Quantum Dynamic Networks, Chaotic Solitons and Emergent Structures in Subcellular Processes: Possible Implications for Learning, Memory, and Cognition

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Abstract
Molecular dynamics across large neural membrane and dispersed cytoskeletal structures are conjectured to provide the matrix of actions required for the emergence of coherent self-organized behavior. These patterns may be representable as non-stationary yet stable solitons, chaoitons, occurring as topological deformations at the scale of protein subchains, capable of stability over time for the storage of information, providing the basis for learning, memory, and consciousness. The problem of scalability may be addressed by examining self-similar soliton-like behavior among complexes of neurons operating within the matrix of synapto-dendritic field activity. Atomic force microscopic observation is seen as the most promising avenue toward experimental confirmation of such theoretical models.

Introduction
The present work stems from a line of research currently underway into the role of quantum mechanical processes in biological systems, specifically in neural cytoskeletal formation growth and the role played by these structures, uder quantum effects propagated from synapto-dendritic regions of the neuron, in the intracellular flow of information. The connection between quantum mechanics and biology has been the subject of speculative and theoretical investigation for some time but there has always been a barrier on the issue of how a link can be drawn between the reversible events of the quantum scale and the irreversibility of molecular neurodynamics. Ultimately this problem draws in the whole fundamental problem of measurement and time flow, and it is hoped that the present line of reasoning and research will point out the necessaity of that fundamental connection.

The problem may also be restated as a question of how supposedly incoherent low-energy processes can collectively have an effect at scales requiring much higher energies, and for which there is no apparent transfer mechanism. Recent theretical investigations by Yasue [[2]] and Hagan [[3]] have drawn attention to possible coherent processes within microtubules, specifically within

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[2] Yasue, K. & Jibu, M. (1992), Quantum Brain Dynamics, First Appalachian Conference on Brain Research and Information Science, Radford University, Radford, VA, October 1992

[3] Hagan, S., Yasue, K., & Jibu, M. (1993), Consciousness and Anesthesia: An Hypothesis Involving Biophoton Emission in the Microtubular Cytoskeleton of the Brain, Second

the hydrodynamics of tubulin interiors and exterior Debye-layer surface regions. Cytoskeletal networks of protein filaments and tubules have long been recognized for their role in maintaining cell structural stability and as a mechanism for motility. Microtubulin centrioles play a role in internal motion control for chromosomal distribution and are thus directly involved in mitotic regulation. They have also been associated with the flow of information along axon paths and in mechanisms for intracellular representations of memory [4]. The assembly and dissasembly processes for microtubulin in particular have evinced interest as possible mechanisms for information transmission because of similarities with computational processes involved in both cellular automata and neural networks [5]. What has been missing thus far is a descriptive link between field-like processes for which quantum dynamics clearly is a foundation and molecular processes within synaptic structures. Where learning and memory fit into the picture has traditionally ben associated with neurons and firing activity, but Pribram et al [6] have outlined the theoretical foundations for a synapto-dendritic model of brain function and experimentally demonstrated the field-like nature of information processing in neural structures that is not sufficiently explained by discrete neurotransmitter functions.

The current investigation is influenced by an approach to science that is not necessarily new but perhaps uncomon in the modern era, less so in physics but certainly in the biological sciences. This approach is grounded in two fundamental premisses. The first claims that the universe really is simpler and more efficiently modeled than it may seem from a reductionist, analysis-driven viewpoint (this may be called the OCCAM principle) and the second argues that it is appropriate and productive in science to openly begin from an intuitionist perspective and work toward developing a hypothesis and theory that could support that intuition, being careful of course to avoid locking into the vision to the exclusion of the obvious and observed events (this may be called the INTUIT principle).

This approach is characterized by a view of phenomena at any scale or dimension as being fundamentally non-object-like; i.e., processes formed by the interactions of sets of processes, collective actions having structure that is perceived as regular and semi-permanent due to cyclical behavior within the network of the interacting processes, as opposed to saptio-temporal localizable events. These cycles may functionally be understood as providing a means by which excessive energy gradients can be dissipated by systems that have maximized their ability to

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[4] Hameroff, S. (1990) Scanning tunneling microscopy of cytoskeletal proteins: Microtubules and intermediate filaments, J. Vac. Sci. Technology A 8(1), Jan/Feb, 687-691

[5] Rasmussen, S., Karampurwala, H., Vaidyanath, R., Jensen, K., & Hameroff, S. (1990) Computational Connectionism Within Neurons: A Model of Cytoskeletal Automata Subserving Neural Networks, Physica D 42, 428-449

[6] King, J., Xie, M., Zheng, B., Pribram, K. (1994) Spectral Density Maps of Receptive Fields in the Rat's Somatosensory Cortex (pre-publication; submitted)

dissipate through the usual channels. The network dynamics model of coherent and stable quantum events occuring within macromolecular structures such as microtubules and intermediate filaments can be understood to be acting as a form of massively parallel self-regulation system that maintains the macroscopic topology required for optimal transmission of signals with an economy of energy dissipation. Within this quantum regulatory (measurement) system is the place by which such economical transmissions can occur, namely the long-theorized and yet-to-be-demonstrated biological solitons, hypothesized to be not stable localizeable solutions of partial differential equations but nonstationary sets consisting of some subset of all possible states of a field, ϕ, and in this way considered to be *chaotic*.

Fields, Neurons, and ANNs

There is a striking conclusion that may follow from these steps off the beaten track. Neurons and the somatic activity, including cycles of polarization and depolarization following by axonal discharges, become far less significant for the problem of information processing activity in the brain than have been previously considered, and the modeling universe of artificial neural networks (ANNs) gets tipped on its side in the process. This is not to demean the effectiveness and power of ANNs in pattern recognition and classification and varieties of non-linear mapping but to question certainly whether an ANN can ever be engineered to sufficiently mimic the behavior of a continuum / field-based operational space so as to produce the same kinds of events including those that are characterized strongly by self-reflexivity and innovation, and given the descriptor of 'consciousness.' This logic also suggests that a computational model that is mathematically based on field-like ooperations, akin to Sutherland's Holographic Network [[7]], may bemore effective in artificial learning tasks because of an inherent similarity to the way biological learning occurs, despite the sufficiencies offered by classical ANNs.

How is the inter-neuron signalling to be understood in relation to synapto-dendritic fluctuations? Is it possible that the neuron's spike train is the equivalent of a thunderstorm or a tropical hurricane or a summer tornado in a large-scale ecology, each a self-organized process that emerges, at the edge of chaos but not in that domain, as a method of dissipating large gradients of energy that must be disposed of from the local system. The thought here is that if they were not dissipated, such excess gradients would push the local system into a definitely chaotic state, disrupting the equilibrium that allows a holographic memory to endure for sufficient periods of time and within a sufficient range of sameness for the language of mental behavior and cognition to develop? There are fuzzy indications of similar types of behavior across the complete scale of natural phenomena, ranging from elementary particles to galactic clusters and perhaps cosmic strings. That in itself does not make the neuron an energy sink instead of a learning machine, but it should trigger a few disturbing ripples in the intuitive cloud of our collective scientific mind.

This view seems consistent with findings by Pribram et al that with reference to other neurons, the spike train is stochastic rather than deterministically chaotic [[8]]. Were it otherwise, one

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[7] Sutherland, J. (1990) A Holographic Model of Memory, Learning and Expression, Int'l J. of Neural Systems, Vol. 1, No. 3, 259-267

[8] Xie, M., Pribram, K., & King, J. (1993) Are Neural Spike Trains Deterministically Chaotic or Stochastic Processes?, Second Appalachian Conference on Brain Research and

might expect to find more deterministic events in synapto-dendritic field activity. The randomness of neural spikes can be linked with the unpredictability of local events that alter the polarization of different neural membrane regions and the dissociation of such events from one another.

A natural caution needs to be expressed - this discussion could lead into teleological speculations, visions of a natural process having an end in sight and thus building the means toward satisfying that end. The end is usually something that can only be defined in terms of human language - a philosophical term begging for ontological priority. However, to use the hurricane as an example, the storm is not a mechanism constructed in order to satisfy some end, much as a futuristic Corps of Engineers might build some machine to redirect ocean currents and create/dissipate cloud fronts. The hurricane is not a separate system apart from and injected into the environment, but is a reorganization of the very fabric - air, water, electromagnetic energy - that is the environment, without any intervention from an outside agent (system). But why should there be any kind of emergence of new organization that dissipates excess energy that the old (prior) organization cannot handle? Why don't things simply build to the point where everything turns chaotic and the prior organizational structures are destroyed? Why doesn't the ocean heat to the point of near boiling and beyond the range of life support? An appeal to some kind of Tiplerian Anthropic principle will not suffice. The phenomena is too universal - organization and complexity increasing, as local systems reach their limits. Where this is not to be found, by the way, is in any kind of true *machine* - an assembly of units brought together by something outside the asembly (i.e., the builder) and acting under a mixed set of constraints, some of which are controlled by outside the system (source of energy, some kind of initialization switch and stop switch) and some of which are internal (e.g., friction, tension, energy consumption).

At this point all that will be offered is the proposition that natural systems however complex follow a derivative of the most basic principle of inertia and that this manifests in a variety of least action principles, one of which is that equilibria near the 'edge of chaos' are somehow easier to maintain than in other situations. Non-stationary stability mechanisms seem to be built-ins for the universe as we know it. 'Why?' may not be an appropriate question. 'How?' may be begging for a mechnistic answer and also inappropriate. This is all terrain to be explored rigorously but also freely, without the kinds of restraints that have generally been imposed upon the sciences, particularly the biological disciplines. Here also is where philosophy properly belongs in concert and synergy with the hard sciences. Whether the tradition built up over the past two hundred years will allow that to happen remains to be seen - the jury is still out.

Statement of the Fundamental Hypothesis

The hypothesis is best described in terms of a simple abstract model and then translated into a description of processes in the brain which can then be the object of experimental observation. The success of using network circuit models, based upon Kirchoff's Laws and consisting of simple capacitors, resistors and inductors for the most part, for modeling cell metabolism and ligand/receptor regulation [9] has led to a view that similar abstract circuits can be applied to the problem of how synapto-dendritic fields form and modulate over time and in turn affect neural membrane and cytoskeleton dynamics. Thus the approach of using both cellular automata models and network circuit models in concert is viewed as a means for having the level of complexity needed in order to study what kind of new properties emerge that *expressly do not follow deterministically from any of the local equations*. The object of such a simulation is not to provide a mechanistic description but pointers toward the type of phenomena to be sought in experimentation such as the in vivo atomic force microscopy discussed below. It is the massive interaction of simple processes that matters according to this view for the type of organization [organ-ism] that emerges and one should not be looking for a detailed compartmental and causal mechanism.

We begin first with an electrochemical field, not a cell nor any structure that resembles a dendrite. The field influences the formation (assembly) of protein into a structure, not the other way around - that is the point of the argument. Nobili [10] presented some of the earliest work on the existence of electrochemical Schrodinger-type waves representable by simple time-dependent variables s(x,t) and p(x,t) and occurring as a result of the coupling between Na^+ and

$$\frac{\partial \psi}{\partial t} = (\_ + \iota\sigma)\nabla^2 \psi, \quad \frac{\partial \psi^*}{\partial t} = (\_ - \iota\sigma)\nabla^2 \psi^*$$

K^+ ion flux, with the general form

This may involve a double intercoupling of the ion exchanges due to the Na^+-Ka^+-ATPase pumps and feedback modulated by Ca^+ through membrane channels. The individual behavior is

$$\frac{\partial s(x,t)}{\partial t} + \Delta \bullet J_1(x,t) = 0$$

stochastic, but the global effect fits for a continuity equation of the form

yielding in turn, with some assumptions made for homogenity of glial tissue and isotropic

$$J_1(x,t) = \alpha_1(x)\nabla s(x,t) + \beta_1(x)\nabla p(x,t)$$

behavior of macroscopic properties,

where $J_1(x,t)$ is the macroscopic current density for sodium. Similar equations would hold also for potassium. What are the determining factors for current densities? Ion concentration

[9] Prideaux, J., Ware, J., Clarke, A. & Mikulecky, D. (1993) From Neural Networks to Cell signalling: Chemical Communications among Cell Populations, J. Biol. Sys. 1: 131-146

[10] Nobili, R. (1985) Schrodinger wave holography in brain cortex, Physical Review A, Vol. 32, No. 6, 3618-3626

gradients, to be sure, coupled with the action of the ATPase pumps, but this translates into a dependency upon an array of ion channels operating stochastically, governed by local equilibrium laws. The dynamical activity of these channels has not been observed, and for this reason experiments are underway, described below, to generate data on the relational activity of neural ion channels, an attempt to discover if there is any unique pattern that emerges when viewing a large surface of a neural membrane in response to different electrochemical stimulation and to determine if anything that could be termed coherent activity emerges within a given region of the cell surface. Coherence is not to be measured only in terms of some spatial-temporal coordinate (x,t) but may involve phase relationships between many groups of ion pumps. Here one would be concerned with some relationship θ that holds fairly constant among the rates of channel activation and surface polarization. Moreover, as Nobili has pointed out, the dynamics of ion movement and consequently charge flow through extracellular spaces is hardly as simple as things might appear from a consideration of fixed or nearly fixed cells under observation. Interstitial pockets bound by cell membranes will act as volumes of stagnation relative to the expected flow of ions through membrane channels were there no interference in the fluid flow. Here the cell shape as dictated by cytoskeleton filaments plays a role in determining the number and complexity of such interstitital spaces. Astrocytes are rich in intermediate filaments and microtubules and thus contribute to a 'fractalization' of the extracellular volumes between neurons and among neurons and glial tissue. This in turn must affect the manner in which ion channels can be activated since the extracellular environment is hardly as homogenous as it may seem.

The Na^+-K^+-ATPase pumps can be viewed as a parallel set of voltage-driven amplifiers that linearly boost the signal from ionic fluxes that exist in the neural-glial intercellular medium. Even though the local elements and regions may operate in response to micro-variations in ion concentration, this is happening across the span of a vast surface of dendritic fibers and the global flux of the field within a region much larger than the span of a single neuronal set of dendrites will be detected and amplified. Collectively such amplifiers are working like the nodes in an ANN to smooth out local variations as may be caused by the type of interstitial pocket formation discussed previously.

It is the collective response of a dendritic membrane region that in turn will affect the integrin binding sites where actin filaments are attached and from these in turn the microtubules are affected. Our goal all along is not to argue yet for a specific biophysical process within neuronal microtubules but to present a picture in which there are processes that connect synapto-dendritic activity to neuronal cytoskeleton dynamics and thence to brain systemic behavior. It is from these integrin sites that the feedback from ionic waves delivered in the form of polarization changes in the cell membrane can translate into oscillations conducted along actin and ultimately microtubule filaments. These oscillations may be of the sort that Hameroff, Hagan, and Yasue have investigated, but to look too hard for coherence between events in different microtubules may be going down the wrong track. Criticality seems more significant - build-ups of activity that translate into new cytoskeletal growth and movement of the structure and consequently of the cell membranes overlaying. Such relatively macroscopic changes will in turn effect, over time, the organization of individual neurons and neuronal groups, leading to the formation of both denser and sparser populations of neurons as well as higher and lower degrees of interconnectivity among the neurons within a group. Higher levels of activity in the synapto-dendritic field regions will then require more action to dissipate polarization build-ups on the membranes, and thus higher frequencies in generated spike trains from those neurons. This brings back the notion that what has mostly been observed in the way of neural activity are dissipative/release responses to heretofore unobservable field fluctuations, not basic mechanisms for information flow.

Entrainment and synchronization among oscillators have been well studied and most recently computational models by Campbell and DeLiang indicate recurrent synchronization among networks of only locally-coupled oscillators [[11]]which may indicate similar mechanisms among neurons. It is possible that activations in the cytoskeleton triggered by membrane polarization/depolarization activity can also synchronize, creating stronger movements in the filaments through a kind of cascade or multiplication. Again, this has not yet been observed but AFM imaging may be able to show comparatively slow dynamics that are consistent with a massively parallel set of oscillators moving from stochastic to coherent behavior.

What form these cytoskeletal oscillations may take is suggested by the behavior of a soliton, but likely not a classical soliton in the sense of an object with a definite energy that retains form and velocity after interactions or 'interference.' The notion of a chaotic solition or chaoiton is developed by Werbos [[12]] and is the subject of related research by this author and others, stemming from an attempt to understand stability at the particle scale, much far removed from that of proteins but with perhaps more in common with protein conformal stability than would at first be considered despite the vast difference of scale. A classical soliton could be represented by some function $\theta(x,t)$ which is close to an initial state $\theta_0(x)$ such that for some infinitesimal interval τ $\theta(x,t)$ does not converge to $\theta_0(x)$. Instead there is a convergence to a sum of components consisting of a base component $\theta_0(x+\delta)$ and a propagating component that moves away from x in space. Werbos defines a chaoiton in distinction as a set of field states that are localized in space, not dispersing out to infinity, and invariant under the PDE that define these states. Moreover, it must have 'emissive stability' similar to that of a classical soliton, in that any given state $s(\tau)$ within a finite neighborhood range of the soliton S will converge to a nearest state $s_i(\tau)$ that is within S.

A more physical-oriented measure of emissive stability that is being examined has to do with what Werbos terms H-stability and a weaker derivative H'-stability, wherein the chaotic soliton must have the minimum energy H of all possible states within a neighborhood of H that could be occupied by the soliton S. If all neighboring states to S have an energy > H, then it would have to be part of another set of states belonging to a separable chaotic soliton or else be in the process

[11] Campbell, S. & Deliang, W. (1994) Synchronization and Desynchronization in a Network of Locally-Coupled Wilson-Cowan Oscillators, preprint, available through anonymous ftp to ohio-state.edu; /pub/neuroprose/campbell.wc.oscillators.ps.Z

[12] Werbos, P. (1993) Quantum Theory, Computing and Chaotic Solitons, IEEE Trans. Fundamentals, Vol. E76, No. 5, 689-694

of emitting energy and reducing itself toward H as a limit. The conceptual basis of H-chaoitons and methods of generative H-stability from Langrangian field theories is currently being investigated. It may prove useful to ask the question of if such chaoitons were to exist in the macro-scale of biomolecular interactions, what would be the possible observables that would correspond to H/H'-stabilities andhow could these be tested?

How could such chaotic solitons arise biologically? This may be the place where the collective stochastic behavior at the channel level could, over a region of dendritic space, not contiguous (i.e., surfaces of dendrites that are separated by extracellular flkuid or perhaps not even connected to the same neural soma) generate a coherent pulse of the form Hagan and Yasue term a

$$\pm i \frac{2\pi\_\mu l_{MT}}{\hbar V} S^{\mp}$$

biophoton, where energies might be of the order
This coherence would occur within the cytoskeletal pathways. The key link may be in something that is too often overlooked in the dynamics of molecular biology - the structure and active role of water molecules in the neighborhood and within channels and tubules and surrounding filaments. Does a membrane-integrin-microtubule engine create laser-like effects through the collective dynamics of water that is structured and channeled by the macromolecule form surrounding it, attributing almost an inverse role to both the water and the protein-based structures in cells? The total Hamiltonian for a system of N water molecules within an electromagnetic field inside a cylindrical form of the sort understood to exist within microtubules

$$H = H_{EM} \;+\; \_S - \mu_{\_k}(E^{-}_{k} S^{-}_{k} \;+\; S^{+}_{k} E^{+}_{k})$$

is given by Hagan et al (op. cit.) as
This is consistent with a model of brain function where collective and stochastic events in local regions of the synapto-dendritic matrix give rise to spontaenous pulsed emissions that are devoid of any macroscopic pumping action, the absence of which has often been used as the argument against such coherent micro-actions. The spontaneous emissions could be thought as as criticality points, or as Stuart et al have suggested, a form of symmetry breaking [[13]].

If chaotic-type solitons are generated and maintained through these collective processes at the subcellular level, there may be some common ground with the manner in which chaotic solitons are conjectured to act as the means for effecting stability of elementary particles. Are dynamic networks of quantum vacuum fluctuations working in a way similar to electrochemical events in the dendritic fields? Whether or not this is pushing the mathematical-symbolic analogy too far is not clear at this point, but it is worth keeping in mind the possibilities.

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[13] Stuart, C. I. J., Takahashi, Y., & Umezawa, H. (1979) Mixed-system brain dynamics: neural memory as a macroscopic ordered state, Foundations of Physics 9, 301-327

Models of liquid water and its clustering behavior have been developed using cellular automata (CA) by Kier and Cheng [14]. Further extensions of this modeling technique are currently being implemented using CELLANG 4.0 developed by D. Ekart at Radford University. The CELLANG system allows rapid modification to the CA plus options for introducing time-cycle-sensitive agents - this is particularly useful in treating part of the CA as stationary monomers and dimers. The new simulations are using 3D structures, corresponding to the nanometer-dimensionality of microtubule protofilaments, which act as the fixed boundariesof the cellular automata array; the movement and clustering behavior of water inside and surrounding the MT structure is what is actually the subject of the simulation.

A Dynamical Experimental Approach

This is, granted, all hypothetical, and while current simulation models under development using CA principles point toward building a working illustration of the concepts, experiments have to be designed and performed. Measureable quantities are needed to move toward a realistic quantum bio(neuro)dynamics. In order to bring theory and praxis closer together, our approach has been to begin examining dynamical events in the cytoskeletal and channel scale using the combined power of scanning probe microscopy and off-line image processing. Atomic force measurements are seen as the most conducive means to acquiring hard observables that can be compared with and even integrated into more accurate and realistic simulations. One reason is the range of scale of observability, from the cell as a whole down to the single nanometer scale of ion channels and individual protein chains and helices. Recent advances in AFM, particularly by Henderson et al [15] and by the development team at Digital Instruments have resulted in powerful non-contact and tapping mode AFM methods that have been applied to studying actin filament dynamics in glial cells and cytoskeletal dynamics in cultured epithelial cells [16]. These methods overcome many of the obstacles to using AFM with live cells in the past, since contact mode probes could not handle some of the surface height variations of biological samples and both non-contact and tapping modes did not work well within fluid media. We have begun experimenting with tapping mode in fluid deposits on a 12 μm scanner, using variable drive amplitudes, gains, and modifications to center and sweep frequencies to overcome problems in false engagement and refraction of the laser beam from the cantilever tip. The results will be compared to performance using a glass profusion fluid cell and a combined optical/AFM microscope (Bioscope) built by Digital Instruments, Inc.

Initially we have been observing changes in surfaces of neurons collected from pre-natal and post-natal mice. Cells are plated onto glass cover slips and both height and deflection

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[14]Kier, L. & Cheng, C. (1994) A Cellular Automata Model of Water, J. of Chem. Info. and Comp. Sciences, Vol. 34, 647-652

[15]Henderson, E., Haydon, P., & Sakaguchi, D. (1992) Actin filament dynamics in living glial cells imaged by atomic force microscopy, Science, Vol. 257, 1944-1946

[16]Chang, L., Kious, T., Yorgancioglu, M., Keller, D., & Pfeiffer, J. (1993) Cytoskeleton of living, unstained cells imaged by scanning force microscopy, Biophys. J., Vol. 64, 1282-1286

measurements are being collected. A glass fluid cell has recently been provided by Digital Instruments, Inc. and is adaptable to their Multi-Mode AFM. Variation of glutamine, sodium and potassium is acomplished through the microchannels built into the fluid cell. The goal is to disturb the cell surface as little as possible from external sources but to allow gradients of extracellular medium to change over an extended period and to be returned to approximately the original values. Scans will be recorded at intervals of 30 - 40 sec. maximum in order to correlate image features directly with known changes in ionic concentrations in the extracellular medium. The different feature types or categories are as yet an unknown.

While individual channel and surface motion within local regions occurs too rapidly for detection, the collection of large numbers of images from the same sample region and the identification of characteristic feature types should enable a topographical mapping between observed channel activity and different steps or stages. In other words, some channels in different scans will be caught in the middle of the act. Statistical analysis of images over a sequence of time may provide indicators of how channel activity and membrane surface movement are related over time. Fractal roughness and granularity analysis of the images may also prove useful. The numbers of observed sites (e.g. channels) in an image that are in a given state will change and in keeping with the connectionist-topological model, it is not the individual channel (or filament) behaviors that matter but the activity of large collections and sets in parallel. Thus the important observable to strike for, and the subject of our experimentation, is the topology of the observed cell surface region(s), relating changes in one geometric scale (channel sets) with another scale (cytoskeletal reshaping). The thought here is that AFM observation will lead to a kind of topological dynamics that defines the rules of field-effected interactions of the sort discussed earlier purely in terms of geometry. Thereafter the connection can be made from the geometry to the biochemistry, showing the molecular processes involved in component operations that make up the topology, including support for or against the elusive non-stationary chaotic solitons.

Neural Nets A Special (Limited) Case

For a solid ten years artificial neural networks (ANNs) have been built upon over an earlier generation of study that viewed neurons as machines and the neural soma-axon structure as the controlling device and power train for a brain built out of components much as a Turing computer is built out of semiconductor elements. ANNs have been advanced as a model of learning, memory, and higher cognitive functions with application to problem-solving of the sort generally attributed to intelligence. Thus neural nets fit into the picture of artificial intelligence and the tradition of building algorithms for Turing machines to emulate human behavior. However, the variances between even the most sophsticated ANN and a real brain or portion of a real brain are striking and should be considered obvious. This has been the stumbling block to understanding how consciousness can be connected with brains - the view of the brain as a machine, a mechanistic concept that has given rise to everything from Shelley's Frankenstein to Putnam's brains-in-a-vat. If one can start thinking about brains as something different from machines, more like a vast network of stochastic *processes that maintain stability by virtue of their chaotic attractor elements maintaining energy flow through self-organization, then the brian looks less and less like a cog-and-gear machine and more like the type of entity we equate or associate with mind and consciousness.

This is not idealism in the sense of the historical philosophers who argued against the reality of the physical. The brain is a solid and real experience, and neurons grow in fuzzy networks that with an increase of scale become distinct modular regions, clusters, subsystems occupying themselves with distinct tasks, just as certain brain tissues have over the course of fetal development differentiated into neurons and astrocytes, blood vessels, membranes and connective tissue. But is the brain or any part of it as much an object or substance as one would be inclined to think according to the old neural machine model? Are ANNs not only a rough approximation of connectionist organization in the brain but even more a broad simplification of behavior that exists between the neurons more than in them? It may be that a neural network model can be fitted to the hoped-for observable dynamics of ion channels over a region of membrane and the associated changes in cytoskeletal configuration. Perhaps the neural net can serve as a circuit diagram of the sort discussed by Mikulecky (op. cit.) where a collection of channels acts as the internal structure of an n-port, connecting out to microtubule and actin links, each channel being a node in the network.

Conclusion: Missing Links and Paths to Consciousness from a Near-Chaotic Brain

The theme of this conference and volume deals with the emergence and relationship of consciousness from and within the neurobiological framework of the human being. What has been presented is a new way of looking at brain processes over several scales of observables, from the atomic and molecular up to the neurosystemic. This view shakes apart the traditional neo-mechanist view that operational functions by which consciousness is often discussed - learning, memory, recognition, invention - are not the result of not a mapping from a many-to-many interconnected neuron machine and that the notion of a machine, however unlike the conventional, even one that operates according to connectionist designs, is inappropriate for discussing how thoughts are conducted with(in) a brain. More radical than that, it is suggested that the foundations for a brain working to produce such behavior must employ what appears to be the most unlikely kind of processes, chaotic and asynchronous interactions of wave fronts that modulate ion channel activity and in turn contribute to regional effects triggering cytoskeletal signalling, and that these processes give rise in a potentially non-simulatable fashion to well-ordered activity that can be predicted, modeled, measured and reproduced.

The mind-body problem as a whole may be sustained (and therefore removed) by re-examining the way that the brain is treated - not as a machine or aggregate of machines, but a vast set of instabilities that give rise to steady state conditions. Ultimately this is another aspect of the case against objects and for pure action as the fundamental constitutent of the universe, but in that transition must also be a removable of the demand for mechanistic cause-effect relationships that depend upon there being substantive objects that can be attached as the causes and effects. Is this a direction into which science can move? So long as the methods of observation, including simulation and modeling, are maintained, there should be no inherent barrier other than that of the human mind and its predispositions to making objects out of processes, beings out of a stream of becoming.