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Neurological Positivism's Evolution of Mathematics

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This article describes how Pribram's holonomic brain theory fits into Neurological Positivism's (NP) overall perspective of the evolution of the algorithmic organization of space and time in the brain. It is proposed that the principles of holonomic theory themselves represent a dynamical "diagram of forces" that have resulted from evolutionary processes—thus the holonomic space and time in the brain. The maximum-power evolution guided self-organizing, exteriorizing derivation of mathematics from the algorithmic patterns of the preadapted human brain is described. It is proposed further that the workability of mathematics in the "real world," far from being a mystery, is a necessary result of the origin of mathematics in neural circuitry patterns that are, in turn, encapsulations of real world dynamics. It is concluded that the organization of symbol systems is naturally approaching in power the algorithmic organization of the brain itself.

In previous articles (Vandervert, 1988, 1990, 1991, 1992) I have proposed and developed a neuroepistemology called Neurological Positivism (NP).[1]

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[1]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 (1941/1962a, p. 29; 1977, chapter 1), MacLean (1990, chapters 1 and 29), and Pribram (1986, 1991, pp. xxii-xxix).

NP subsumes the three traditional positivisms 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[2] 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 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 *in* space–time (Vandervert, 1991, pp. 211–214).

The present paper has two purposes: (a) to extend and refine NP's energetic maximum-power evolution argument to include the encapsulation of microdendrite networks of what Pribram (1991) in his holonomic brain theory calls *holoscapes*, and (b) to describe the maximum-power principle's energetic exteriorization of mathematics from the preadapted algorithmic organization of the brain through thinking.

Pribram's Holonomic Composition of Space and Time in the Brain

In NP it is proposed that space and time have been encapsulated in the brain through countless millennia of iterations of maximum-power principle

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[2]In NP algorithms are defined as *orderly methods* of energy/information *transfer* that will provide solutions to problems. Energy/information cannot solve problems (cannot do work) unless it is transferred in some thermodynamic algorithmic manner. The thermodynamic *methods* of heat and work constitute the definitional transfer bases for all algorithms. It may surprise some readers to learn that heat and work are described thermodynamically as *methods* of energy/information transfer and not as *things*. For a detailed explanation of these ideas that is clear to the layperson see, for example, Atkins (1984, chapter 2). In NP, since algorithms, energy, and information are interdependently defined, there are necessarily no "nonalgorithmic" problem-solving processes in the brain. For more complete discussion of algorithms see Vandervert (1991, 1992).

energy flow refinements via the struggle for survival (energy capture) among creatures and in the face of the vicissitudes of the environment (Vandervert, 1991, 1992). In this section the specific question that will be addressed is: What neurological structures and related dynamics have evolved to represent space and time in the brain?

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, and all composed within the skull. Holoscapes are by definition algorithmic (see footnote 2) 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 order to survive, must master an environment cluttered with prey and predators, and a myriad of other objects and events in constant flux. Before going on to a listing of these holonomic features, it is important to note that they have emerged in the brain (been encapsulated) as the result of the dynamics of evolution and *not* simply imposed upon the brain by Pribram's modeling. Konrad Lorenz (1973/1977), in his epistemological writings, expressed this concept of evolution well:

> The scientist sees man as a creature who owes his qualities and functions, including his highly developed powers of cognition, to evolution, that age-long process of genesis in the course of which all organisms have come to terms with external reality and, as we say, "adapt" to it . . . . Similarly, anatomical development, morphogeny, produces in the organic system actual "images" [quotes added] of the outside world. The fish's motion and the shape of its fins reflect the hydrodynamic properties of water . . . . (p. 6)

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, 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. From the perspective of NP, therefore, it is not so much that Pribram has imposed holonomic theory on the brain, as the brain has imposed holonomic theory on Pribram—more on this in the next section.

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 for all other constancies, for example, the color, size, and shape constancies. (See Vandervert, 1990, pp. 9–11, for 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.)

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 holonomic features of the algorithmic organization of the brain have been described as an outcome of autocatalytic maximum-power evolution. In the next section the emergence of the exteriorization of symbol systems (including mathematics) and mental models will be described as a natural evolutionary outcome of these holonomic features—form autocatalytically arising from pre-existing autocatalytic form. The space–time algorithmic patterns in the brain will be connected to the space–time of mathematics.

Unfoldment: How and Why the Algorithmic Organization of the Brain Exteriorizes in the Form(alisms) of Mathematics

In NP that which has traditionally been referred to as "mind" is described as an outcome of an emergent level of maximum-power autocatalytic (feeds upon self) self-referencing that progressively exteriorizes the algorithmic patterns of energy dissipation of the preadapted brain, for example, those associ-

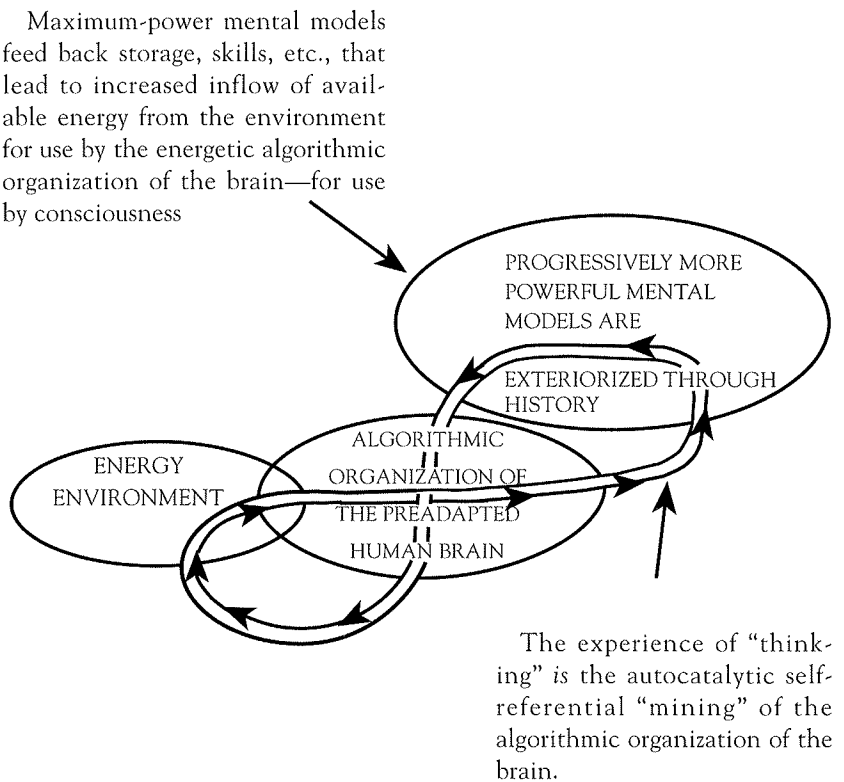

Figure 1: Simplified positive feedback autocatalysis (self-organizing) energy diagram illustrating the exteriorization of mathematical symbol systems from the algorithmic organization of the brain. Symbol systems and mental models feed back into the algorithmic organization of the brain, which can thereby 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).

ated with the invariances of the perceptual constancies,[3] in the form of symbol systems and shared mental models through cultural history (Vandervert, 1991, 1992). The autocatalytic production of mind in this manner is an entirely natural energetic affair that follows thermodynamic principles in making progressively more high quality energy (see Odum, 1988; Vandervert, 1991) available to the brain–mind system. This natural maximum-power process is depicted in Figure 1. It is proposed that this continuously iterated process has resulted in the gradual cultural exteriorization of the features of the algorithmic organization of the *consciousness* (the flow of the dynamically integrated features of perception, cognition, and action, and their reciprocal feedback) of the approximately 40,000 year old brain of homo sapiens. 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 the overall system, it bestows 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. (It is my belief that the relationship between the algorithmic organization of the brain, and the symbol systems it creates on the one hand is *homologic* to the relationship between computer machine language that underlies the development of easier to use high-level computing languages such as FORTRAN on the other hand. This is a deep homologic relationship in NP, and I will return to it below.)

The autocatalytic transformation to symbol systems constitutes the evolution of a second universal variant of the perceptual–cognitive order of the brain *that is now applicable to the energy-information manipulation of the entirety*

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[3]Lorenz (1959/1962b) articulated the idea that the mechanisms of the perceptual constancies might underlie the operations of scientific activity; although he did not have at his disposal a specific process by which to connect them:

> Without the perceptual apparatus, above all without the literally *objectifying* achievement of the so-called constancy mechanisms, we could know nothing about the existence of those natural units of varying duration which we call *objects* . . . . If one assumes a real external world at all, one has to concede that the way in which the simplest forms of space orientation and perception transmit to us, by analogy, knowledge of extra-subjective actuality; is basically equivalent to the way in which the highest forms of reason [science, in this context] do the same (differing only in degree of analogy reached). (pp. 37–38)

Lorenz seems to have been close to developing a NP-like neuroepistemology. In this regard see also Lorenz (1941/1962a, 1973/1977).

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 maximum information 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 external tree *itself.* The transformation from perceived tree in the brain to tree outside the brain in the formalisms of shared symbol systems is a possible natural outcome of maximum-power evolution because the fundamental thermodynamic principles governing the tree itself, the tree in the perceptual holoscape, and the tree in sharable mental model and its related network of holoscapes are the same, and they are inseparably linked in the playing out of maximum-power evolution. The same transformational processes that are behind the evolution of the encapsulation of real world forces in holoscape perception/cognition (see Pribram, 1991, "Computation and Representation," pp. xxv-xxix) are also behind the evolution of their isomorphic exteriorization in symbol systems that are, therefore, necessarily mappable back onto those original real world forces—thus the necessary workability of mathematics in the "real world" (see footnote 1). The natural emergence of mathematics through the energetic process of self-referential, self-organized shared mental models can be referred to as "nonmagical emergence."

Mathematics De-mystified

According to NP, mathematics consists of algorithmic patterns that are pure symbolic forms of the patterns of the algorithmic organization of the brain. In commenting on earlier brief descriptions of NP's evolution of mathematics, Combs (1992) accurately and succinctly captured this idea: "For example, [in NP] the startling and seemingly unwarranted correspondence between mathematics and the physical universe is a natural outcome of the brain of the mathematician" (p. 12). How does Combs' description and NP's notion of mathematics as algorithmic *patterns* square with modern conceptions of mathematics *as conceived by mathematicians*? Prominent mathematician Lynn Arthur Steen (1988) has pointed out that the modern idea of mathematics has moved to a new level of abstraction beyond even that of space and number. Steen suggests that with the advent of powerful computing systems a more apt conception of mathematics has become evident:

> Mathematics is the science of patterns. The mathematician seeks patterns in number, in space, in science, in computers, and in imagination. Mathematical theories explain the relations among patterns; functions and maps, operators and morphisms bind one type of pattern to another to yield lasting mathematical structures. Applications of mathematics use these patterns to "explain" and predict natural phenomena that fit the patterns. (p. 616)

Within the perspective of NP we can now understand that these patterns do indeed originate in the algorithmic patterns of the brain of the mathematician; while at the same time the brain of the mathematician (or anyone else) is an encapsulated composite of the forces of the real world or at least those of the human *umwelt*, the human slice of reality (see von Uexküll, 1934/1957, for the classic work on the *umwelt* conception).

Historically, scientists and mathematicians have been mystified by the workability of mathematics in the "real world."[4] Einstein asked, "How can it be that mathematics, being after all a product of human *thought* [emphasis added], is so admirably appropriate to the objects of reality?" (see Bell, 1937, p. xvii). This same question is explicit in the title of a classic paper by another Nobel laureate, Eugene Wigner (1967), "The Unreasonable Effectiveness of Mathematics in the Natural Sciences." Wigner concluded the paper with this comment:

> The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand or deserve. We should be grateful for it and hope that it will remain valid in future research and that it will extend for better or worse to our pleasure, even though perhaps to our bafflement, to wide branches of learning. (p. 14)

In their times, Einstein and Wigner did not have the information upon which to consider the possibility of an intricate, yet totally deterministic, homological isomorphy among patterns associated with the "objects of reality," their patterns in the brain, and those of mathematics. Although the problem of the nature of thought was at the forefront of Einstein's epistemological writings (see, e.g., Einstein, 1949, p. 7; Holton, 1979, p. 311), he did not seem to recognize the possibility that "thought" itself might be a dynamic

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[4]While it is true that leading mathematicians and scientists have been puzzled by the workability of mathematics in the real world, Kant (1781/1929) in his *Critique of Pure Reason*, while definitely not solving the mystery, or even relating mathematics to the real world (*Ding an sich*, or "thing-in-itself"), did come incredibly close to NP's position in outlining the derivation of mathematics from his a priori synthetic space and time. In his *Prolegomena to Any Future Metaphysics* (Kant, 1783/1953), which is a quite readable introduction to the *Critique of Pure Reason*, Kant is clear on his proposed relationship of space and time to mathematics:

> Now space and time are two intuitions on which pure mathematics grounds all of its cognitions and judgements that present themselves as at once apodictic and necessary; for mathematics must first exhibit all its concepts in intuition, and pure mathematics exhibit them in pure intuition, i.e. *construct* [emphasis added] them. (p. 39)

For Kant (e.g., 1781/1929, pp. 40, 65ff) pure intuition is based upon the nature of the human mind a priori (before experience). The a priori counterpart in NP is the algorithmic organization of the brain. When Kant says that pure mathematics must exhibit its concepts in pure intuition, he means that mathematical knowledge must arise from the *construction* of concepts and not from concepts themselves (see Kant, 1781/1929, pp. 577ff). This is a very similar notion to NP's autocatalytic exteriorization (construction) of symbol systems.

nested in the real world that operated, like everything else, in accordance with the principles of thermodynamics (see Figure 1).

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 systems ecosystems theory, thermodynamics, evolutionary theory, and holonomic brain theory, this paper describes mathematics as evolving totally from patterns of real world dynamics and structures, and therefore necessarily mappable back onto them.

The NP systems view of the evolution of mathematics leads to many important interrelated conclusions and implications:

1. Holonomic brain theory may provide a conceptual, thermodynamic, and mathematical model of neural activity that is virtually equivalent, through known transformational rules, to the experience of the unified space and time, and all of the possibilities of things and events in it, of the modeler him/herself. It is proposed that this sort of alignment with the algorithmic organization of the brain should not only be the goal of all modeling, but by its very nature is the finest expression of the workings of the human brain.

2. The progressive unlocking of the energy resources of nature throughout cultural history is, at the most fundamental level, the history of the autocatalytic exteriorization of the pre-adapted algorithmic organization of the brain of homo sapiens in the formalisms of mathematics, science and technology, and in the arts. *Human history, like everything else, evolves in accordance with thermodynamic principles.*

3. Ultimately every *dissipative pattern* in algorithmic perceptual–cognitive–motor consciousness is autocatalytically exteriorizable in some mathematical formalism (science of patterns). Eugene Wigner has little to worry about. Mathematics will not, cannot, ever cease to be applicable to the formulation of the laws of physics.

4. NP's view of the evolution of symbol systems, including mathematics, can provide a sense of direction about where we are headed with mathematics and why we are headed there. The development of brain-like computing systems and brain-like virtual reality systems can be viewed as natural exteriorizations of brain processing. Perhaps this is why computing systems have led us to redefine mathematics as the science of patterns. They are approaching perhaps the origins of patterns in the brain. 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 (2020–2030); reasoning robots (2030–2040); human equivalence (2050 and beyond). According to NP, Moravec's scenario predicts an evolutionary unfoldment culminating with the full exteriorization of *appropriate portions* of the algorithmic organization of the brain in symbolic mental model form—that is what it will take to obtain human computational equivalence (Gödel notwithstanding, see, e.g., Nagel and Newman [1958]).

We can begin to wonder about the possibilities of what some "final or full exteriorization" of the algorithmic organization of the brain might be like. According to NP's emergent hypothetical realism, that outcome is presently unpredictable and not fully imaginable; however, one might perhaps imagine a science and technology in full control of the very emergent evolutionary processes 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 theory of everything; here would be, as Stephen Hawking (1988) put it, "the mind of God" (p. 175). Perhaps this would represent the exteriorization and understanding of the deepest of mysteries, of our consciousness of the universe itself.

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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; (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 and 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. These feedback designs are sometimes called *autocatalytic* (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 brain. It is manifest, for example, in the self-organization of the perceptual constancies, cognitive systems (e.g., Stadler and Kruse, 1990), and the autocatalytic emergence of mental models.