CHAOS THEORY AND THE EVOLUTION OF CONSCIOUSNESS AND MIND: A THERMODYNAMIC–HOLOGRAPHIC RESOLUTION TO THE MIND–BODY PROBLEM

LARRY R. VANDERVERT*

American Nonlinear Systems, 711 W. Waverly Place, Spokane, WA 99205-3271, U.S.A.

Abstract—This address describes Neurological Positivism's (NP) energetic evolution of consciousness, mind, and the brain–mind relationship within a model that integrates ideas and research from chaos theory, Pribram's holonomic brain theory, evolutionary theory, and the laws of thermodynamics (the energy laws). The energetic evolution and encapsulation of space–time consciousness from chaotic–holographic environments is described. *Consciousness* is described as a natural evolutionary space–time template of continuously generated self-referential energy patterns (algorithms). The energetic evolution of *mind* is described as a natural self-referential exteriorization of the algorithmic organization of consciousness in the form of culturally shared mental models. It is proposed that the brain–mind energy relationship has historically undergone and continues to undergo change, and that this change is a natural thermodynamic arrow that constitutes the evolution of culture. That is, the evolution of culture proceeds in the direction of progressively more complete and efficient exteriorizations of the algorithmic organization of the brain—thus, for example, the recent evolution of brain-like computing systems and virtual reality systems. Accordingly, an uneven, but closing, central-energy-state identity (self-similarity) between brain and mind is described. It is concluded that NP's conception of mind helps us understand the evolutionary unfoldment of culture, and provides a sense of direction as to its future.

CHAOS THEORY IN THE CONTEXT OF THIS ADDRESS

Almost everyone these days has at least heard about chaos theory, although not many lay people really understand what it is all about. In this paper it will not be possible to provide a comprehensive introduction to chaos theory. I will assume that the reader has enough knowledge, or perhaps enough of an intuitive feel, to know that chaos theory has something to do with the deeper underlying order that seems to reside virtually everywhere in nature. That, along with a few introductory ideas that will be provided, should be enough for the alert lay person to follow the general theses and arguments of this address. For those who would like to pursue a comprehensive introduction to the idea and methods of chaos theory, see Gleick (1987), and Abraham, Abraham and Shaw (1990).

It is upon the more *general patterns* of the deep underlying dynamic order of complexity in nature that attention will be focused. Of course, the mathematics of chaos theory fit hand-in-glove with these patterns, but as it will be seen later within the framework of Neurological Positivism (NP) the patterns have their origins in the algorithmic organization of the brain, and therefore *precede* in time the mathematical science that describes them. Whether we are studying turbulent flows in rivers, dynamic energy hierarchies in ecosystems, or the four nested characteristics of the human "stream of consciousness" delineated introspectively by William James (1890), for example, *the fundamental underlying organizational patterns are in general the same.*

For our purposes, a thumbnail summary of the chaos–theoretical features of pattern that apply to dynamical systems such as the foregoing would be as follows:

1. The dynamical unfoldment of the patterns immanent in complex systems lies behind the grasp of everyday experience. Phenomena such as those mentioned above that may *appear* "chaotic" or totally unorganized and unconnected in everyday experience actually contain indwelling, interconnected deterministic order.

2. The order lying behind the appearance is that of self-similarity (not self-same) and self-referentiality across scale and aspect of nature. This means that (a) a general similarity of patterns repeats itself *ad infinitum* and more detail is revealed across finer and finer scales of measurement, and (b) the similarity of pattern arises from its pre-existing pattern (self-referentiality)—form arising dynamically from pre-existing form creating a seamless web of organization and interconnectedness, Darwin's central theme, and the mechanism that underlies maximum-power principle evolution (see Appendix).

3. Self-similar, self-referential "jumps" or rapid bifurcations occur in the system in a periodic fashion. "Emergent" or nonlinear (non-additive) branchings occur periodically in unfolding chaotic systems.

4. As the behavior of the system unfolds, small, seemingly inconsequential and often dismissed initial conditions of the unfoldment may diverge nonlinearly in rapid fashion toward unpredictable conditions. This feature is referred to as sensitivity to initial conditions, or, metaphorically, the Butterfly Effect. The Butterfly Effect metaphor is meant to convey in a simple way that a miscalculation of conditions in a weather regime as small as that associated with the flapping of butterfly or bird wings might surprisingly evolve nonlinearly toward unpredictable major weather conditions. As with all metaphors, the *Butterfly* metaphor should be taken with a grain of salt. In this paper, attention will be focused upon the self-similarity and self-referentiality features of chaos.

Chaos theory, and the discovery of the world-picture

It is becoming increasingly apparent that chaos theory is not simply another theory that will take its place among theories. The dynamical organizational patterns of chaos theory provide an *overarching* theoretical framework that both enables and encourages us to cross traditional disciplinary boundaries in order to discover the natural interconnectedness among *all* phenomena—to find the common ground among all theories. Accordingly, in this paper the powerful, perhaps universal, dynamical patterns of chaos theory are used to undergird the

modeling of a unified world-picture of the evolution of the brain, consciousness, and mind in a *trans*disciplinary manner, i.e., "focusing on knowledge or natural processes or mechanisms which are common 'across' many disciplines or scalar levels of organization" (Troncale, Lee, Nelson & Tres, 1990). This chaos-theoretical effort involves the merging of ideas and research across psychology, philosophy, neuroscience, thermodynamics, mathematics, evolutionary theory, and general systems theory.

Softening psychology's boundaries

Psychology, I often think, is potentially the most diverse and generalizable discipline; it is the one that potentially ". . . can handle the largest possible part of the totality of the facts of experience"—the final test of all theoretical work (Holton, 1979, p. 313). *After all, any science that defines itself as the scientific study of human behavior, cognition, and experience would have to be exactly that pervasive in scope.* It is difficult to imagine on what grounds certain categories of human experience would be excluded. As psychologists, therefore, it seems to me that we have the scientific responsibility to attempt to understand and describe virtually *everything* that involves human experience. Not only must we psychologists concern ourselves with the traditional topics and dynamics of research and practice, but must extend our understanding to the *categories of experience* of the people of all the other disciplines. It seems to me that a complete psychology would ask also, for example, why it is that human beings do physics, mathematics, and art *at all*; how are consciousness, mind, and thought related to these activities, and how does it all fit together? From this point of view it would seem to follow that if there is to be a "theory of everything," that physicists are so fond of claiming as *their* territory, psychology will likely have to provide it.

In order to begin to answer such questions about the fundamental nature of consciousness, mind, and thinking, we are not forced to *become* physicists, for example, but to soften the traditional boundaries of psychology so that its efforts are extended fully to those realms of experience. Since all of the disciplinary realms of experience are "vapor trails" of human mental activity, it seems we will have to combine them all in a single model in order to understand the processes of human consciousness fully. In my view chaos theory and general systems theory will more and more become natural partners in leading psychology toward this broadened, transdisciplinary conception of itself.

In previous articles (Vandervert, 1988, 1990, 1991, 1992, 1993) I have proposed and developed a neuroepistemology called Neurological Positivism (NP).* NP subsumes the three traditional positivisms that describe what is basic or

---

*Although one might interpret NP's focus on the algorithmic organization of the brain as a skull-bound solipsism, NP is *not* a solipsism. NP represents an "emergent hypothetical realism," that is a variant on Campbell's (1959, 1974) "hypothetical realism" emphasizing emergence that comes with the evolution of symbol systems. NP proposes that the algorithmic organization that becomes encapsulated in the brain mirrors *a* real world accurately, but in addition proposes that the real world can be modeled cognitively in symbolic form in a variety of unpredictable, but deterministic, *emergent* ways. The cognitive models of, for example, Einstein's relativity, Gödel's incompleteness/inconsistency, Heisenberg's uncertainty, are all implicated here. Compare NP's emergent hypothetical realism with, for example, Lorenz (1941/1962, p. 29; 1973, 1977, chapter 1), MacLean (1990, chapters 1 and 29), and Pribram (1986, 1991, pp. xxii–xxix).

preinferential to scientific knowledge (see Boring, 1950, pp. 633–634) by describing that which is preinferential to *them*, namely, their common neurological heritage in the algorithmic organization of the brain and the evolutionary mechanisms of its exteriorization in/as the mental models of culture:

> Neurological positivism proposes that the preinferential, undebatable basic data and order for all that can be known by any creature are in the algorithms* of its neurological order (its neurological computational characteristics, organizations, and functional interaction with environment); and further, that the data for all other positivisms (social, experiential, and logical) exist as high-level homological [having common descent] *transformations* of the neurological order. (Vandervert, 1988, p. 314)

Within the framework of NP, the algorithmic organization of the human brain has been described as the outcome of maximum-power evolution selection dynamics (see Appendix) operating in a space and time that gradually became encapsulated (literally, placed in a protective container) in the skull and the rest of the nervous system (Vandervert, 1991, 1992). In addition to the encapsulation of the algorithmic *organization* of space and time (described in Vandervert, 1992, pp. 257–259), the self-referential, self-organizing (autocatalytic) *dynamics* of maximum-power evolution are likewise thought to have been encapsulated as the driving features and forces behind the processes of perception, cognition, and behavior, and, subsequently, mind *in* space–time (Vandervert, 1991, pp. 211–214).

It is common knowledge that the brain is organized through evolution in such a way that all of its subsystems are interconnected; all of its own internal energy flows and the energy flows it guides in the rest of the nervous system are thereby interconnected and interdependent. From this perspective it seems that any

---

*In NP an *algorithm* is any set of rules, including those which govern chaotic dynamical systems, that perform translational or transformational operations (mathematical, mechanical, linguistic, neurological, metaphorical, homological) that link problems, input data, and solutions. At the same time algorithms cannot solve problems (cannot do work) either in theory or practice unless transferred in some thermodynamic manner. The thermodynamic *methods* of heat and work constitute the definitional bases for all algorithms. Algorithms are therefore also orderly methods of energy/information *transfer* that will provide solutions to problems (see e.g., Atkins, 1984, chapter 2). NP's definition of algorithm places the origins of all algorithms in the evolution of problem solving in the brain as depicted, for example, in Figs 1 and 2. In the thermodynamic scheme of things, since no change of any kind can occur without an energy/information flow (not even an abstract thought about algorithms, or an observation), there can be no such thing as "nonalgorithmic" problem solving. Penrose (1989), for example, discussed the relationship of algorithms to mathematics, and to a small degree mental processes. Penrose's description of algorithms occurs at the level of the mental models of mathematics and artificial intelligence as if these mental models somehow represent the fundamental nature of reality and then works backward to the problem solving organization of the brain. He thus is forced to infer that some processes of consciousness—for example, intuition—must be "nonalgorithmic." By describing algorithm at the mental model level only, some aspects of consciousness for Penrose become inexplicable and thus his term nonalgorithmic. Yet, he uses terms like "see" and "feel" in the brain process intuitional sense as if these come to consciousness free of any rules or methods (nonalgorithmic) at all—a rather surprising suggestion for a physicist! When it is recognized that all algorithmic organization begins in the brain, and these, in turn, give rise to the mental models of mathematics and artificial intelligence, the term nonalgorithmic could only mean "nonbrain." In NP what Penrose calls nonalgorithmic are the deterministic, yet unpredictable features of chaotic nonlinear dynamical systems. These are not ruleless nor methodless. For more complete discussion of algorithms see Vandervert (1991, 1992).

consistent modeling of *consciousness, mind,* and the *mind–body relationship* could proceed only in a likewise fully interconnected and interdefined fashion.

Accordingly, the present paper has three interconnected purposes: (a) to describe the evolution of an energy flow guidance framework (algorithmic organization) for space–time *consciousness,* (b) to describe the subsequent energetic exteriorization of the mental models of culture (collectively, *mind*) from the preadapted algorithmic organization of the brain described in (a), and (c) to describe a holographic energy framework relationship between our experiences of "body" on the one hand, and "mind" on the other, as a generalized differentiation of (a) and (b) above.

The evolutionary instantiation of the space–time activity framework of consciousness

Consciousness, like everything else in nature, can be understood as an outcome of dynamic energy principles—the principles of thermodynamics (see Atkins, 1984 for a sophisticated, yet easy to follow introduction). Viewed from its energy framework, the evolutionary struggle for existence is always the struggle for energy capture within the two fundamental conditions of organic existence, *space and time* (see Boltzmann, 1905, 1974; Lotka, 1922, 1945; Odum, 1988; Odum & Odum, 1981). In NP the evolution of brain algorithms, or brain energy patterns of *space and time* and those of *consciousness* are inseparable. A definition of consciousness as the activity of the space–time algorithms of the brain will be provided shortly.

The common basic design of brains and nervous systems across phyla illustrates that the evolution of algorithms that deal with space and time contingencies, for example, those of the brain's hippocampus, the evolutionary floor of the cerebral cortex (O'Keefe, 1985; O'Keefe & Nadel, 1978), extends back in time over hundreds of millions of years. Thus, consciousness as a category of nervous activity is very old, and the human brain can be viewed as carrying in it a triune paleontology of consciousness that involves that of reptiles, prehominid mammals, and humans (MacLean, 1975, 1990).

From where did consciousness come? From what general dynamical conditions was it constructed and encapsulated in the brains of creatures? Lotka (1945) provided a rather straightforward universal way of understanding the manner in which brain algorithmic patterns of energy flow might be selected and retained from (constructed from) space and time activity on the parts of "*the dynamics of systems of energy transformers*" [the dynamics of systems of energy creatures] (p. 179). We can adapt the scenario provided by Lotka to help understand the evolutionary and dynamical instantiation and encapsulation of the algorithms of consciousness as the pure or generalized form of this space–time *activity.* It might be helpful in the following example to imagine, for example, the "pursuer" as a fox, and the "pursued" as a rabbit:

> An admittedly primitive illustration of the mode of approach to the problem [for our purposes the problem of describing the dynamic selection of the algorithmic organization of consciousness in the brains of creatures in terms of the maximum-power principle] is the case of a "pursuing" transformer [a creature] of velocity v_1 seeking encounter with a "pursued" transformer of velocity v_2 while

the latter flees in a straight line [or any other pathway for our purposes here] toward a refuge of safety. The pursuer, constantly directed toward the pursued, then follows a so-called "curve of pursuit" [or ensemble of curves]. Whether capture occurs or not depends on the relative position of the pursuer and the pursued at the *time* [italics added] when the first stage of the pursuit, the "stalk," begins (that is, when the pursuer first directs his course toward the pursued); and depends further on the *time* [italics added] when the second stage begins, namely when the pursued first reacts by "flight" to the "attack" of the pursuer. [These two stages combined describe a dependency on initial conditions, much as sensitivity to initial conditions is a feature of the behavior of chaotic systems.] The problem [see opening line of this quote] thus conventionalized resolves itself to a problem of geometry. [More accurately described, we now know by *fractal* geometry, the geometry of chaos, and nonlinear flight and pursuit paths.] Capture certainly occurs [receptor–effector neural circuitry of pursuer is selected], or does not occur [receptor–effector neural circuitry of pursuer is selected], according as a certain circle[s] and ellipse intersect, capture occurs for some initial positions [initial conditions] and does not occur for others. In this conventionalized case we can, for example, discuss the influence upon the probability of capture, or variations in the velocities v_1 and v_2 or in the degrees of perfection of the receptors, etc. Carrying this model somewhat further, the influence of the density of the distribution of refuges in the territory may be discussed [for the mathematical treatment see Lotka (1932)]. (p. 183)

In sum, through countless iterations of Lotka's scenario (extended to the time scale across phyla) and its space–time representation that appears in Fig. 1, isomorphic energy transforms of the space, time, and sense modalities of evolving creature activity involving the pursuer/pursued *relationship* become encapsulated (literally, placed in a protective "container") in a chaotic/fractal algorithmic
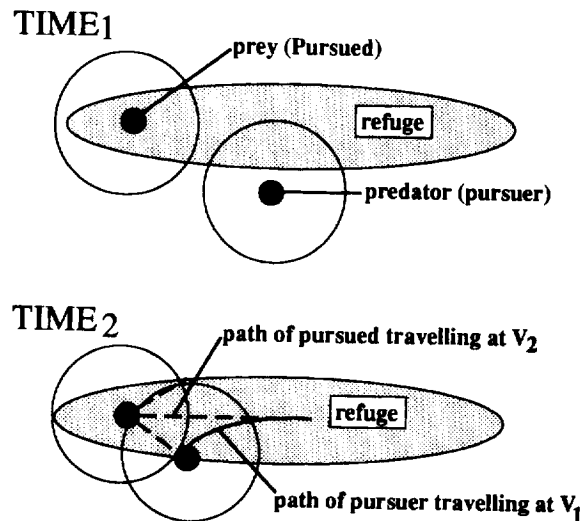

Fig. 1. Countless millennia of iterations of selective processes in this generalized prey–predator scenario resulted in the encapsulation of space–time algorithms in the brain. Algorithms are patterns of energy pathways (methods of work) that solve problems.

organization of the nervous systems and their bodies of each generalized species. As Crutchfield, Farmer, Packard, and Shaw (1986) suggested, the chaotic/fractal nervous system that has been selected has met the demands of the chaotic/fractal possibilities of an ever-changing environment:

> Chaos is often seen in terms of the limitations it implies, such as lack of predictability. Nature may, however, employ chaos constructively. Through amplification of small fluctuations it can provide natural systems with access to novelty. A prey escaping a predator's attack could use chaotic flight control as an element of surprise to evade capture. Biological evolution demands genetic variability; chaos provides a means of structuring random changes, thereby providing the possibility of putting variability under evolutionary control. (pp. 56–57) (See also MacLean (1991), and Vandervert (1990–1992) for discussions of chaotic/fractal brain processes.)

In NP the maximum-power evolution of a space–time neuromatrix in creatures constitutes the basis of their self-referential and autocatalytic (see Appendix) *consciousness*. It is to such a description and definition of consciousness we now turn.

The definition of consciousness

The hardwired space–time cognitive mapping functions of the brain's hippocampus have been described in some detail by O'Keefe (1985), and O'Keefe and Nadel (1978). However, there is a deeper question. Is there evidence for a hardwired space–time neuromatrix in the brain that could translate into the experience of consciousness? Melzack (1992) has developed a pervasive model to account for the diversity of phantom limb experiences that involves circuitry throughout the brain, and that I think jibes well with our everyday experience of an active "stream of consciousness." To explain vivid phantom limb experiences among people born without the particular limbs in question, Melzack has proposed a hardwired neuromatrix dispersed over three major brain circuits that *continuously generates* a pattern of impulses that indicates "that the body is intact and unequivocally one's own" (p. 123). I interpret these hardwired patterns of impulses closely in line with Melzack's interpretation to represent a continuously-generated *feedforward* template of the *active* "body universe." That this continuously-generated pattern of impulses represents a pure space–time template for the body is evidenced by the fact that the missing body part *even if congenital* is experienced as extended in space and time.

Thus, the phantom limb experience, somewhat surprisingly perhaps, is a(the) vital clue as to the origin and nature of consciousness we all experience. While Melzack did not connect his model with consciousness, I propose that conscious experience *is* the continuously-generated entirety of the activity of the *pure* space–time template of the *body in the brain*—it feeds forward the integrity and "whereabouts" of the genetically-derived template of the body universe. It is my view that consciousness continuously constructs this model of space–time in the brain as a comparator system by which the brain can movement-by-movement, moment-by-moment differentiate itself from, and make sense of, the constant barrage of incoming sensory information *as it itself continuously reconfigures its own*

dimensionalities as, for example, in the Lotka scenario. (One of the three major brain circuitries proposed by Melzack provides the brain with a sense of self.) Without the comparator function of consciousness as described here, the evolution of self-contained, self-referential organisms would not seem to be possible. Without the continuously fed forward parameters of the space–time of the organism moving through the larger space–time of its surroundings as depicted in the Lotka scenario, the organism (figure)-environment (ground) differentiation would breakdown, and the chaos of total disorder that preceded the cosmos (order) would reign. It appears that consciousness is as fundamental to our being as it possibly could be, and as it, in fact, *seems* to us to be.

Lotka's space–time activity scenario coupled with Melzack's continuously generating neuromatrix has provided the basis for a preliminary chaos-theoretical definition of consciousness. However, the more complete story of space–time, and therefore consciousness, lies with Pribram's (1991) holonomic brain theory.

PRIBRAM'S HOLONOMIC COMPOSITION OF SPACE AND TIME IN THE BRAIN

In NP it is proposed that *chaotic–holographic* space and time have been encapsulated in the brain through countless millennia of iterations of maximum-power principle energy flow refinements via the struggle for survival (energy capture) among creatures as depicted in the Lotka scenario and Fig. 1 (Vandervert, 1991, 1993). In this section the specific question that will be papered is as follows: what neurological structures and related dynamics have evolved to represent holographic space and time in the brain's neuromatrix that give rise to consciousness (and the holographic apparitions of phantoms)?

Within Pribram's (1991) *holonomic* brain theory (as differentiated from his earlier purely "holographic" brain theory, see pp. 26–29) holoscapes are described as organizations of dendritic microprocessing wherein space and time, and spectra (sensory modality and form information) are embedded. Holoscapes are the fundamental units of dendritic microprocessing and are comprised of ensembles of frequency, amplitude, and phase activity—the coordinated information necessary to project a hologram. Networks of holoscapes are therefore transformable in the brain into our everyday holographic-like experiences of perception and cognition (including dream states) *in* a ground of space–time consciousness, and all composed within the skull. Holoscapes are by definition algorithmic* in guiding energy/information flow compositions toward optimization (minimum entropy or disorder/maximum information) both in phylogenesis and ontogenesis. This entropy/information aspect of processing in holoscapes connects their evolution with the complementary thermodynamic principles of maximum-power evolution (as modified by Vandervert, 1991) which drive living systems progressively toward higher qualities of energy flow and entropy minimization.

We can now describe in terms of maximum-power evolution how holonomic networks have come to provide just an essential fit of characteristics and tremendously refinable processing in motor-perceptual-cognitive systems that, in

---

*See footnote, p. 110.

order to survive, must master an environment cluttered with prey and predators, and a myriad of other objects and events in constant flux. D'Arcy Thompson (1917) long ago anticipated the dynamical evolution of whole systems such as networks of holoscapes that compose the adapted world inside the skull:

> The form, then, of any portion of matter, whether it be living or dead, and the changes of form which are apparent in its movements and in its growth, may in all cases alike be described as due to the action of force. In short, the form of an object [including its detailed internal structure] is a 'diagram of forces', in this sense, at least, that from it we can judge of or deduce the forces that are acting or *have acted upon it* [italics added]. (p. 11)

Like the fish's fin that reflects the hydrodynamic properties of water (Lorenz, 1977, p. 6), then, the holonomic organization of the brain represents a "diagram of forces" that mirrors its own evolutionary history of the complex energetic necessities of survival.

Below is a description of the features of the diagram of forces (as Thompson would have put it) of holonomic processing:

1. The projection of experience away from its locus of processing—the world composed inside the skull appears to consist of objects and events "out there." It is difficult to imagine any workable evolutionary prey–predator scenario without such holographic-type exteriorizing projection. In NP this automatic projection of experience away from its actual locus in the brain is referred to as *primordial perceptual constancy,* which is thought to provide the ground and process of consciousness for all other constancies, for example, the color, size, and shape constancies. (See Vandervert, 1990, pp. 9–11 for a discussion concerning the primordial constancy, and how it has influenced the development of science.)

2. The enfoldment and storage of multiple "hidden" nested orders among networks of holoscapes which may be activated by attentional and intentional processes. And, the immediate recognition of any minute portion of a figure as the entire figure *even if never before consciously perceived in that particular fraction.* The tip of a predator's ear, a muffled sound displaced in space and time, or an olfactory nuance is immediately recognizable as the presence of the entire figure. (Many images may be recorded in a single hologram, and any portion of a hologram contains the entire hologram.) It is my view that Melzack's hardwired neuromatrix is holographic.

3. Tremendous storage capacity, rapid retrieval, and practically instantaneous cross- and auto-correlation in computing power for processing 1 and 2 above.

In summary of this section, the space–time, and spectral, holonomic features of the algorithmic organization of the brain provide a better picture of the body neuromatrix or "diagram of forces" that reflects the overall dynamics of the Lotka scenario. Pribram's holonomic model is absolutely critical, it seems, in that it allows us to understand the generation of holographic-like spatial and temporal experience of phantom limbs; it allows us also to extend Melzack's neuromatrix conception to aspects of the sense modalities to understand holographic-like phantom seeing and phantom hearing experiences (see Melzack, 1992, p. 123) among those so impaired. In NP, consciousness *is* the continuously generated

entirety of the *pure* holonomic body in the brain—a continuously active body universe of space–time, and spectra, including the constancy mechanisms. Consciousness is this holonomic world of awareness composed within the skull. In the next section the emergence of the exteriorization of symbol systems (including mathematics) and mental models will be described as a natural evolutionary extension of these holonomic features—form autocatalytically arising from pre-existing autocatalytic form. The space–time, spectra algorithmic patterns of consciousness in the brain will thus be connected to the space–time, spectra of *mental models* including those of the mathematics of chaos and holography— collectively, *mind.*

UNFOLDMENT: HOW AND WHY THE ALGORITHMIC ORGANIZATION OF THE CONSCIOUS BRAIN EXTERIORIZES IN THE FORM(ALISMS) OF MENTAL MODELS

In NP, mind and its definition are derived directly from the dynamics of brain evolution, and from the algorithmic properties of consciousness described above. Mind consists of patterns of brain subcircuitry that are selected from those of the algorithmic organization of the brain in accordance with the maximum-power principle (see Appendix). Mind is palpable in two forms: (a) as patterns of subcircuitry erected and nested in a self-similar, self-referential fashion in the holonomic brain, and (b) as exteriorizable (culturally sharable) mental models.* More than 20 years of sophisticated global electroencephalographic studies that monitor circuitry-specific modeling activity in the brain are completely consistent with this idea (Gevins, 1989). *Mind* is defined as one's collection of culturally sharable mental-model circuitry configurations in the brain. Mind thus began with cultural evolution, perhaps with *Homo habilis* some two million years ago, and continues to evolve in both its composition and nature. (Lower animals are conscious, but since they do not have culture they likewise do not have appreciable "minds.")

The chaotic/fractal maximum-power autocatalytic production of mind in this manner is an entirely natural energetic affair that follows self-referential and thermodynamic principles in making progressively more high quality energy (see Odum, 1988; Vandervert, 1991) available to the brain–mind system—the struggle for energy capture extended to a new level. The autocatalytic evolution and exteriorization of mental models through *thinking* is depicted in Fig. 2. It is proposed that the continuously iterated process of thinking has resulted in the gradual, yet progressively accelerating, cultural exteriorization of the features of the algorithmic organization of *consciousness* as defined earlier, especially of the more recent approximately 40,000 year old brain of *Homo sapiens* (Vandervert, 1991). This process constitutes the unfoldment of cultural history (Vandervert, 1991, 1992). As the algorithmic organization of the brain feeds upon itself in its autocatalytic search for symbolic patterns that maximize information processing and energy inflow to

---

*Mental models in NP are *representations* of conscious reality as defined earlier (space, time, spectra and constancies) which are *self-similar* in many ways, but not in all ways, to what is being represented. These models vary in level of abstraction (remoteness from what they represent) and in complexity. A common breakdown of types of mental models, in order of increasing abstraction and complexity, is the following continuum: (a) *iconic* (in its own image), (b) *analogic/homologic* (parallel in form, but not self-same), (c) *symbolic* (algebraically isomorphic) (Ackoff, Gupta, & Minas, 1962).

the overall system, it *inherently* bestows (dynamic from pre-existing dynamic) upon them appropriate portions of its own algorithmic patterns—the patterns that must undergird shared symbolic mental models of, for example, mathematics, science, art, music, if they are to be of any adaptive advantage. (Symbol systems in themselves are worth nothing if not produced and read by humans or human-designed contrivances.) The thus exteriorized algorithmic patterns that appear in symbol systems are therefore not really new patterns, but are in a variant isomorphic form that has proven to be a newly useful advantage to the creature's survival.

The autocatalytic transformation to symbol systems constitutes the evolution of a second universal variant of the conscious perceptual–cognitive order of the brain *that is now applicable to the energy-information manipulation of the entirety of those things and events perceived, cognized, and moved about, including the brain and its operations themselves.* This means, once exteriorized in shared mental model form, the powerful holonomic neural energy dissipative patterns that once only governed "seeing" a tree, for example, can be applied to the manipulation of the complete energy/matter patterns that constitute the knowable "external" tree *itself.* The tree "itself" (as it is constructed by the brain) can be "holonomized" in the form of exteriorizeable mental models in the same fashion that the brain created that representation of it in the first place—a comparatively rapid cultural unfoldment into mental model form of the maximum-power evolutionary process that originally instantiated it. The holonomic brain algorithms can create (are autocatalytically exteriorizeable as) models of a number of levels of abstraction and complexity leading to those of its own holonomic organization. Since the same transformational processes that are behind the evolution of the encapsulation of real world forces in holonomic conscious perception/cognition (Pribram, 1991, pp. xxv–xxix) are also behind the evolution of their isomorphic exteriorization in symbol systems they are, therefore, necessarily mappable back onto those original real world forces—thus the necessary workability of science and mathematics in the "real world".* We should no more be surprised by the workability of mathematics in the real world than we are at the *possibility* of music and art. For human beings, locked inside the general chaotic attractor loop depicted in Fig. 2, a system's essence is its overall holonomic existence. It is my view that the autocatalytic thinking process that emerged from the continuously generated space–time, spectra algorithms of consciousness represent the actual relationships among world, brain, and mind that undergird what Bohm (1973) and Bohm and Peat (1987) refer to as the *holomovement.* I think Bohm's theoretical model is incorrect, but he has the conclusion essentially right.

In summary, we can now define consciousness and mind dynamically and interdependently. *Consciousness* is the activity of the algorithmic organization of the brain that is associated with the continuously generated, fed forward holonomic neuromatrix of the body universe (the uniquely human slice of reality arising originally from the generalized Lotka scenario). The self-contained activity of consciousness is an encapsulation of the activity of the Lotka scenario that
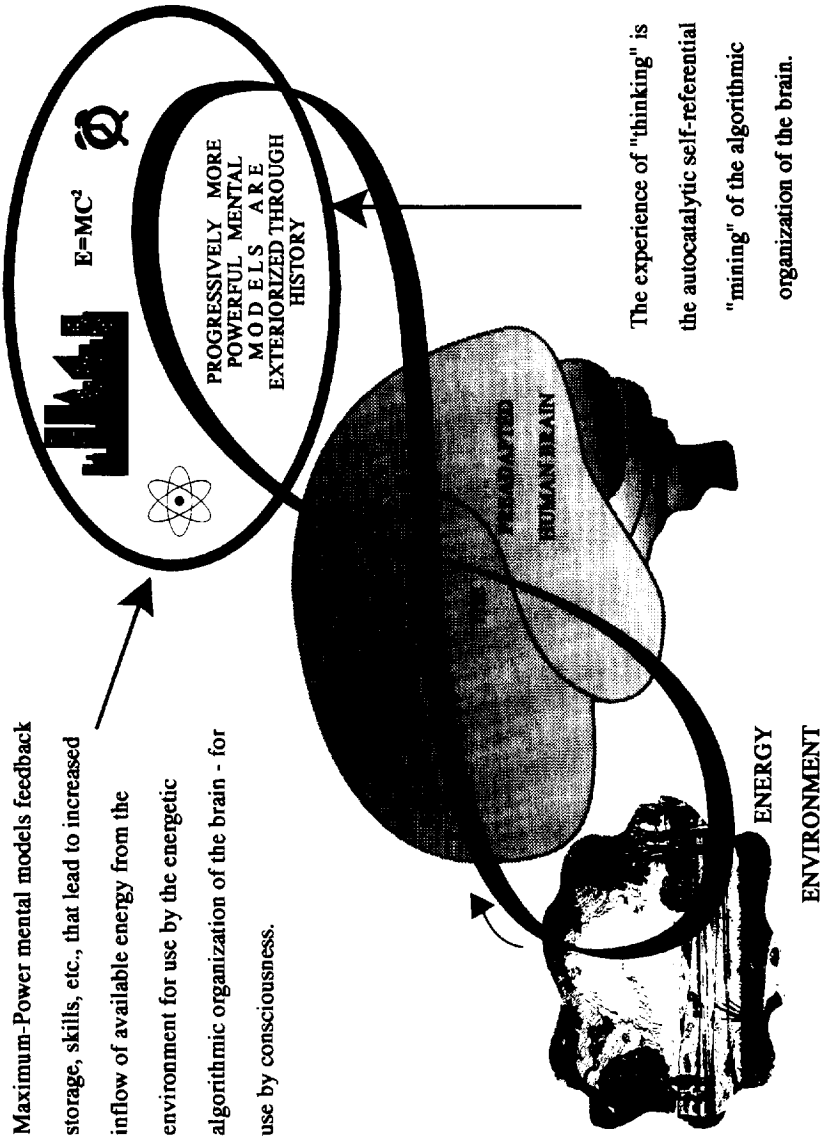
*See footnote, p. 109.

Fig. 2. Simplified positive feedback autocatalysis (self-organizing) energy diagram illustrating the exteriorization of mathematical symbol systems from the algorithmic organization of the brain. Symbol systems and mental models feed back into the algorithmic organization of the brain, which can thereby modify the environment in new ways. The appearance of the figure-eight mobius energy loop connecting world, brain, and mind is more than coincidentally reminiscent of Hofstadter's (1979) "strangeloop." In NP it is its algorithmic origin. For more detailed illustrations of autocatalytic energy diagrams consult, for example, Odum (1983, 1988); Odum and Odum (1981).

differentiates itself from the larger dynamics of the environment. *Mind* arises autocatalytically from the feedforward dynamic of the holonomic neuromatrix of consciousness in the form of culturally sharable mental models. The feedforward dynamic "mines" the algorithmic organization of the brain in maximum-power manner for modeling patterns that increase the probability of energy flow available for use by the brain. *The mental models of mind are thereby mappable back onto the neuromatrix of conscious experience—back onto experienced human reality.* Mind and body are *algorithmically isomorphic.** With consciousness and mind dynamically nested as described above, we can understand the perplexing problem of how it is possible to simply sit quietly thinking, and create a new idea, system of equations, or technology that works in the "real world." Consciousness, thinking, and mind are dynamically interconnected in a seamless web (see Fig. 2).

A THERMODYNAMIC–HOLOGRAPHIC RESOLUTION TO THE MIND–BODY PROBLEM

Now that consciousness and mind have been connected dynamically, we are in a position to understand better the seemingly different in *kind* experiences of mind and body—the age-old mind–body problem (for easy to follow discussions of various aspects of the mind–body problem see, for example, Bertalanffy, 1964; Fodor, 1981). It seems that any useful modeling of the mind–body problem should be consistent as to its dynamical features and processes so that (a) the respective experiences of mind and body can be delineated within them clearly, and that (b) the method of interaction between mind and body follows directly from them. We may never get at actual essences of the natures of mind and body and their interaction; it seems, however, we *can* at least expect what Neils Bohr (1934) expected from the quantum universe:

> In our description of nature the purpose is not to disclose the real essence of the phenomena but only to track down, so far as it is possible, relations between the manifold aspects of our experience. (p. 18)

In NP the experience of the mind–body problem, and the explanation of the mind–body relationship take place only among the manifold collections of subcircuitry inside each of our skulls.

---

*Within the system–theoretical framework Bertalanffy (1967) described *algorithmic isomorphism* among machines, brains, and conscious mind:

Obviously, logical operation performed in consciousness and the structure and function of the brain "is" not an electronic computer with transistors, wires, currents, programs and the rest. But in their formal structure they are comparable. Similar algorithms obtain: a computer (and a brain in its rational aspects) is, as it were, a materialization of logical operations, and vice versa logical operations are the conceptual counterpart of the functioning of a suitably constructed computer. This correspondence is a rather deep one. Boolean algebra and binary notation used in modern computers, the functioning of synapses according to the all-or-none law, and Aristotelian logic in thinking are structurally the same; the same algorithm or abstract model applies. (p. 100)

The algorithmic unity of world (machines in Bertalanffy's example), synaptic configurations in the brain, and mind (the subcircuitries for the mental model of, for example, Aristotelian logic) is the central positivistic tenet of NP (Vandervert, 1988, 1990). Since, in NP, everything knowable is based upon the algorithmic organization of the brain, there are necessarily no "nonalgorithmic" processes possible. This position would be falsifiable with the demonstration of something moving about at absolute zero. Such a demonstration would, however, violate the third law of thermodynamics.

Body

As described earlier, the activity of the neuromatrix of the body *is* consciousness, and this consciousness provides us with the only "body" we can really ever know. Whenever we imagine or think about bodies, brains, or the objects of awareness they seem to be "out there," just as do phantom limbs. This world "out there" is the world of physics and the physicists with all their instrumentation cannot study a world that lies beyond the neurology of human consciousness. As MacLean (1990) put it:

> Every behavior selected for study, every observation, and every interpretation, requires subjective processing by an introspective observer. Logically, there is no way of circumventing this or the other inescapable conclusion that the cold, hard facts of science, like the firm pavement underfoot, are informational transformations by the viscoelastic brain. No measurements obtained by the hardware of the exact sciences are available for comprehension without undergoing subjective transformation by the "software" of the brain. (p. 5)

(In NP this predicament of consciousness translates into a limitation on the mental models of physics—including the mind–body modeling I am presently describing, see Fig. 2 caption. It is my belief that this predicament is the actual source of the limitations that have been encountered with quantum mechanical theory and the variety of observer-constrained realities it suggests (see, e.g. Herbert (1985) for straightforward and easy to follow discussions of quantum realities)).

Body is palpable in the form of the continuously generated space–time, spectral *activity* of its hardwired neuromatrix. This is in no way a solipsistic body. It is a body fully in tune with its larger environment. Here I am describing our only possibility of the experience of a body (or a palpable brain)—that which is provided by the activity of its neuromatrix. Melzack (1992) captured my intent here well:

> The brain does more than detect and analyze inputs; it generates perceptual experience even when no external inputs occur. We do not need a body to feel a body . . . the brain generates the experience of the body. Sensory inputs merely modulate that experience; they do not directly cause it. (p. 126)

Again, it is my view that this is, in fact, the *only* space–time body we can ever feel, know, or analyze. When we model the mind–body relationship, it is always this body neuromatrix that we have as referent. It is all we can ever mean by "body."

Mind

Through the energetic process of cultural evolution, mind (sharable mental models constructed in the algorithmic organization of the brain) arises autocatalytically from the body neuromatrix and the rest of the preadapted brain in accordance with the maximum-power principle (see Fig. 2 and Appendix). Mind is palpable in the form of the neural circuitry patterns of mental models in the brain that reside in a nested fashion among those of the body neuromatrix in holonomic networks of holoscapes. Thus, the body neuromatrix and the rest of the preadapted brain is projected into the fundamental algorithmic organization of mental models. Johnson (1987) has proposed a thoroughgoing theory of human meaning, imagination, and reason that is based upon metaphor and that squares well with

NP's account of the evolution of mental models from the body neuromatrix. However, Johnson has not provided evolutionary, or dynamical mechanisms for his body–mind relationship theory. The dynamically nested relationship between body and mind neuromatrices is depicted in Fig. 3.

The chaotic–holographic–thermodynamic mind–body relationship

Inside the skull, "body" is projected to seem to be "out there" (left image, Fig. 3); while the mental models of mind are projected to seem to originate and seem to be "in there" (right image). It is my view that the projective separation of body and mind is a new macro level self-referential copy of the original figure–ground separation of the dynamical body from its dynamical surround described earlier. The survival value of the mind–body separation is as great as the original environment–body separation upon which it is erected. For example, confusion in the overall brain system between consciousness itself and hypothetical mental models of consciousness would be disastrous! For cave dwellers living 40,000 years ago confusion between themselves and their cave paintings (mental models) would equally not make sense.

Fig. 3. Two images photocopied from the same hologram. Holograms, with their various features, represent a fundamental way in which to demonstrate aspects of Pribram's (1991) holonomic brain theory which models (both conceptually and mathematically) perceptual and cognitive processing going on in the brain. The many regimes of information processing that are embeddable in holograms (as portrayed in two regimes in these images of Arnold Schwarzenegger) illustrate in a simple way how the many experiences of body and mind (mental models) might occupy the same space–time, spectral dynamical field. *Note:* From Polaroid Corporation, Holography Business Group, Cambridge, MA. Computer adapted by permission.

Many other features of experience fall within the theoretical horizon of the conception of a holonomically nested mind and body. For example, the *interpenetration* of conscious and unconscious activity, the *organization* of dream mentation, *alternation* of personality regimes in multiple personality disorders, and perhaps the *patterning* of Jungian archetypes. All of these phenomena could be viewed as nested children of the larger holonomic mind–body differentiation.

Interaction and change in the mind–body relationship

The principles of mind–body interaction and change can be only adumbrated here. Interaction between the algorithmic organization of the body neuromatrices on the one hand, and those of the brain's collection of cultural mental models on the other is that of the maximum-power (autocatalytic) organization of the latter from the former (see Fig. 2). Energy autocatalysis is the algorithm or method of interactive causation. This self-referential activity originated and continuously occurs because it results in increased energy flow to the modeling systems. I will provide examples of such increased energy flow in a moment. The autocatalytic relationship between mind and body is a completely natural process occurring in accordance with the second law of thermodynamics—the law that describes the distribution of energy in nature (see, for example, Atkins, 1984).

The body neuromatrices influence and constrain in a *downward* causal fashion the possibilities of mental model circuitries—they create them in a self-similar pattern. Within the brain's holonomic scheme the generation of potential mental models is virtually boundless, and, given their history and ongoing environmental circumstances, the *particular* form new mental model creations will take is unpredictable. However, the autocatalytic creation of *progressively* more powerful mental models in mathematics, computer science, and technology, for example, illustrate the general trend. The mental models of mind can influence the body neuromatrices only in the indirect sense that they can alter the *rate* of autocatalysis that leads to the formation of new models. For example, "paradigmatic" mental models accelerate the creation of new mental models within that paradigm.

Change in the mind–body relationship

The algorithmic efficiency of the mental models of mind have historically lagged behind that of the algorithmic organization of the body neuromatrices (Vandervert, 1991, 1992, 1993). The gap was great in the time of *Homo habilis* and its simple fire-making (energy capturing) mental model algorithms. On the other hand the development of brain-like computing system mental models that tremendously amplify information flows (high quality energy flows) match more closely the algorithmic organization of the neuromatrices. The gap between the algorithmic efficiencies of mind and body constitute a mind–body *uneven central-energy-state "identity."* In NP, the term *identity* is redefined in terms self-similarity and self-referentiality (not self-same) to describe the actual chaotic/fractal

thermodynamic processes of dynamical unfoldment. The historically closing mind–body relationship provides an explanation for the cultural evolution of mental models toward greater and greater efficiency. We can now see that the drive toward the modeling of, for example, virtual reality computing systems, and physical "theories of everything" are completely natural outcomes of the autocatalytic process depicted in Fig. 2. A true or "even" central-energy-state identity could only be achieved with a full exteriorization of the neuromatrices of consciousness in mental model form. Perhaps this would take the form of a hardwired, conscious computing system. Only time will tell. It appears that the mind–body relationship *itself*, like everything else in the universe we can know, undergoes constant change.

Conclusion and implications

NP is a new kind of positivism that is equally a dynamical evolutionary epistemology, and a systems-theoretical epistemology (see, for example, Bertalanffy, 1967, 1968, for systems theory). It is a contention of NP that the most complete understandings of phenomena are obtainable with the interpenetration of disciplinary boundaries. Drawing upon interrelated ideas and mechanisms from dynamical systems theory, general systems theory, psychology, thermodynamics, evolutionary theory, neuroscience, philosophy, and holonomic brain theory, this paper describes the interconnections among consciousness, mind, thinking, and the mind–body relationship, and their implications for the unification of intuition and science/mathematics.

NP's view of the evolution of mental model systems, including mathematics (collectively, mind), can provide a sense of direction about where we are headed with them and why we are headed there. The development of brain-like computing systems, and brain-like virtual reality systems can be viewed as natural cultural exteriorizations of brain algorithmic patterns of organization. Perhaps this is why computing systems have led us to redefine mathematics, for example, as *the science of patterns* (Steen, 1988). Computing systems are approaching perhaps their own origins in the patterns of the brain. Along this line, Moravec (1988, 1992), for example, has predicted a future evolution of robotic brain-like systems through the following sequence: the dumb robot (ca. 2000–2010); learning robots (ca. 2010–2020); imagery world-modeler robots (ca. 2020–2030); reasoning robots (ca. 2030–2040); human equivalence (2050 and beyond). According to NP, Moravec's scenario is in complete agreement with an evolutionary unfoldment culminating in the full cultural exteriorization of *appropriate portions* of the algorithmic organization of the brain in symbolic mental model form—that is what it will take, precisely, to obtain human computational equivalence in a computing system (Gödel notwithstanding, see, for example, Nagel and Newman, 1958). At this point the mind–body relationship will have achieved a true *central-energy-state-identity*.

We can begin to wonder about the possibilities of what some "final or full cultural-level exteriorization" of the algorithmic organization of the brain might be like. According to NP's emergent hypothetical realism (see footnote, p. 109), that

outcome is presently unpredictable and not yet fully imaginable; however one might imagine a science/arts technology in full control of the same emergent evolutionary process that brought humans to consciousness and then to mind—an emergent "self-selection" toward entropy minima (maximum information) where ultimately anything and everything imaginable might be realizable. Here would be a *true* theory of everything; here would be, as Stephen Hawking (1988) put it, "the mind of God" (p. 175). Perhaps this would represent the cultural-level exteriorization and understanding of the deepest of mysteries, of our consciousness of the universe itself. But, this would only be the beginning of a new emergent level of human understanding.

REFERENCES

Abraham, R., Abraham, R., & Shaw, C. (1990). *A visual introduction to dynamical systems theory for psychology.* Santa Cruz, CA: Aerial Press.

Ackoff, R., Gupta, S., & Minas, J. (1962). *Scientific method: Optimizing applied research and decisions.* New York: John Wiley & Sons.

Atkins, P. W. (1984). *The second law.* New York: Scientific American Books.

Bell, E. T. (1937). *Men of mathematics.* New York: Simon and Schuster.

Bertalanffy, L. von. (1964). The mind–body problem: A new view. *Psychosomatic Medicine, 26,* 29–45.

Bertalanffy, L. von. (1967). *Robots, men and minds: Psychology in the modern world.* New York: George Braziller.

Bertalanffy, L. von. (1968). *General system theory.* New York: George Braziller.

Bohm, D. (1973). Quantum theory as an indication of a new order in physics. Part B. Implicate and explicate order in physical law. *Foundations of Physics, 3,* 138–168.

Bohm, D., & Peat, F. D. (1987). *Science, order, and creativity.* New York: Bantam.

Bohr, N. (1934). *Atomic theory and the description of nature.* New York: MacMillan.

Boltzmann, L. (1905). *The second law of thermodynamics.* Dordrecht: Reidel.

Boltzmann, L. (1974). *Theoretical physics and philosophical problems.* Dordrecht: Reidel.

Boring, E. (1950). *A history of experimental psychology* (2nd ed.). New York: Appleton-Century-Crofts.

Campbell, D. T. (1959). Methodological suggestions from a comparative psychology of knowledge process. *Inquiry, 2,* 152–182.

Campbell, D. T. (1974). Evolutionary epistemology. In P. A. Schilpp (Ed.), *The philosophy of Karl R. Popper* (pp. 413–463). LaSalle, IL: The Open Court Publishing Company.

Crutchfield, J., Farmer, J., Packard, N., & Shaw, R. (1986, December). Chaos. *Scientific American, 12,* 46–57.

Fodor, J. A. (1981, January). The mind–body problem. *Scientific American, 244,* 114–123.

Gevins, A. (1989). Signs of model making by the human brain. In E. Basar & T. H. Bullock (Eds.), *Springer series in brain dynamics 1* (pp. 408–419). Berlin: Springer-Verlag.

Gleick, J. (1987). *Chaos: The making of a new science.* New York: Viking Press.

Hawking, S. (1988). *A brief history of time.* New York: Bantam.

Herbert, N. (1985). *Quantum reality.* Garden City, NY: Anchor Press/Doubleday.

Hofstadter, D. (1979). *Gödel, Escher, Bach: The eternal golden braid.* New York: Basic Books.

Holton, G. (1979). Constructing a theory: Einstein's model. *The American Scholar, 48,* 309–339.

James, W. (1890). *The principles of psychology.* New York: Holt, Rinehart & Winston.

Johnson, M. (1987). *The body in the mind: The bodily basis of meaning, imagination, and reason.* Chicago: The University of Chicago Press.

Koestler, A. (1964). *The act of creation.* New York: The MacMillan Company.

Lorenz, K. (1962). Kant's doctrine of the a priori in light of contemporary biology (C. Ghurye, Trans.). *General systems: The yearbook of the society for general systems research* (Volume

VIII, pp. 23–35). Ann Arbor, MI: University of Michigan Press. (Original work published 1941)

Lorenz, K. (1977). *Behind the mirror: A search for a natural history of human knowledge* (R. Taylor, Trans.). New York: Harcourt Brace Jovanovich. (Original work published 1973)

Lotka, A. J. (1922). A contribution to the energetics of evolution. *Proceedings of the National Academy of Science,* 8, 140–155.

Lotka, A. J. (1932). Contribution to the mathematical theory of capture. *Proceedings of the National Academy of Sciences,* 18, 172–178.

Lotka, A. J. (1945). The law of evolution as a maximal principle. *Human Biology,* 17, 167–194.

MacLean, P. (1975). On the evolution of three mentalities. *Man-Environment Systems,* 5, 213–224.

MacLean, P. (1990). *The triune brain in evolution: Role in paleocerebral functions.* New York: Plenum.

MacLean, P. (1991). Neofrontocerebellar evolution in regard to computation and prediction: Some fractal aspects of microgenesis. In R. Hanlon (Ed.), *Cognitive microgenesis* (pp. 3–31). New York: Springer-Verlag.

Melzack, R. (1992, April). Phantom limbs. *Scientific American,* 266, 120–126.

Moravec, H. (1992). The universal robot. *Speculations in Science and Technology,* 15, 286–294.

Nagel, E., & Newman, J. R. (1958). *Gödel's proof.* New York: New York University Press.

Odum, H. T. (1983). *Systems ecology: An introduction.* New York: John Wiley and Sons.

Odum, H. T. (1988). Self-organization, transformity, and information. *Science,* 242, 1132–1139.

Odum, H. T., & Odum, E. C. (1981). *Energy basis for man and nature.* New York: McGraw-Hill.

O'Keefe, J. (1985). Is consciousness the gateway to the hippocampal cognitive map? A speculative essay on the neural basis of mind. In D. Oakley (Ed.), *Brain & mind* (pp. 59–98). London: Methuen.

O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map.* Oxford: Oxford University Press.

Penrose, R. (1989). *The emperor's new mind: Concerning computers, minds, and the laws of physics.* New York: Oxford University Press.

Pribram, K. (1986). The cognitive revolution and brain/mind issues. *American Psychologist,* 41, 507–520.

Pribram, K. (1991). *Brain and perception: Holonomy and structure in figural processing.* Hillsdale, NJ: Lawrence Erlbaum.

Stadler, M., & Kruse, P. (1990). Cognitive systems as self-organizing systems. In W. Krohn, G. Kupers, & H. Nowotny (Eds.), *Selforganization: Portrait of a scientific revolution* (pp. 181–193). Dordrecht: Kluwer Academic Publishers.

Steen, L. A. (1988, April 29). The science of patterns. *Science,* 240, 611–616.

Thompson, D. (1917). *On growth and form.* London: Cambridge University Press.

Troncale, L., Lee, C., Nelson, K., & Tres, J. (1990). Six case studies of empirically-based chaos/fractal research: Does chaos/fractal analysis yield isomorphies for general systems theories. In B. H. Banathy & B. A. Banathy (Eds.), *Proceedings of the Thirty-Fourth Annual Meeting of the International Society for the Systems Sciences* (pp. 1157–1164). Portland, OR: International Society for the Systems Sciences.

Vandervert, L. R. (1988). Systems thinking and a proposal for a neurological positivism. *Systems Research,* 5, 313–321.

Vandervert, L. R. (1990). Systems thinking and neurological positivism: Further elucidations and implications. *Systems Research,* 7, 1–17.

Vandervert, L. R. (1991). A measurable and testable brain-based emergent interactionism: An alternative to Sperry's mentalist emergent interactionism. *Journal of Mind and Behavior,* 12, 201–209.

Vandervert, L. R. (1992). The emergence of brain and mind amid chaos through maximum power evolution. *World Futures: The Journal of General Evolution,* 33, 253–273.

Vandervert, L. R. (1993). Neurological positivism's evolution of mathematics. *Journal of Mind and Behavior,* 14, 277–288.

APPENDIX

Maximum-Power Principle. The maximum-power principle may be stated as follows: *Those systems that survive in the competition among alternative choices are those that develop more power inflow and use it to meet the needs of survival.* They do this by: (1) developing storages of high-quality energy; (2) feeding back work from the storages to increase inflows (self-referentially); (3) recycling materials as needed; (4) organizing control mechanisms that keep the system adapted and stable; (5) setting up exchanges with other systems to supply special energy needs; and (6) contributing useful work to the surrounding environmental system that helps maintain favorable conditions (Odum & Odum, 1981, pp. 32–33). Lotka (1922, 1945) formulated the maximum-power principle, suggesting that systems prevail that develop designs that maximize the flow of useful energy through feedback. These feedback designs are sometimes called *autocatalytic* (self-releasing, or feeding upon self) (Odum, 1983, p. 6). The autocatalytic relationship between brain and mind is one of *positive-feedback*, whereby energy dissipation is progressively accelerated. The maximum-power principle is a macro principle of self-organization (Odum, 1988; Vandervert, 1991) that *itself* becomes encapsulated in the algorithmic organization of the human brain, thus giving rise to the possibility of the evolution of the holonomic neural subcircuitry of the mind, It is manifest, for example, in the self-organization of the perceptual constancies, cognitive systems (e.g., Stadler & Kruse, 1990), and in the autocatalytic emergence of mental models (Vandervert, 1991, 1993).

The autocatalytic feeding back of higher-quality energy into increased energy inflow into the brain, as described by the maximum-power principle, can be viewed as an energy appearance of chaotic/fractal organization. Odum (1988) expresses this relationship in the following manner:

> Ecosystems, earth systems, astronomical systems, and possibly all systems are organized in hierarchies because this design maximizes useful energy processing. These systems look different until they are drawn with energy diagrams. . . . The series of energy transformations in the hierarchies formed by self-organization are cascades of successive energy fractions, which explains why Mandelbrot's (1977) fractals often describe nature. (pp. 1133–1135)

The relationship between the algorithmic organization of the brain and the algorithmic organizations of its mental model circuitry configurations can be viewed either in terms of *self-referential* energy flows (causal pathways), as Odum has done, or in terms of *self-referential* chaotic/fractal energy designs (Vandervert, 1991).

Recognition of the equivalence between the fundamental characteristics of maximum-power-principle hierarchies and those of chaotic-fractal energy designs, namely self-similarity (not self-sameness), self-referencing, and infinite hierarchy nesting, leads to the central principle of NP governing the cultural evolution of mind: in its production of mental-model brain circuitry, the algorithmic organization of the brain can increase energy inflows to itself most efficiently (maximum-power principle) by feeding back algorithmic mental model designs that are *similar* to itself. This is so because the brain, being at the top of the energy

hierarchy, represents the highest-quality energy configuration and could not feed back designs other than or superior to its own. Thus the brain is constrained to create its mental models, for example, science, art, technology, computing systems, virtual reality, in its own dynamical image, so to speak.