteny.

The word "neoteny," literally meaning "holding youth," was first popularized by the Dutch anthropologist Louis Bolk in the early 1920s.

Neoteny, or paedomorphosis, "is the process whereby the fetal and/or juvenile traits of ancestors ... are retained into later stages of individual development."[20]

The enigma of Homo sapiens is that externally the adult human being looks exactly like

> an ape which is still in the fetal or juvenile stage of development.... Reprogramming was the secret, changing the rules of timing. The strategic slowing down of [the human being's developmental] timetable arrested the growth of certain features of the primate anatomy, freezing them at an infantile stage of development. Fetal apes have flat faces, long necks, round heads, small teeth--and massive brains in relation to the weight of the whole body. The bones of the cranium are thin, the ridges over the brows undeveloped, and there is not much hair on the body. Even more remarkable, in an ape at the fetal stage, the place at which the spinal cord enters the skull lies directly under the brain, allowing an erect posture. As the ape develops, however, the place of entry shifts back behind the brain, making it impractical to stand upright. The retarded timetable adopted by humans means that this critical shift backward never takes place, and it enables the human to walk erect all through life.[21]

The retarded developmental timetable is not an evolutionary mechanism unique to Homo sapiens. Neoteny is a developmental strategy traceable all the way back through the entire line of primate evolution: While monkeys are dependent on their mothers' care for only a few months, chimpanzees remain in the childhood stage for four or five years, and human beings for three times as long as that.

The deep meaning of this long-term evolutionary strategy is quite clear. As Charles LeBaron notes, "with its hundred trillion synapses, the human brain offers the highest density of order and information, or negentropy, of any object in the known universe."[22] This organic complexity was generated as a product both of spontaneous gene duplication and of experiential diversity translated through sexuality into epigenetic flexibility. As Erich Jantsch put it, the gradual complexification of the genetic and neurological aspects of living systems really represents an expansion of the systems' capacity for "time-and space-binding."[23]

The process, however, as noted in figure 1 of this essay, is cyclical. As specified by Prigogine's Theory of Dissipative Structures, the rapid differentiation of genetic and neurological structures is predicated and intensified by the very complexity and level of negentropy of those structures. ("Complexity begets complexity.") Yet in the context of the Second Law of Thermodynamics there is nothing intrinsically "natural" about increasing complexification: In order for living systems to survive and thrive at ever-higher thresholds of stability, levels of increasing differentiation must be matched by increased levels of structural/functional integration that are justified, as James Bonner points out, by the system's enhanced capacity to extract matter, energy and information from its environment.

Neoteny, as a specific algorithm particularly significant in the context of primate and human evolution, ensures that there will be a meaningful fit between genetic/neurological (organic) and experiential (environmental) complexity. In Campbell's words,

> The more various the range of experience open to the individual, the more intense are the pressures for greater variety in the information system of the genes. This requires a long period of protected, predictable gestation, free from surprises and risks, enabling the intricate circuits and billions of nerve cells to be laid down in the brain under orderly, stable conditions. It also calls for a burst of genetic variety, switched on after birth. [Morris] Goodman believes that this blaze of postnatal richness may be the biochemical source of the tremendous range of different talents, tastes, skills, temperaments, and divergent types of thinking that is the mark of a successful society. In recognition of the fact that humans need both phases of the timetable, prenatal and postnatal, to rise to their intellectual preeminence in the animal kingdom, Goodman christens mankind "the conservative and revolutionary mammal."[24]

As Rene Dubos notes in *Beast or Angel? Choices That Make Us Human*, "life evolved progressively from a low level of unity toward a higher level of integration through the intermediary of pluralistic diversification."[25]

In human societies, persons may be diversified, differentiated, according to such factors as sex, age, rank and function. As Peacock & Kirsch note, functional differentiation in modern society may be especially rapid: "As specialties and skills change and multiply faster and faster, it becomes impossible for the individual to master all of them; and the mastery is accordingly divided among numerous specialists and specialized groups."[26]

Such diversity, functional and otherwise, according to Dubos' theory, stimulates the concurrent development of new "organs of communication" which make possible "a new and higher level of unity."[27]

The new organs of communication, in fact, become critically necessary, because as production systems become more complexified and sophisticated in the modern world, they become much more "interdependent with regard to natural resources."[28]

What are the new organs of communication that have been generated to facilitate the growth of complex human social systems? I see two essential ones: symbolic language and secondary group structures--and the secondary group structures, I think, are largely attributable to the existence of symbolic language.

It is important, in considering these concepts, not to fantasize too much about Man's uniqueness in the evolutionary scheme of things. Some theorists are prone to become unnecessarily mystical when evaluating human consciousness. One must realize that any special qualitative dimensions of human language must be attributed first of all to a very quantitative factor: The levels of complexity inherent in the human genetic and neurological systems. As the linguist Noam Chomsky suggests,

> Human language competence, which must be among the most complicated structures in the universe, arises uniquely in evolution at a certain stage of biological complexity. In other words, it appears when, and only when, evolution has led to an organism as complex as a human being.[29]

The deliberate use of symbolism may be traced very far back in human evolution, as far back as 300,000 years ago when Homo erectus was making symbolic engravings on ox ribs.

According to Bertalanffy, there are two somewhat distinct types of symbols: "(a) discursive (language in a broad sense, including technical languages of mathematics, etc.); (b) non-discursive (myth, art, customs, rituals and their material signs, etc.). ... [I]t is proposed that discursive symbols are concerned with facts, whereas experiential or existential symbols are concerned with values."[30]

Both varieties of symbols, discursive and non-discursive, serve as efficient, flexible integrative mechanisms in human social systems. Discursive symbols helped give rise to the secondary group structures that are one hallmark of such systems. As Harry H. Turney-High notes in *Man and System: Foundation for the Study of Human Relations*,

> Secondary interaction is that type of human relationship wherein neither the originating nor the responding actors are in each other's physical presence in space and time, but rely on a material invention as a medium of communication or on the intervention of other parties. Many material inventions have no other function than to overcome the frustrating aspects of space. The terms telegraph, telephone, and teletype come at once to mind .... A host of such inventions could be listed, the written word being the most important.... Man is the only species capable of secondary interaction and transaction, and no human group is without it.[31]

To some extent, of course, what Bertalanffy calls the "non-discursive, or experiential, value-oriented" symbols also play a role in secondary group formation. For example, what would America be without its Uncle Sam, its Star Spangled Banner of red, white and blue, its national anthem?

Non-discursive symbolism also serves a special integrative function in religious institutions both primitive and modern. The very word "religion" is derived from the Latin verb "religare" (to bind), and religious symbolism serves to bind together human beings both horizontally (in organizational terms) and vertically (in historical terms). As Bernard Campbell observes in *Human Evolution*,

> birth rites, puberty rites, marriage rites [and] death rites … consolidate social roles and social structure, as well as bind members of the society together. But religion does more than that, for it directs social sentiments toward one stable and symbolic center. In many primitive societies, this further binding property of religion takes the form of ancestor worship, which creates, as it were, a continuum between the living and the dead.[32]

I wish, finally, to summarize what my central line of argument has been throughout this discission of key stages in the evolution of living systems.

There are essentially two lines of thinking in regard to the matter of continuity or discontinuity in the evolution of biological and social systems. The anthropologist Marshall Sahlins, author of *The Use and Abuse of Biology: An Anthropological Critique of Sociobioiogy*, represents one line of thought in arguing that human symbolism and culture constitute a distinct qualitative break in the continuity of systems evolution. Human institutions, Sahlins asserts, require an entirely new type of analysis. The second school of thought is represened by system theorists such as Bertalanffy and Jantsch, biologists like Dubos, information theorists like Jeremy Campbell, linguists like Noam Chomsky and, this author.

We intrepid members of this second school will admit that, yes, human symbolism and culture represent a "great leap" ahead of the social and communicative mechanisms utilized by "lower" forms of life. Our argument, however, would be that there is a profound difference between a sudden leap and an infinite gap. Our argument would be that the "leap" from ape to man is the same sort of phenomenon represented by the "leap" from amphibian to mammalian phylogeny which occurred 165 million years ago. Both these leaps represented relatively rapid metamorphoses of phenotypes, the observable surface structures of living systems.

Preceding such rapid, almost "magical" phenotypical metamorphoses, however, were long periods of slow, calm genetic gestation in which multitudes of redundant, dormant gene copies were produced, lying quiescent for several million years until appropriate environmental conditions released the systems' latent capacity for epigenetic flexibility.

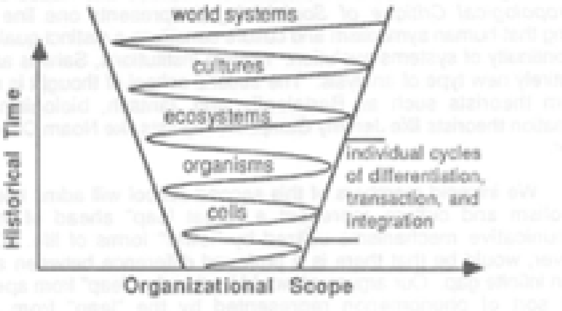
To be sure, then, admittedly, discontinuities and imbalances in relative rates of differentiation, transaction and integration are readily observable in the long-term evolution of living systems. The wheel of complexification does not revolve with monotonous exactitude. The three phases of the cycle, however, are equally manifest in the evolution of both biological and cultural systems, and it does not matter a whit whether we call such repetitive isomorphisms "homologous" or "analogous"; they are most aptly characterized, in Raymond Miller's words, simply as "similar developmental patterns … manifest throughout all of nature's systems."[33]

The Rationale for a Unitary View of Nature

I shall try to end this paper on a less technical, more personal note by summarizing the evolutionary model I've outlined and attempting to give a few reasons why I believe very deeply that such unitary models of nature are exceptionally useful for students in the 1980's.

The model itself, first of all, may be summarized in the following diagram:

Figure 3
The Power of Recurrence



I've entitled this diagram "The Power of Recurrence," because that is essentially the lesson inherent in the model I've outlined. A relatively definable and comprehensible, if not exactly simple, pattern of differentiation, transaction and integration emerged when the very first amino acids began to form on this earth four billion years ago. As the late Ilya Prigogine demonstrated through his elegant mathematics, the pattern is predominant in purely physical systems whether we want to call them "living" or not. And the pattern persists or recurs in other areas: Biologists such as Rene Dubos provide us with reasonable proof that the processes of differentiation and integration are fundamental in the evolution of living systems, and social scientists such as Alfred Kuhn make transactional and integrative processes a fundamental part of their models of human social systems.

So what is the human message here? Having taught at the secondary and college level for over thirteen years, I know that the typical American high school student graduates having been exposed to thousands of "facts" and "answers" in the context of thousands of fifty-minute periods. The environment in which he has perhaps been learning is one hopelessly fragmented, not least of all by ringing bells. What of the "knowledge" he's left within the final analysis?

Most likely he'll have taken three or four courses in English, a couple in mathematics, two or three in the physical and biological sciences, and probably about an equal number in history and government. It can be stated almost as a certitude that nowhere along the way has he worked with teachers possessing the desire, imagination, insight or academic framework with which to encourage deeply significant syntheses of these areas.

Consider for example, how unlikely it is that he would have encountered the idea that the genetic systems he studies in biology and the grammatical system he studies in English both evolve and change because of higher-order organizational principles acting on a very finite number of basic informational units, it wouldn't be necessary in order to convey this idea to cite any of the more abstruse aspects of information theory, nor would it be necessary to talk about the combinational principle and algorithms when suggesting the existence of basic informational units and higher-order organizational patterns. The important thing is that the student should be exposed to the exciting, intriguing probability that there is a common yet marvelously uncommon link between two courses and two academic fields, and, more marvelously than that, between the intrinsic logic inherent in the words in his mouth and the genes in his cells.

Young, flexible, curious, promising minds have a right to more--more than rote "knowledge," more than deceptively simplistic answers to multiple choice questions, more than mass-produced diplomas representing fragmented learning environments and fragmented worid views. It should be not the tangential and incidental, but rather the primary and fundamental function of educators to possess and convey to their students an ineradicable sense of the miraculous interconnectedness of life, to make the miracles explicit, to make them coherent.

Education without progressive meaningful synthesis is nothing. The English poet John Milton realized this 350 years ago when he advocated in his essay "Of Education" that over a period of years high quality instruction must inevitably proceed from the conveyance of linguistic/mathematical modes of communication, to exposure to various scientific methodologies, and finally to creative opportunities for students to synthesize personal, coherent world views that can excite and sustain them, both intellectually and ethically, till the end of their lives. Milton, for his time and place in history, regarded rhetoric and ethics as the ultimate interdisciplinary endeavors through which young people might begin to become personally engaged in lifelong quests for valid, sustaining syntheses.[34]

I believe that for our time and place in history--building on the diverse, eclectic, insular, quarrelsome scientific endeavors of the last century--some attempt at a truly meaningful synthesis must be sincerely made, and made not merely for the sake of the extrication or sanctification of any wing of the academic establishment, but for the sake of students.

The first step in this endeavor must be the formulation of some kind of unitary view of nature that meets two criteria: 1. It must be connectible to and coherent with the longstanding, valid contributions emanating from eclectic yet sound scientific disciplines. 2. It must constitute a world view (or set of them) that is capable of being transmitted to students in gradual stages of depth and sophistication.

The sort of unitary view I've promulgated in this essay, I think, adequately meets these two criteria. It has a central question: "Why does the evolution of biosocial systems during the last four billion years exhibit recurring cycles of identical, isomorphic processes contributing to a clear yet still mysterious thread of continuously increasing complexification that flies in the face of the Second Law of Thermodynamics, that is, toward complexity and away from entropy? I have attempted to answer this question utilizing useful contributions from such diverse disciplines as physical chemistry, genetics, theoretical biology, information theory, linguistics, anthropology and sociology.

The unitary view also can be presented to students of various ages in various stages of depth and sophistication. Though college students might be at least a little bit mercilessly exposed to the details and ramifications of such concepts as entropy, the Combinational Law, algorithms and epigenesis, teachers at the secondary school level can just as easily and effectively talk about such matters as the deterioration of energy, basic informational units, higher-order organizational patterns, and the emergence of organisms from genes. Indeed, there is good evidence that basic systems concepts can be successfully taught to very young students--much younger, in fact, than those of high school age.[35] So the difficulty of the task hardly seems prohibitive.

Use of the word "system" in this discussion is perhaps misleading because for many people it connotes a brand of inhuman, inhumane, rigid, mechanistic, materialistic determinism from which they find it possible to conjure haunting visions of *1984* and cruel metal humanoids creaking their way around the world. All this and more, the nightmare goes, may come from accepting a watered-down view of our humanness: We will become what we think we are, and we should consequently avoid any temptation to think of ourselves as just another material system playing an essentially mindless, spiritless role in what is admittedly a predominantly impersonal universe.

But this is not a necessary view of a "system" or of man as part of a system. As Bertalanffy defines it, a "system" is simply a set of entities interacting within the context of some kind of fairly consistent, comprehensible pattern. The entities need not be seen as non-spiritual nor the patterns as strictly material or rigidly predetermined.

It is, however, necessary to insist that our human life, whatever else it may be, is a subset of biological life which is itself a subset of the purely physical universe. Without truly, humbly recognizing our ecological embeddedness in fragile biological and physical suprasystems, without adopting spirituality in its ultimate sense, we are inevitably destined to perish under the sheer weight of a technological sophistication that has become arrogance. The systems paradigm, the unitary view of nature, is a long-overdue antidote to such fatal anthropocentric egotism: When the first amino acids started to conjoin with others in the primordial seas, there was nothing to indicate that we should necessarily be one of the end products of four billion years of tentative, lurching creation. It has always been, according to Progogine, the instability and tentativeness of living systems that allowed them to "escape" recurrently into existences as entities of a higher order and a greater organizational scope. Perhaps, as Bonner pointed out, this increased complexity, this increased organizational scope, has been advantageous--and perhaps there is a very definite rationale for the complexification process. But there are no ironclad inevitabilities. The preeminent aspect of evolution is its pervasive fluidity.

We are, then, led back to the ideas of the late Erich Jantsch, with which we began: "Every day of our lives," he wrote, "we serve as significant participants in an evolution which is neither in its emerging and decaying structures, nor in the end result, predetermined. Science is about to recognize these principles as general laws of the dynamics of nature. Applied to humans and their systems of life, they appear therefore as principles of a profoundly natural way of life."[36]

NOTES

[1]Kirtley F. Mather, "Objectives and Nature of Integrative Studies," *Main Currents in Modern Thought*, as cited by Robert W. Winquist in "What Are Transdisciplinary Principles?" *Issues in Integrative Studies*, 1982, pp. 49-50.

[2]Ludwig von Bertalanffy, *General Systems Theory: Foundations, Development Applications*. (New York: Braziller, 1968), p. 38.

[3]Erich Jantsch, The Self-Organizing Universe. (New York: Pergamon Press, 1980), p. 8.

[4]Jantsch, *op. cit.*, p. 237.

[5]John D. Barrow and Joseph Silk, *The Left Hand of Creation: The Origin and Evolution of the Expanding Universe*. (New York: Basic Books, 1983), p. 10.

[6]Marilyn Ferguson, *The Aquarian Conspiracy: Personal and Social Transformation in the 1980s*. (Los Angeles: J. P. Tarcher, Inc., 1980), p. 164. For a more detailed presentation of the Theory of Dissipative Structures, see: Ilya Prigogine, "Order Through Fluctuation: Self-Organization and Social System," in Erich Jantsch and Conrad H. Waddington, eds., *Evolution and Consciousness: Human Systems in Transition*. (Reading, Mass., London and Amsterdam: Addison-Wesley, 1976).

[7]Erwin Schrodinger, *What Is Life? The Physical Aspect of the Living Cell*. (New York: Macmillan, 1947), pp. 72, 75. As quoted by Jeremy Rifkin in *Entropy: A New World View*. (New York: Bantam Books; 1981), p. 52.

[8]Bertrand Russell, *The Scientific Outlook*. (New York: Norton, 1962). As quoted by Rifkin, *op. cit.*, p. 53.

[9]John Tyler Bonner, *On Development: The Biology of Form*. (Cambridge, Mass.: Harvard University Press, 1974), pp. 77-78.

[10]Erich Jantsch, *The Self-Organizing Universe*, p. 129.

[11]*Ibid.*, p. 125.

[12]Jeremy Campbell, *Grammatical Man: Information, Entropy, Language and Life*. (New York: Simon & Schuster, 1982), p. 150, citing Susumo Ohno, *Evolution by Gene Duplication*. (New York: Springer-Verlag, 1970).

[13]*Ibid.*

[14]*Ibid.*

[15]Francis Crick, *Life Itself: Its Origins and Nature*. (New York: Simon & Schuster, 1981), p. 59.

[16]Jeremy Campbell, *op. cit.*, p. 130.

[17]*Ibid.*, p. 133.

[18]Emile Zuckerhandl, "Programs of Gene Action in Progressive Evolution," in Morris Goodman, Richard E. Tashian, and Jeanne H. Tashian, eds., *Molecular Anthropology*. (New York: Plenum Publishing, 1976), pp. 387-447.

[19]Jeremy Campbell, *op. cit.*, p. 141.

[20]Ashley Montagu, *Growing Young*. (New York: McGraw-Hill, 1981), p. 9.

[21]Jeremy Campbell, *op. cit.*, p. 139.

[22]Charles LeBaron, *Gentle Vengeance: An Account of the First Year at Harvard Medical School*. (New York: Richard Marek Publishers, 1981), p. 70.

[23]Erich Jantsch, *The Self-Organizing Universe*, p. 237.

[24]Jeremy Campbell, *op. cit.*, p. 136.

[25]Rene Dubos, *Beast or Angel? Choices That Make Us Human*. (New York: Scribners, 1974), p. 181.

[26]James L. Peacock and A. Thomas Kirsch, *The Human Direction: An Evolutionary Approach to Social and Cultural Anthropology*. (New York: Appleton-Century-Crofts, 1970), p. 284.

[27]Dubos, *op. cit.*, p. 187.

[28]*Ibid.*, p. 189.

[29]Jeremy Campbell, op. cit., p. 102, citing Noam Chomsky, *Language and Mind*, enlarged ed. (New York: Harcourt, 1972).

[30]Bertalanffy, *Systems View of Man*, pp. 53, 55.

[31]Harry H. Turney-High, *Man and System: Foundation for the Study of Human Relations*. (New York: Appleton-Century-Crofts, 1968), pp. 185, 192.

[32]Bernard G. Campbell, *Human Evolution: An Introduction to Man's Adaptations*. (Chicago: Aldine, 1974), p. 360.

[33]Raymond C. Miller, "Varieties of Interdisciplinary Approaches in the Social Sciences: A 1981 Overview." *Issues in Integrative Studies*, 1982, p. 23.

[34]John Milton, "Of Education," in Oliver Morley Ainsworth, ed., *Milton on Education: The Tractate of Education With Supplementary Extracts from Other Writings of Milton*. Volume XII of the Cornell Studies in English Series. (New Haven: Yale University Press: 1928), pp. 51-64.

[35]Ruth-Ellen & J. P. Miller, "Systems Concepts for Early Grades," in *General Systems: Yearbook of the Society for General Systems Research*, vol. XXVI (1981), pp. 253-259.

[36]*Op. Cit.*, p. 8.

BIBLIOGRAPHY

Barrow, John D., and Silk, Joseph. *The Left Hand of Creation: The Origin and Evolution of the Expanding Universe*. New York; Basic Books, 1983.

Bertalanffy, Ludwig von. *General System Theory: Foundations, Development, Applications*. New York: Braziller, 1968.

__________________. *A Systems View of Man*. Boulder, Colorado: Westview Press, 1981.

Bonner, John Tyler. *On Development: The Biology of Form*. Cambridge, Mass.: Harvard University Press, 1974.

Boulding, Kenneth. "The Future of General Systems." In *Interdisciplinary Teaching.* Edited by Alvin M. White. San Francisco: Jossey-Bass, 1981. Number 8 of the *New Directions for Teaching and Learning Series*.

Campbell, Bernard G. *Human Evolution: An Introduction to Man's Adaptations*. Chicago: Aldine, 1974.

Campbell, Jeremy. *Grammatical Man: Information, Entropy, Language, and Life.* New York: Simon & Schuster, 1982.

Capra, Fritjof. *The Turning Point: Science, Society and the Rising Culture*. New York: Simon & Schuster, 1982.

Chomsky, Noam. *Language and Mind*, enlarged ed. New York: Harcourt, 1972.

Crick, Francis. *Life Itself: Its Origins and Nature*. New York: Simon & Schuster, 1981.

Dubos, Rene. *Beast or Angel? Choices That Make Us Human*. New York: Scribners, 1974.

Engemann, Joseph G., and Hegner, Robert W. *Invertebrate Zoology*, 3rd ed. New York: Macmillan, 1981.

Ferguson, Marilyn. *The Aquarian Conspiracy: Personal and Social Transformation in the 1980s*. Los Angeles: J. P. Tarcher, Inc. 1980.

Jantsch, Erich. *The Self-Organizing Universe: Scientific and Human Implications of the Emerging Paradigm of Evolution*. New York: Pergamon Press, 1980.

Jantsch, Erich and Waddington, Conrad H., eds. *Evolution and Consciousness: Human Systems in Transition*. Reading, Mass., London and Amsterdam: Addison-Wesley, 1976.

Klein, Julie Thompson. "The Dialectic and Rhetoric of Disciplinarity and Interdisciplinarity." *Issues in Integrative Studies*, 1983.

Kuhn Alfred, *Unified Social Science*. Homewood, Illinois: Dorsey Press, 1975.

Laszlo, Ervin. *The Systems View of the World*. New York: George Braziller, 1972.

LeBaron, Charles. *Gentle Vengeance: An Account of the First Year at Harvard Medical School*. New York: Richard Marek Publishers, 1981.

Mair, Lucy. *An Introduction to Social Anthropology*. Oxford: Clarendon Press, 1965.

Miller, Raymond C. "Varieties of Interdisciplinary Approaches in the Social Sciences: A 1981 Overview." *Issues in Integrative Studies*, 1982.

Miller, Ruth-Ellen & J. P. "Systems Concepts for Early Grades." *General Systems: Yearbook of the Society for General Systems Research*, vol. XXVI (1981), pp. 253-259.

Milton, John. "Of Education." In *Milton on Education: The Tractate of Education With Supplementary Extracts From Other Writings of Milton*. Volume XII of the Cornell Studies in English Series. Edited by Oliver Morley Ainsworth. New Haven: Yale University Press, 1928.

Montagu, Ashley. *Growing Young*. New York: McGraw-Hill, 1981.

Ohno, Susumo. *Evolution by Gene Duplication*. New York: Springer-Verlag, 1970.

Peacock, James L. and Kirsch, A. Thomas. *The Human Direction: An Evolutionary Approach to Social and Cultural Anthropology*. New York: Appleton-Century-Crofts, 1970.

Prigogine, Ilya. "Order Through Fluctuation: Self-Organization and Social System." In *Evolution and Consciousness: Human Systems in Transition*. Edited by Erich Jantsch and Conrad H. Waddington. Reading, Mass., London and Amsterdam: Addison-Wesley, 1976.

Rifkin, Jeremy. *Entropy: A New World View*. New York: Bantam Books, 1981.

Russell, Bertrand. *The Scientific Outlook*. New York: Norton, 1962.

Sahlins, Marshall. *The Use and Abuse of Biology: An Anthropological Critique of Sociobiology*. Ann Arbor: University of Michigan Press, 1976.

Schrodinger, Erwin. *What Is Life? The Physical Aspect of the Living Cell*. New York: Macmillan, 1974.

Turney-High, Harry H. *Man and System: Foundation for the Study of Human Relations*. New York: Appleton-Century-Crofts, 1968.

Winquist, Robert W. "What Are Transdisciplinary Principles?" *Issues in Integrative Studies*, 1982.

Zuckerhandl, Emile. "Programs of Gene Action in Progressive Evolution." In *Molecular Anthropology*. Edited by Morris Goodman, Richard E. Tashian, and Jeanne H. Tashian. New York: Plenum, 1976.