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# FOREWORD

This, the second Appalachian conference on neurodynamics, focuses on the problem of "order", its origins, evolution and future. Central to this concern lies our understanding of time. Both classical and quantum physics have developed their conceptions within a framework of time symmetry. This has led to notions such as Feynman's, which are portrayed in his famous diagrams as time arrows pointing in opposite directions "from time to time". DeBeauregard has challenged this conceptualization, proclaiming instead that it is causality that becomes reversed, not time itself.

My own view as a biologist steeped in time asymmetry, is that all such interpretations, despite their mathematical rigor, are nonsense. My views stem from those proposed by Dirac, who noted that the Fourier transform describes a reciprocal relationship between formulations describing spacetime and those describing a spectral domain. The spectral, holographic-like, domain has enfolded space and time---and thus causality. A new vocabulary (such as talking in terms of spectral density, needs to be applied to fully understand the coherence/correlational basis of phenomena observed in this domain. The Einstein, Podolsky & Rosen proposal, Bell's theorem and the like, lose their "mystery" when conceived as operations taking place in the spectral domain. However, we are unskilled and unused to thinking in such terms which make these phenomena appear strange to us.

One of the reasons for strangeness is that most phenomena are observed to take place in a domain that partakes to one extent or another of both spacetime and spectrum. Hilbert gave formal structure to this "intermediate" domain and Heisenberg applied it to a formulation of quantum physics. It was Gabor who extended this application to the communication sciences, and thus to the classical scale of operations. Nonetheless, to emphasize the relation to quantum physics, Gabor named the maximum density with which a signal could be transmitted without loss of fidelity, a "quantum of information".

Both biological and engineering applications of Gabor's insight have vindicated the usefulness of thinking about this hybrid (space time/spectrum) domain. In image processing (such as magnetic resonance imaging - MRI) which is based on "quantum holography" and in understanding visual processing by the brain, Gabor functions have played a major role during the past two decades. Many of these applications were presented in the proceedings of Appalachian I: New Directions in Neural Networks: Quantum Fields and Biological Data.

These contributions to understanding do not, however, completely resolve the issue of the irreversibility of time. Most of the formalisms describe linear or quasilinear processes and practically all of them are invertible. What is needed is a strongly non-linear, irreversible conceptualization in which time symmetry becomes irrevocably broken. Ilya Prigogine has provided such a conceptualization and I asked him to review for us his most recent insights to keynote Appalachian II. Prigogine, in his application, introduces formally the concept of "possibilities" which goes well beyond the much touted inherent probabilistic aspect of quantum physics. Two consequences emerge from "possibilities" and both have played a major role in the development of non-linear dynamics (or Chaos Theory as it is usually called---turbulence theory, I believe, would better reflect what the theory is about). One consequence, emphasized by the Santa Cruz group, notes that what appears to be random at any moment, may have deterministic roots. In a sense this insight is also given in holography: any spread function that transforms spacetime into a spectral representation, produces an order which appears random but which, by way of the inverse transform, again appears recognizably orderly.

The second consequence emerging from "possibilities" is to me the more interesting: It is Prigogine's demonstration that temporarily stable orders can be formed out of apparent chaos. These stabilities far from equilibrium are the stuff that life is made of. My interest lies in how the brain becomes involved in such orderings of psychological processes. To this end, Appalachian II was convened.

The contributors to Section I sketch the broad outlines within which inquiry can begin. None of these contributions would ordinarily be subsumed under headings such as learning and memory; yet by providing refreshingly new approaches to the problem of the evolution of order, these contributors frame not only the remaining papers in this volume, but also indicate the directions that need to be taken in subsequent conferences, which will address learning and memory more directly.

Werbos provides a global perspective; Shaw, Kadar and Kinsella-Shaw, in a beautiful presentation, bring us a perspective of how to approach intentional dynamics in psychology. Gyr fills out this perspective with regard to self-reference.

MacLennan prepares the ground for understanding the continual switch between discrete and continuous and again discrete processing in the brain, processing which at a particular level, is delineated by Hagen, Jibu and Yasue. Bak and Game indicate how self organization can occur in such processing domains.

In continuation of an interest explored in Appalachian I and in keeping with the theme of the current conference, Section II is composed of papers addressing the issue of how information becomes transmitted in the nervous system. Signal transmission (in distinction to order construction) is performed by way of nerve impulses, by "spike trains" as they are colloquially known. Time series analyses are needed to decipher the code by which "information", a pattern, originating in one part of the brain becomes available to another and Cariani reviews the field for us and adds insights of his own. In keeping with the theme of the conference, the question addressed by Min Xie is whether spike trains recorded from non-stimulated, anesthetized preparations show evidence of a basic deterministic process, or whether such spike trains are truly stochastically random. As far as the evidence Xie, King, and Pribram present, stochasticity is basic, leaving order to be imposed by resonance with the order constructed by processes operating at the synaptodendritic level which are "sampled" by the axons from which recordings are made. A model of stochastic resonance processing, and the importance of "noise" in such models, becomes evident in the papers by Levine; by Segundo and his collaborators; and by Longtin; several excellent contributions and by Bulsara; and one that takes this model a step further by Petr Lansky. What can be accomplished when such models are networked is presented by Farhat and his group, and by Szu and his collaborators.

Section III is devoted to how patterns are constructed at the synaptodendritic level of processing and how such pattern construction relates to image processing. Central to this set of papers is an understanding of the receptive field properties of the dendritic network and how they are demonstrated in the laboratory, a topic developed by our group at the Center for Brain Research and Informational Sciences (King, Xie, Zheng, Pribram).

Eugene Sokolov pursues this line of research with respect to color vision and Vadim Glezer with respect to the perception of visual pattern. One of the issues that needs to be addressed is how, in a distributed process, different spatial locations become synchronously activated. Varela and his colleagues show that such synchronization occurs in the superior colliculus; Bressler demonstrates the dynamics of self organization of such synchronicities at the cortical level; and Erwin applies the results obtained to radar pattern recognition.

Section IV deals with the control operations which operate on image processing to construct entities such as visual and auditory objects such as phonemes, described in a beautiful contribution by Fowler. Manfred Clynes does the same for musical phrases as auditory objects. With regard to his initial mysteries of mystery, I wish he would acknowledge "Brain and Perception" and acknowledge the related presentations in Appalachian I and II some of which he attended. But once he gets going on temporal entities, the going is provocative and substantial. In an important paper Goodale and Milner show that the so called dorsal pathway from the visual cortex to the parietal lobe, as described by Glezer, does not deal so much with <u>where</u> some entity is located (its place) but rather <u>how</u> the entity is to be manipulated (used). Bolster continues this line of investigation with respect to attention: the non-primary sensory-motor cortices (parietal, frontal and temporal lobe) are shown to be uniquely involved in organizing the operations of visual scan (defined as post-eye-movement processing) necessary to controlled aspects of attention. Crawford focuses on the frontal of these cortices in her presentation, showing how disattention, necessary to the control of distraction, operates. Werbos summarizes the section and the conference with the same grand sweep with which he inaugurated it. In a very real sense, as Werbos' contribution shows, the conference itself is an exercise in self-organization.

A caveat: in reading these proceedings, do so in the spirit in which they were presented: progress reports to a workshop. The aim was to bring us together to exchange ideas. Some of these ideas were fairly well worked out; others were in their infancy. As a result, one of the most rewarding aspects of the conference is that it fostered lasting interactions. At the time of going to press, a conference on consciousness has taken place at the University of Arizona--many of the protagonists had met initially at Appalachian I and II. In Prague, in the Czech Republic, two workshops have been organized, one on spike trains and one on brain and biophysics; again contributors to Appalachian I and II have served as seeds to crystalize these meetings.

Karl H. Pribram

*Professor Emeritus, Stanford University*
*James P. and Anna King University Professor*
*and Eminent Scholar, Commonwealth of Virginia*

*Radford University*
*Radford, Virginia 24142*

## AFTERWORD

By: Karl H. Pribram

As did Appalachian I, Appalachian II resolved, for me, certain hitherto intractable problems that plague the mind/brain relationship. In Appalachian I, the problem was: how can psychological processes reflect brain activity? Psychological processes such as language seem to be organized so differently from the recorded activity of the neurons and neural systems known to be critically involved. The answer came in the form of an identity at the subneuronal, synaptodendritic and cytoskeletal level. At that level, descriptions of the organization of the elementary neural process and descriptions of the organization of the elementary psychological process are identical: assuming that the brain is an information processing organ, the description of the organization of synaptodendritic cortical receptive fields is identical with the description of the organization of information processing in communication devices such as those that process language--e.g. telephony, and those that process images--e.g., tomography and television.

Appalachian II addressed a problem that emerges as a direct consequence of this identity. The form of the identity is symmetrical. The informational process is a two-way interaction: in a manner of speaking, the organization of the subneuronal process produces (causes) the organization of the elementary psychological process; but at the same time, this organization shapes (causes) the subneuronal process. The identity of organization, the information process involved, makes this way of speaking seem awkward and old fashioned, rooted in a pervasive Cartesian dualism. But it does call attention to the fact that identity implies symmetry.

Life and mind are not governed completely by the laws of symmetry. In fact, one might define an all important characteristic of life and mind is that symmetries become broken--especially time symmetry. In biology, birth, growth, procreation and death; in psychology, learning and memory, attention, intuition and thought are all time-symmetry breaking processes.

Prigogine's keynote addresses this issue and clarifies, for me, the "how" of time symmetry breaking. As I understand Prigogine's presentation (with help from Kunio Yasue and Mari Jibu), there are formulations in which spectral representations do not render both real and virtual "images" when Fourier transformed. Prigogine's discussion is restricted to certain quantum and/or classical systems driven by (non-self-adjoint) Hamiltonian operators (for quantum systems) and/or Liouville operators (for classical systems) which are "chosen" so that their time developments are kept contractive (i.e. loose information) and dissipative (i.e. loose energy). Thus, as Prigogine states in a letter to me in response to a question:

> The difference between real and complex spectrum is very simple. Take the Hamiltonian in Hilbert space, it has real eigenvalues $E_1, E_2 \ldots$
>
> Similarly the evolution operator $U_{(t)}=e^{-iHt}$ has complex eigenvalues such as $e^{-iE_1 t}$.

> In generalized spaces, non square integrable eigen functions of H may be complex eigenvalues such as $E_1=\alpha_1-i\beta_1$. As a result the evolution operator has damping terms $e^{-i(\alpha_1-i\beta)t}=e^{-i\alpha_1 t}e^{-\beta t}$. Then time symmetry is broken.

Critical to this formulation is the use of imaginary numbers. Equations that need complex numbers for their solution have an imaginary and real part. As indicated in the above equation in generalized (rather than Hilbert spaces) non square integrable eigen functions, though they have complex eigenvalues, their evolution operator (e.g. a Hamiltonian) has damping terms that essentially eliminate the imaginary component leaving only the component that falls on the real line. Thus, as a consequence of taking a path, time symmetry is broken. Is this also the mechanism whereby the virtual image produced (by means of a Fourier Transform) by the lens of the eye is suppressed?

In short undertaking a path, by explicit or implicit movement---whether as attention to input, as intending an action or as rummaging through memory (thought)---breaks time symmetry. The path not taken can never be retrieved.

Thus, Appalachian I and II have prepared the ground for future conferences. The topic for Appalachian III stems from the fact that undertaking a path lands us in a level, a scale, different from the terrain within which the path is located. The substrate, the landscape, of a psychological process such as consciousness may reside in the subneuronal architecture of the brain but the path taken through that landscape can configure very different "views" or scales. Appalachian III is therefore entitled "Scale in Conscious Experience: Is the Brain Too Important to Be Left to Biologists to Study?"

Further conferences are hoped for. The time is ripe, I believe, to tackle problems such as describing the brain processes involved in valuation (reinforcement and deterrence), in learning (self organization) and in making choices, with the same richness in technique and content as have characterized the first three conferences.