

Endophysics and *The Thoughtbody Environment* – An outline For a Neo-computational Paradigm
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Abstract:

This paper seeks to present a series of related ideas enfolding concepts surrounding Endophysics, the creation of a model for an Electrochemical Computer — *The Thoughtbody Environment*, and a series of new research methodologies that might inform both of these undertakings. The notion is to present an outline for a Neo-computational Paradigm. This research has been inspired by an ongoing conversation between Otto Rössler and Bill Seaman. The paper will cover the following topics:

- 1) An Ongoing Conversation between Rössler and Seaman
- 2) Endophysics – A Definition
- 3) Addressing the Nature of the Cut Between Observer and Observed
- 4) Special Characteristics of Endophysics – Differences between Physics and Endophysics
- 5) The Creation of Reciprocal Virtual Environments
- 6) A Situated Approach
- 7) *The Thoughtbody Environment, Toward a Model for an Electrochemical Computer*
- 8) Chemical Computers by Pask and more recent work by Cariani
- 9) *Ultimate Computing*
- 10) *Biophotonics*
- 11) *The Benevolence Engine* | *The Thoughtbody Environment* — Developing an N_S.E.N.T.I.E.N.T. Entity
- 12) The Limits of Science
- 13) Summation of the N_S.E.N.T.I.E.N.T. Paradigm
- 14) Conclusion

Key words – sentience, adaptive, situated, neo-sentient, self-organizing, environmentally embedded, nascent, temporal, intra-active, emergent, navigational, transdisciplinary

1) An Ongoing Conversation between Rössler and Seaman

I have been involved with a long-distance collaboration with Otto Rössler. We have had discussions in person, at various conferences and we have exchanged letters. In particular these discussions have covered two related areas: we have spoken about differing virtual approaches to the articulation of Endophysical processes (Endophysics means physics from within¹) as well as discussed the construction of a *Model for An Electrochemical Computer*, emulating the body as a sentient entity. In Endophysics “The basic idea is that the interface between an internal observer and the rest of his or her universe — the effective forcing function²— represents the sole reality that exists for the observer.”³

There are a series of problems that make the research both fascinating and difficult. I will begin to discuss each of these in this paper. I am also seeking to have discussions with many different scientists, philosophers and artists related to the project. These discussions will be included in future papers and the eventual creation of a relational database. The project is large in scope and may encompass many years of research. The notion is that one continues to work on the problem set as an ongoing process. Findings of the research will be folded into other related research projects and poetic works. This process will form an on-going shifting course.

In this paper I will focus on a number of approaches to Endophysics that arise in part from my ongoing research explorations that include the study of meaning production, the articulation of an expanded linguistics, the creation of generative virtual environments, and research related to multimodal sensing systems both human and machinic. The main project enfolds a number of areas of research:

- 1) To create a generative virtual environment to help elucidate Endophysical processes.
- 2) To generate a model for an electrochemical computer (a neo-computational model).
- 3) To articulate how these two approaches inform each other.
- 4) To outline a set of ongoing research foci.

- 5) To produce a series of papers that elucidate the research from a didactic perspective.
- 6) To produce a series of installations and individual artworks that abstract the research in a poetic manner.
- 7) To generate a relational database to house all of these foci.

This transdisciplinary project is extremely complex and involves the following:

Physics – Endophysics / Exophysics

Biology

Chemistry

Computer Science

Cognitive Science

Engineering — Mechanical, Electrical, Biological and Nano-technological

Philosophy

The articulation of bridging languages between disciplines

The Articulation of An Expanded Linguistics of Pattern Flows⁴

Poetics

We are approaching the problem set in a holistic manner. Thus, how can such a model embrace a holistic paradigm shift for physics, and reciprocally, mind/brain theory? Alternately, this study suggests new models of computing that arise as a byproduct — both in terms of attempting to embody the mathematics that enables the study of Endophysics, as well as in extending the very nature of computation by modeling quantum processes and deep biological functionality in the brain/mind/body/environment continuum. The construction of a new holistic neo-computational paradigm surrounding this premise is central. A further area of consideration relates to the substrate enabling electrochemical processes to flourish in the body – what relevance does this substrate have to sentience?

Rössler articulates a central assumption:

Microscopic observer properties “percolate up” to affect the macroscopic spatiotemporal appearance of the world. Physics becomes dependent on brain theory.⁵

Alternately, brain theory becomes dependent on physics. A critical concept is here provided by Rössler:

The observer is the sum total of the dynamical processes which go on inside him or her. There is a macro dynamics (the coarse-grained responses of the dissipative structure called “observer”), and there is an underlying, much faster microdynamics. Even the most rapid macro change in the observer lasts several orders of magnitude longer than a micro time slice does. The micro time slices therefore are necessarily “integrated over” from the macro point of view. An analog to “flicker fusion” – but much faster – can thus be predicted to hold good for micro time slices.⁶

Thus, sentience arises in part due to this “integrated over” set of processes.

2) Endophysics – A Definition

Endophysics is a “physics from within”. David Finkelstein gave the name to this branch of physics in a letter to Otto Rössler. Rössler states:

Finkelstein designed a program for a “holistic” physics in the spirit of Bohr, but discrete. He hypothetically attributed both the quantum limit and the relativistic limit to the fact that the whole is not accessible to us. Later, he indicated an explicit example of a dissipative finite automaton (computer) whose internally evaluated state is different from the objectively existing one. Shortly thereafter, he endorsed the two notions “physics from without” and “physics from within,” by proposing the antonyms “exophysics” and “endophysics” as more attractive terms. The name “endophysics” is his creation.⁷

So we begin with a fascinating conundrum. If we can not make a cut between what we want to study and the study itself, then how can we proceed? Peter Weibel in the Preface to Otto Rössler's book *Endophysics: The World as Interface* provides this articulation.

Endophysics shows us to what extent objective reality is necessarily dependent on the observer. Ever since the introduction of perspective during the Renaissance and of group theory in the 19th century, we have known that the appearances of the world depends in a lawful manner on the localization of the observer ("codistortion"). Only if one is completely outside a complex universe is a complete description of the latter possible (cf. Gödel). According to endophysics, it is only in a model that this position on the outside of a complex universe is possible, but *not* in reality itself. Endophysics hence provides an approach to a general model and simulation theory (and also to the "virtual realities" of the computer age). It is an outgrowth of chaos theory, to which Otto Rössler has contributed since 1975.⁸

One asks, as a "model generator" of a view of a "physics from within" to what degree do the limits of computing throw off the nature of this model? What degree of similarity needs to be maintained between the physical and the virtual? One is reminded of the 100% scale model articulated by Borges in the book *Labyrinths*. Does a new branch of computing need to be articulated that would enable the deep complexity of such models to be entertained? Weibel continues:

The only scientific method for finding out whether or not our own world possesses an exo-objective flip side is the construction of model worlds (or artificial universes) on a level that lies below our own world. This way of proceeding is called endophysics.⁹

So one task before us is to begin forming a model for a virtual reality that would enable one to 'figuratively' step outside of themselves. Rössler points to the origination of this observance:

A chaos-generated cellularity may, if it is the finest systematic feature of a macroscopic system like you and me, leave some indelible mark on everything one touches or tries to touch... The first who apparently saw this was John von Neumann, when he formulated: "The result of the measurement is indeterminate because the state of the observer before the measurement is not known exactly. It is conceivable that such a mechanism might function because the state of information of the observer regarding his own state could have absolute limitations, by the laws of nature."¹⁰

As a researcher I can only primarily come to know Endophysics through textual relationships, especially through metaphor (a linguistic limitation on my part). The mathematics involved is extremely complex. One hope of the endophysical project is to potentially devise virtual environments to help "embody" the mathematics underlying endophysical processes or at least some aspects of these processes, through visualization and sonification. To bring mathematics into a realm of heightened physical presence. The ability to perform and understand Mathematics arises out of an embodied set of experiences. Mathematics relies on the senses and a functional linguistics (pattern producing and pattern receiving methodology) for the observer. Such virtual environments could shed light by providing experiential relations that are tied to particular Endophysical processes and perhaps elicit further understandings through alternate experiential linguistic means to that of an equation. Rössler suggests the following approach:

Endophysics therefore has to be worked out in a step-by-step manner – starting with very simple model universes. Once a model universe has been finished, the next – involving one or two more forces – has to be tackled, and so forth. Arithmetic is simple but some chains linking individually simple results are not. This means that there is a danger of getting lost even during the first (zeroth) round of iteration.¹¹

If one wants to build up a whole universe, on the other hand, it is necessary to reach a level of geometric understanding which allows one to extrapolate from small to arbitrarily high particle

numbers without effort. That is, a “building-blocks principle” is needed. Such a principle indeed exists – in one-dimensional billiard systems.¹²

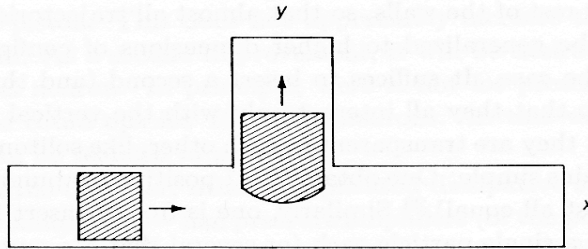


Fig. 1. A 1-D universe of two chaotic billiard balls.

This “building-blocks principle” is an interesting and logical approach to the problem. Yet, part of the problem is that the ideas that Rössler has articulated, come from his deep knowledge of scientific and mathematical theory. Thus, to a degree he is drawing on Platonic 1st principles to approach this science. Science, historically, as a larger set of disciplines, has often suggested the need for *verifiable experiences* to progress. Unfortunately, in order to study the physics of the processes that form our behaviors, we disturb them. We are one with the environment that houses us and can only study it by making an articulated “cut” which is physically impossible at this time, although it may be accessible through artificial world modeling as Rössler suggests. Primas states:

By environment we simply mean everything which does not count to the object system under investigation – the rest of the world. At first sight, the distinction between object and environment is quite blurred when one considers the object and its environment not as separate static entities but as dynamically interacting systems.¹³

Primas later states:

The environment of an object system acts as *background* which is indefensibly neglected in historical quantum mechanics. From our first principles we have absolutely no arguments which would justify the neglect of the environment. The omnipresent Einstein-Podolsky-Rosen correlations imply that *electrons, atoms, or molecules of the empirical reality never exist in total isolation*. That is, the environment of an exophysical quantum system can never be left out of consideration. The environment induces symmetry breakings and is responsible for the audible separability of the empirical reality and the localizability of contextual objects.¹⁴

Rössler has suggested that virtual worlds may also run simulations in which observation might be undisturbed in terms of the observer, providing insight into Endophysical phenomena by defining a virtual, non-interacting, “frictionless” division. Rössler states:

An objective physics must keep the observer at bay. The goal of keeping the observer outside can, paradoxically, be achieved only if the observer is explicitly included in a larger picture – which then is observer-independent again. When proceeding in this way, one realizes that the world is necessarily defined only on the interface between the observer and the rest of the universe. Since this interface is inaccessible as an object, there seems to be no solution left for internal observers like us. We cannot step out of our own world in order to adopt the role of a “superobserver.” Hence we cannot understand the world. Unexpectedly, there is a loophole: “model universes” can be set up which contain an explicit (microscopically specified) internal observer.¹⁵

Certainly Heisenberg’s Uncertainty Principle is the most widely quoted text on the subject in terms of Quantum Physics.¹⁶ Yet, Rössler wished not to lament this characteristic of the connectedness of all things in the world but to circumvent it via conceptual/technological means. He seeks to come to better reflect on

Endophysical processes through the generation of specific virtual environments. His idea (as was Finkelstein's) was to define a virtual computer-oriented model physics that might embody and illuminate the mathematics that is used to posit and articulate endophysics.¹⁷

Rössler seeks to make an artificial life¹⁸ model that runs but is not of one to one relation to the world he is modeling.

The advantage of the artificial life approach ... is precisely that nothing forces one to choose an explicit universe that is "completely realistic" at the same time. Thus, artificial observers that arise in reversible cellular automaton are of the same standing, in principle as are artificial observers arising in a molecular dynamics simulation, and as will be artificial observers generated in a "quantum molecular dynamics simulation" of the future.¹⁹

It is this endophysical virtual simulation that will play a role in helping us to define a model for an electrochemical computer. Perhaps the space of mathematics is already a variety of virtual space. Rössler notes:

It is in principle possible to identify those features of the world which exist only from the inside. Both quantum mechanics and relativity may be virtual realities. The computer paradigm of molecular dynamics simulation, in which a pure chaos, enables the investigation of explicit interfaces – and thereby suggests a novel interpretation of both relativity and quantum mechanics.²⁰

Because we are dealing with the infinitely small, what are the pragmatics of such a research path? How could we construct virtual worlds that would enable new insights to be formed related to the study of Endophysics? Rössler comments:

At last, we reach our main object of study, the internal observer. The present approach was motivated by the aim to arrive at a special-endophysical result that would be valid for a "large" class of observers. Observers that (a) are dissipative structures and (b) contain indistinguishable particles do form a "large" subclass of possible internal observers in artificial Hamiltonian universes.²¹

Could this "billiard ball" "building block" approach seeking to better articulate relations surrounding the physics of the "internal observer" be extrapolated. Pagels, in the book *The Dream of Reason* writes:

The primary research instrument of the sciences of complexity is the computer. It is altering the architectonic of the sciences and the picture we have of material reality. Ever since the rise of modern science three centuries ago, the instruments of investigation such as telescopes and microscopes were analytic and promoted the reductionist views of science. Physics, because it dealt with the smallest and most reduced entities, was the most fundamental science. From the laws of physics one could deduce the laws of chemistry, then of life and so on up the ladder. This view of nature is not wrong; but it has been powerfully shaped by available instruments and technology. The computer, with its ability to manage enormous amounts of data and to simulate reality, provides a new window on that view of nature. We may begin to see reality differently simply because the computer produces knowledge differently from the traditional analytic instruments. It provides a different angle on reality.²²

Yet, it is the very nature of "the smallest and most reduced entities" that opens out another set of problems, particularly in relation to our normal concepts of time moving in one direction. Rössler states:

Norman Campbell proposed in 1921 that all the phenomena characteristic of the quantum domain might be explicable by a single monistic assumption; that time ceases to be well-defined in the microrealm. More specifically, he said: "[Time is] a statistical conception, significant only with

respect to large aggregates of atoms [so] that it is as meaningless to speak of the time interval between atomic events as of the temperature of an isolated molecule.”²³

It is this special nature of the reciprocity of time that makes the creation of relevant computer models a fascinating task to realize. It is interesting to note how science proceeds and paradigms change²⁴. “Thomas Kuhn developed the notion of the ‘paradigm shift’ to help account for the fact that sometimes ‘a law that cannot even be demonstrated to one group of scientists may occasionally seem intuitively obvious to another.’”²⁵ To some degree the creativity involved in the advancement of science relates to the creativity that enables new forms in art to emerge. I believe this is where both Rössler and Seaman find interest in conceptual exchange. In the book *The Evolution of Technology*, George Basalla speaks about “technological dreams”:

Technological dreams are the machines, proposals and visions generated by the technical community, whether in the Renaissance or the present time. They epitomize the technologists’ propensity to go beyond what is technically feasible. Fanciful creations of this kind provide an entry into the richness of the imagination and into the sources of the novelty that is the heart of Western technology. They also challenge the conventional depiction of the technologist as a rational, pragmatic, unemotional person dominated by a utilitarian outlook. (Basalla, 1988, p.67)

Rössler is an extremely erudite conceptualist. He often uses his deep historical knowledge drawn from differing realms including literature, philosophy, art and science, to inform the articulation of his ideas. This forms the vocabulary of his “qualitative” language. We live in a time where what was once described through science fiction can now quickly become authored scientific fact. In particular this is the case with virtual reality which was initially posited in fiction²⁶. We must first arrive at the insight to construct such approaches, mechanisms and technologies. A shift of paradigm, I would argue, only emerges when a particular poetic or creative sensibility is at play. If you have ever read the style of Rössler’s writing, this rich poetic nature is by all means in evidence. Yet, his use of computer-based models has a long tradition. Rössler states:

Today, after the invention of the molecular dynamics simulation paradigm by Alder and Wainwright, who were the first to put billiard balls into a computer,¹⁷ any connotation of sorcery has long vanished.²⁷

3) Addressing the Nature of the Cut between Observer and Observed

Are current computer systems up to the challenge of modeling Endophysical processes? One question is, can we entertain such models, or do we equally become implicated in their study? Do all models become “physical” to be communicated and are thus enfolded in quantum entanglement problems? Does this form an infinite regress where we make a model to study an Endophysical set of processes and then realize we need to make a model to study the model that was made to study these processes, etc. ad infinitum. Along with the entanglement questions are another set of problems related to infinite ‘detail.’ If we truncate a variable to slightly simplify the equation, how does this affect our model world? How can we simplify our simulated world yet derive relevant data?

I have elsewhere articulated an approach to meaning production within the sphere of a subject \leftrightarrow object unity. In a paper written with A. Gaugusch entitled *(RE)Sensing the Observer / Offering an Open Order Cybernetics*²⁸, we articulate the notion that language arises out of reciprocal relations between others, self and environment. We discuss the fact that language is both social and cultural. We suggest that the body is an open system that is continuously changing and expanding in terms of its self-understanding – its linguistic sphere. In particular, that language is “projective” onto environment. Thus our linguistic understandings form and frame the world and actually enable our understanding of the world to arise. More recently I have written about the body as being open in a differing sense — Kelso in his book “Dynamic Patterns” writes the following in terms of the body as an “open, non-equilibrium system”:

These are called open, non-equilibrium systems: open in the sense that they can interact with their environment, exchanging energy, matter or information with their surroundings; and non-equilibrium, in the sense that without such sources they cannot maintain their structure or function.²⁹

I am interested in the pattern flows that inform our coming to know the world. In a paper entitled “Pattern Flows | Hybrid Accretive Processes Informing Identity Construction”³⁰ to be published in *Convergence Magazine*, I conclude with the following passage.

We can summarize here how pattern flows contribute to the hybrid accretive processes that inform ongoing identity construction — *meaning-becoming*. Each sense contributes an experienced pattern over time. Similar but different patterns reinforce particular absorbed/constructed understandings. Multimodal patterns become enfolded and inform an embodied hybrid pattern conjoining spatial/temporal flows of sense perturbations. Through self-reflection we can focus on different qualities of these patterns.

Given a new context, one draws on fragments or residues of these pattern flows and recombines them to both articulate context in a projective manner, and absorb new patterns in a relevant manner from the context. This points to the hybridizing of identity. A projective conceptual linguistic *assemblage* is continuously generated to inform and frame new experience. This projection intermingles the history of experience with new pattern flows in an accretive manner. This bi-directional flow functions within the unifying *space of thought*. Thus, identity is always forming, enfolding memory with new experience. Each new instance of relation potentially enfolds another perspective into the multimodal ‘composition’ of a given identity. Fields of meaning are conjoined and become articulated in the space of thought as an ongoing hybridizing process.

If we pragmatically understand the articulations above, we can begin to address the construction of new linguistic ‘behaviours’ of embodied pattern flows and subsequently hybrid patterns flows. These embodied relations arise in the sphere of the social, the cultural, and the environmental and through self-reflection — through embodied reciprocal relations — intra-actions. We learn to generate patterns, to reproduce patterns, to abstract and recombine sense-oriented perturbations. Let us call this hybrid pattern production. The notion of the ‘recombinant pattern’ draws from a genetic metaphor. This term suggests a living meaning brought about through the intermingling of particular patterns that are both literally and metaphorically ‘spliced’ together — hybridized. The computer is a particularly useful pattern-generating and pattern distributing device, contributing to this expanded pattern-oriented understanding of linguistics.

Both Mathematics and Virtual Reality, driven by mathematics, are particular branches of this linguistic sphere — a sphere that is dynamically being expanded through the potentials of computing — precise pattern production. In particular, virtual reality enables a particular form of potential expansion of the linguistic realm³¹. Central to this essay is the notion that we are in a unity with the world. This notion flies in the face of a primarily dualistic understanding of the world that has been propagated by philosophers and scientists in the west for thousands of years, although there are many instances of this concept of unity in Eastern philosophy.³² Yet, it is ironic that one must create a dualism (Endophysics / Exophysics) in order to better come to know this unity. One famous quote attributed to Buddha states: “Unity can only be manifested by the Binary. Unity itself and the idea of Unity are already two.”³³ The notion of the field, its ability to contain the one and the many, becomes central.

4) Special Characteristics of Endophysics – Differences between Physics and Endophysics

In the book *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*, Edited by Atmanschaper and Dalenoort, Hans Primas provides a clear set of differences related to “Endo- and Exo- theories of Matter”.³⁴

Table 1. A short characterization of endo- and exo- descriptions

	Endo-description	Exo-description
Regulative principle	<i>Universality</i> : Platonic simplicity of the abstract and general	<i>Contextuality</i> : Aristotelian richness and variety of the concrete and particular
Laws	Fundamental first principles	Phenomenological
Referent of the theories	Hypothetical “things-in-themselves”, Platonic ideas	Concrete objects directly perceivable phenomena, empirically accessible phenomena
Truth criterion	Platonic	Verum factum principle
Natural interpretation	Ontic	Epistemic
Logic	Sharp logic (Boolean or orthomodular)	Fuzzy logic (Boolean or orthomodular)
Descriptions	Descriptions are within certain limits universal, but not operational	Descriptions are operational, but in a crucial sense context-dependent
Parameters	Very few universal constants	Many context-dependent empirical constants
Time	Newtonian time, no asymmetry between	“Bergsonian” time, asymmetry between past and future
Events	No facts	Emergence of facts

It is clear that Endophysics has a number of characteristics that exist in opposition to many established approaches to contemporary science. Yet again, it is only through these deep moments of insight that science can progress. There is no ongoing correct direction... each new paradigm shift potentially shapes a new generation of thinkers. Primas goes on to state:

The relation between quantum endophysics and quantum exophysics corresponds to that of Plato’s transcendent universals and the shadows on the wall of Plato’s cave. The existence of such universals can only be inferred intuitively and expressed mathematically. The problem of linking endophysical ideas to exophysical empirical concepts is the task of a theory of measurement. The notorious *measurement problem* in quantum mechanics is an example of such an interface problem: the derivation of a statistical interpretation of quantum exophysics from ontologically phrased quantum endophysics.³⁵

In reading the above table it came to me that what was needed was some form of bridge between the linguistic methodologies illuminating both the Endo and Exo realms. As an artist working with interaction design, generative systems, and the exploration of virtual environments, I wondered if instead of one virtual world, running based on the endophysical principals that Rössler was positing, could we run two parallel virtual worlds, one endo and one exo, that are in some manner reciprocally connected. My perhaps naïve conjecture was to look for some common ground between the Endo and Exo perspectives. An early question that I asked Rössler dealt with the boundry between Exo and Endo space. How is such a boundry defined? I looked for a common denominator. Primas in the above diagram, suggests that “Hilbert Space” is common between the two realms, yet this was still a misnomer. Primas states:

Our contemporary texts on quantum mechanics fail to analyze the exo/endo-perspective and they mix up endo- and exo-theoretical notions. One of the reasons of this misconception is due to the fact that in traditional quantum mechanics – in contrast to classical mechanics – the ontic endophysical and the epistemic exophysical description can be formulated in the very same mathematical framework: the Hilbert-space formalism of quantum mechanics. If the underlying phase space is locally compact, this procedure is mathematically correct but conceptually misleading. A closer analysis shows that for Hamiltonian theories (including classical mechanics

and quantum mechanics over an arbitrary phase space) in general *the mathematical formalism for ontic endophysics is different from the formalism for statistical exophysics*.³⁶

Yet again, one wonders if there can be some potential mechanism to form this bridge between Endo and Exo realms. Primas articulates the following notion:

Experimentally inaccessible ontic states are not meaningless but play a particularly interesting role in classical mechanics, they lead to the phenomenon of the so-called deterministic chaos, that whose exophysical operational descriptions are nondeterministic.³⁷

James P. Crutchfield suggests the following about the difference between Prediction and Modeling in his text *Observing Complexity and the Complexity of Observation*:

These comments bring us to the fundamental differences between prediction and modeling. The distinctions are rather clearly drawn in computational learning theory. But, roughly, the difference is that in prediction the goal is to produce the best guess of future behavior, *by any means whatsoever*, in contrast with modeling the goal is to learn something about the process's structure. Naturally, prediction is aided by means of a good model; but typically efforts at prediction allow for any sort of representation, as long as it gives good forecasts. And so, for a given process there may be good predictors – such as historical look up tables – that indicate little, if anything, about the process's causal structure. Modeling demands much more and, if successful, it provides much more; certainly more than just good forecasts. The dichotomy, as drawn here, is that modeling is the search for causality, and prediction is the search for determinism.³⁸

We are beginning to get the larger sense that mind/body/environment relations and their dynamic connection to endophysical study, forms an interesting set of problems. It is logical to think that sentience may be arising in part from quantum level physical processes. Most studies of mind are still approaching this functionality in a 'classical' manner.

5) The Creation of Reciprocal Virtual Environments

Seaman and Rössler met first during the *Perspectives* show in Budapest, 1999. Our initial discussions outlining the creation of a virtual environment to explore endophysics began at this time. Seaman and Rössler were both interested in approaching mind and/or meaning production through virtual environments functioning as 'discourse mechanisms'. Seaman had been re-thinking meaning production from an extended linguistic perspective embodied in a generative virtual environment – *The World Generator/ The Engine of Desire (1995-present)*, a collaboration with the Programmer Gideon May. Rössler's thought was popularized at an *Ars Electronica* gathering and also in his wonderful book – *Endophysics – The World As Interface*, published in 1998. Rössler gave the book to Seaman as a gift in July of that year. Much earlier, in 1974³⁹, Rössler had published his "equation for a brain."

6) A Situated Approach

A number of books discuss the beginnings of a situated approach to computation and in particular to AI. Few take an endophysical approach to this task. The book *Plans and Situated actions: The Problem of Human-machine Communication* by Lucy A. Suchman, laid out a series of novel ways to look at human/computer relations. In the chapter entitled *Interactive Artifacts: Automata and Cognitive Science*, she states:

Actually, the term "interaction" has its origins in the physical sciences, to describe a reciprocal action or influence. I use it here in the common sense assigned to it by social science; namely, to mean communication between persons. The migration of the term from the physical sciences to the social, and now back to some ground that stands between them, relates in intriguing ways to a general blurring of the distinction between physical and social in modern science, and to the general question of whether machines are actually becoming more like people or whether, in fact,

people are coming to define themselves more as machines. There is clearly a mutual influence at work.⁴⁰

She went on to state:

... Julien de la Mettrie published *Man, A Machine*, in which he argued that the vitality characteristic of human beings was the result of their physical *structure*, rather than either of something immanent in their material substance or of some immaterial force.⁴¹

she also writes:

The study of cognition is to be empiricized not by a strict adherence to behaviorism, but by the use of a new technology: namely, the computer.⁴²

In subsequent thought and conversation between Rössler and Seaman, an interesting set of connections arose between computation, the notion of the observer, and Artificial Intelligence. In particular, if we understand the ramification of the physics suggested above, then we need to re-approach the study of mind (and alternately artificial intelligence) from an Endophysical perspective. Along with this approach to mind, one also needs to rethink advanced computational theories, i.e. how do very very small endophysical processes enable sentience to arise in the human mind? If one goal of Artificial Intelligence is to achieve a sentient machine, then these micro-processes must also be taken into account, and drawn upon to form new computational models. Yet, such an approach needs to be holistic and take the entire set of processes into account bridging environment/body/brain/mind — if we accept the impossibility of making the “cut.” Thus, if environment can not be “cut” away from how we come to know the world, then new embodied models of computation need to be developed and articulated. Certainly quantum computing begins to approach this endophysical realization⁴³ but it is limited in not having a “body of experience” to inform it’s processes, or senses to build up a set of experiences to abstract from (if self-awareness and sentience is a goal). In Current models of quantum computing both situatedness and mobility are lacking.

Perhaps the biggest problem is the problem of scale and the multiplicity and complexity of systems working together that enable sentience to arise. This speaks to the transdisciplinary nature of the task at hand.

Suchman points out the importance of linguistic interaction as being central to human/machine relations:

A more profound basis for the relative sociability of computer-based artifacts, however, is the fact that the means for controlling computing machines and the behavior that results are increasingly *linguistic*, rather than the mechanistic. That is to say, machine operation becomes less a matter of pushing buttons or pulling levers with some physical result, and more a matter of specifying operations and assessing their effects through the use of a common language.⁴⁴

Yet a sentient machine would function based on a self-organizing set of foci, again with the help of a “common language” and is equally in need of an expanded linguistics to communicate and generate meaningful patterns. Seaman in his paper to be published in convergence magazine states:

An expanded linguistics arises as an ability to fragment, combine and recombine particular pattern instances in the service of evocation and exchange — articulation through intra-action. I am proposing a non-logocentric (or non word-centered) linguistics, although words, both spoken and written, form relevant patterns that are sensually perceived and are part of this new linguistics. Here we are moving to a multi-sensory spatio-temporal pattern-based linguistics. By understanding linguistics in this manner we can bring a series of sensual instantiations and media forms into language study, not mimicking the functional nature of words, but exhibiting their own patterned qualities. The complexity that arises out of this re-interpretation is profound yet is none-the-less necessary to clearly understand an accretive, non-dualistic approach to meaning production.

... The computer is a particularly useful pattern-generating and pattern distributing device, contributing to this expanded pattern-oriented understanding of linguistics.

This concept is central to the notion of devising a virtual environment to study Endophysical processes. It is also important to the functionality of our electrochemical computer. Yet, might a particular kind of emergent environment be devised, that would enable endophysical properties to contribute to the study of the nature of mind. Much of the examination of mind arises from self-reflection as it is intermingled with scientific reflection (facts). Varela, Thompson and Rosch in *The Embodied Mind*, speaking about Buddhist mindfulness/awareness suggest:

Its purpose is to become mindful, to experience what one's mind is doing as it does it, to be present with one's mind. What relevance does this have to cognitive science? We believe that if cognitive science is to include human experience, it must have some method of exploring and knowing what human experience is.⁴⁵

So self-reflection becomes enfolded with scientific reflection. In fact, they are inextricably bound. So how could we devise a neo-computation environment that is deeply self-reflective and also communicative? How could creativity enter into the equation? Interestingly enough Rössler sees both forms of communication as essential to our paradigm. He states:

Imagination is the hard part in biology, not implementation, no matter how cute and familiar the equations may become eventually. But maybe I am only saying this to spare me the trouble of having to switch back and forth all the time between the two levels, one qualitative, one quantitative, both are exact but each need a different language to talk about them.⁴⁶

7) The Thoughtbody Environment / Toward a Model for an Electrochemical Computer

Seaman and Rössler met on a few different occasions between 1999 to the present. During one meeting in Switzerland in April of 2003 the notion of generating a model for an electrochemical computer entered the conversation. Rössler had been exploring related ideas for many years. In the paper *An Artificial Cognitive Map System*⁴⁷ he outlined a fascinating electronic approach which brought together a digital scan converter and a flight simulator to derive an early cognitive map system pointing at the relationship of the memory of context to context explored in real time. Certainly notions surrounding the production of a sentient machine were central to our discussion. The concept dealt with observing the workings of the body on the deepest of levels and generating a mechanism based on these observations. The ethics of such an undertaking were discussed by Rössler and Seaman. The notion to create a "Benevolence Engine" was entertained and agreed upon. A series of letters were exchanged and a set of discussions explored a range of topics. Since this initial meeting I have been researching many books that in one way or another cover the subject. I have also read as many of Rössler's writings that I could obtain. I will here try to pull together a series of relevant ideas gleaned from this study. It must be noted that this particular undertaking has sought to be a holistic approach from the very start, incorporating the notion that the body is an environment nested within a larger environment. Seaman's initial text — *The Thoughtbody Environment, Notes Toward a Model for An Electrochemical Computer*⁴⁸ began to discuss the subject. Yet, Rössler commented that this first text was presented more from the Exophysical perspective, and that I should try articulating some thoughts on the subject using an Endophysical approach. I will here provide a series of quotes that inform this broader methodology:

Certainly Science Fiction often pre-dates or helps to inform eventual science fact. Rössler has in the past pointed to science fiction as articulating or providing ideas surround particular driving research problems. Rössler states:

The second or "special" phase of endophysics, in contrast, cannot do without brain theory. Here, assumptions which are not of a completely general nature but are relevant only if an explicit observer ("brain") is a part of the model universe become essential. This makes the connection with Galouye's (and Stanislav Lem's⁴⁹) science fiction even closer. The only difference would be

that the present model universes are supposed to be microscopically rather than macroscopically simulated. In this context it is perhaps worth noting that the first potentially conscious computer program was developed in 1977 by Kosslyn and Schwartz.⁵⁰

So perhaps some will see elements of science fiction in both our initial plans for the model and in the poetic works that I will be making related to our discussions.

Let us try to acknowledge some beginning moments leading up to these notions from the perspective of science. Central to the paradigm is the concept of physical ‘patterning’ as intermingled across a number of scales.

I will begin with a section from *Turing’s Diffusion-reaction Theory of Morphogenesis*:

Put quite simply, all this is as much as to say that *in an embryonic process, in which the metabolic substances are originally distributed in a homogeneous manner, a regular patternised distribution of specific metabolites may eventually result and a morphological or histological pattern become manifest*. This patternised distribution of specific metabolites (or morphogenetic substances) – the stationary waves of the mathematician – takes place in conformity with the laws of physical chemistry as applied to diffusion-reaction systems.⁵¹

Endophysics may enable us to help articulate the nature of Morphogenetic patterning as it relates to how mind arises. Turing and Wardlaw state:

The idea that diffusion reaction systems are present in all growing regions, indeed in all living matter, is not new: it is basic to all studies of metabolism. What is novel in Turing’s theory is his demonstration that, under suitable conditions, many different diffusion reaction systems will eventually give rise to stationary waves; in fact, to a patternised distribution of metabolites. If we consider an undifferentiated embryonic region, such as the apex of a root, in which a symmetrical, radiate histological pattern develops, the applicability of the theory seems highly probable. In that diffusion reaction systems are present in all growing regions, it would appear probably that they are, in some way, involved in the inception of pattern. Not all aspects of pattern however, can, or need, be referred to the development of stationary waves – the major feature of Turing’s theory as thus far developed (1952).⁵²

So here is where we see the study of chaos theory⁵³ and the study of mind converging. Rössler is famous for articulation of the “Rössler Attractor.” “Rössler-like equations, as this author claims, can be used as guideline for the identification of systems (i.e. natural or artificial) showing the same behavior, for instance in astrophysics, chemistry, biology as also in economics.”⁵⁴ How can we apply such approaches to knowledge to the study of Endophysics and in particular how mind arises as a physical process in terms of finding relevant relations that are isomorphic in nature? This is perhaps one salient question.

8) Chemical Computers by Pask and More Recent Work by Cariani

Early on, Gordon Pask, no doubt familiar with Turing’s ideas, began to work on the notion of growing a computer.

Chemical computers arise from the possibility of ‘growing’ an active evolutionary network by an electro-chemical process.⁵⁵

A number of authors have picked up on this approach to computing. There are few texts which appeared early on that seem groundbreaking. I have been particularly interested in multimodal patterning and how this might inform the construction of a model for an electrochemical computer. Many relevant ideas were explored in *Mind Design II: Philosophy, Psychology, Artificial Intelligence* by Haugeland.⁵⁶

Dennett, like Turing, thinks intelligence is a matter of how a system behaves; but, unlike Turing, he also has a worked-out account of what it is about (some) behavior that makes it intelligent – or, in Brentano’s terms, makes it the behavior of a system with intentional (that is, *mental*) states. The idea has two parts: (i) behavior should be understood not in isolation but in *context* and as part of a consistent *pattern* of behavior (this is often called “holism”); and (ii) for some systems, a consistent pattern of behavior in context can be construed as *rational* (such construing is often called “interpretation”).⁵⁷

So the notion of a holism or holistic approach to mind and to computing, emulating mind, is not new but has been in the air for some time. Certainly an interest in patterning and operations on patterning are central to this history. From *Semantic Recognition Systems*:

The possibility of substituting recognition for search arises because a particular, and especially a rare pattern can contain an enormous amount of information, provided that it is closely linked to the structure of the problem space. When that structure is “irregular”, and not subject to simple mathematical description, then knowledge of a large number of relevant patterns may be the key to intelligent behavior.⁵⁸

It is here that I would equate ‘Pattern Acquisition’ with language acquisition. That the patterns that enable physical change in the brain are the same as the patterns that enable us to sense our world as well as to communicate about it. Thus our experience of pattern via the senses, physically promotes pattern production and pattern change in concert with the electrochemical substrate of our body. Similar but different patterns that are sensually perceived are reinforced and become a means to articulate identity. This is a holistic enterprise where multiple senses create a multi-dimensional space of patterning enfolding new experience with the projective patterning of past experience.

If we begin to articulate the framing of experience as being pattern related, we can understand this “framing” as being formed by the ongoing reinforcing of physical relations, operating on physical pattern domains to alter and/or recombine them. The physicality that enables the generation of these patterns may be environmental or patterns may be generated by the body itself. Haugeland in *Mind Design II* discusses Physical Symbol Systems:

Symbol systems are collections of patterns and processes, the latter being capable of producing, destroying, and modifying the former. The most important properties of patterns is that they can designate objects, processes, or other patterns, and that when they designate processes, they can be interpreted. Interpretation means carrying out the designated process. The two most significant classes of symbol systems with which we are acquainted are human beings and computers.⁵⁹

Yet, what are the systems that enable these environmental patterns and patterns of mind to co-evolve and inform each other. Since we are speaking of a mind/body/environment then we can attempt to trace a physics of forces as a particular approach to mind arising. Again, the nature and physicality of pattern production, pattern association, pattern augmentation, and hybrid pattern production, becomes central.

One response, shared by existential phenomenologists such as Merleau-Ponty and ordinary-language philosophers such as Wittgenstein, is to say that such “knowledge” of human interests and practices need not be represented at all. Just as it seems plausible that I can learn to swim by practicing until I develop the necessary patterns of responses, without representing my body and muscular movements in some data structure, so too what I “know” about the cultural practices which enable me to recognize and act in specific situations has been gradually acquired through training in which no one ever did or could, again on pain of regress, make explicit what was being learned.⁶⁰

Haugeland in *Mind Design II: Philosophy, Psychology, Artificial Intelligence underscores this point.*

Looking back over the past ten years of AI research we might say that the basic point which has emerged is that *since intelligence must be situated it cannot be separated from the rest of human*

life. The persistent denial of this seemingly obvious point cannot, however, be laid at the door of AI. It starts with Plato's separation of the intellect or rational soul from the body with its skills, emotions, and appetites. Aristotle continued this unlikely dichotomy when he separated the theoretical from the practical, and defined man as a *rational* animal – as if one could separate man's rationality from his animal needs and desires. If one thinks of the importance of the sensory-motor skills in the development of our ability to recognize and cope with objects, or of the role of needs and desires in structuring all social situations, or finally of the whole cultural background of human self-interpretation involved in our simply knowing how to pick out and use chairs, the idea that we can simply ignore this know-how while formalizing our intellectual understanding as a complex system of facts and rules is highly implausible.⁶¹

So it is no wonder that AI has had its fair share of difficulties. It has been lacking a direct link to environment and a sensing body. These become central in developing a model for an electrochemical computer. Haugland sets out the following set of relevant principals in the "Connectionist Framework":

The Connectionist Framework

There are seven major components of any connectionist system:

- a *set of processing units*;
- a *set of activation* defined over the processing units;
- an *output function* for each unit that maps its state of activation into an output;
- a *pattern of connectivity* among units;
- an *activation rule* for combining the inputs impinging on a unit with its current state to produce a new level of activation for the unit;
- a *learning rule* whereby patterns of connectivity are modified by experience; and an *environment* within which the system must operate.⁶²

So pattern is central and the repetition of pattern linking body to environment in a multimodal manner is essential. Here we return to a seminal rule, yet seek to "(re)sense" it:

Virtually all learning rules for models of this type can be considered variants of the *Hebbian* learning rule, suggested by Hebb in his classic book *Organization of Behavior* (1949). Hebb's basic idea is this: if a unit u_i receives an input from another unit u_j at a time when both units are highly active, then the weight w_{ij} to u_i from u_j should be *strengthened*.⁶³

Yet, historically studies of mind have attempted to isolate sense-oriented functionalities— to separate out the senses and study them one at a time. In term of our new holistic approach, the study of multimodal inter-functionality becomes central. In this sense we need to study how multimodal perturbations form a timed structure that reinforces different sense-based flows of an ongoing process. Our perceptual focus and projective conceptual /linguistic apparatus also come into play and become enfolded in terms of the nature of this "strengthening". Can we develop a new theory of weighting that takes all sensual stimulation into account, as a multiplicity or how a spatial/temporal set of flows become strengthened? How might non-local quantum affects become part of this system? Can the physical processes that bring about pattern change be re-oriented through the subtle processes of non-local quantum activity?

9) *Ultimate Computing*

Thus, in order to define our model we must take each of the above points into consideration. Yet, much has happened in the study of mind. The apparatus to study physical systems has become much more precise. The workings of the brain and body turn out to have a much greater complexity than every before understood. The book *Ultimate Computing* by Stuart R. Hameroff early on, in 1987, postulated a much deeper approach to the biological functionality at operation in thought. It is from such books that we know that a new computing paradigm, informed by physics and biological study should now be clearly articulated. More recently Hameroff has continued in this process. In particular he has been developing ideas surrounding *Quantum Consciousness*.

Consciousness defines our existence and reality, but the mechanism by which the brain generates thoughts and feelings remains unknown.

Most explanations portray the brain as a computer, with nerve cells ("neurons") and their synaptic connections acting as simple switches. However computation alone cannot explain why we have feelings and awareness, an "inner life."

We also don't know if our conscious perceptions accurately portray the external world. At its base, the universe follows the seemingly bizarre and paradoxical laws of quantum mechanics, with particles being in multiple places simultaneously, connected over distance, and with time not existing. But the "classical" world we perceive is definite, with a flow of time. The boundary or edge (quantum state reduction, or 'collapse of the wave function') between the quantum and classical worlds somehow involves consciousness.

I spent twenty years studying how computer-like structures called microtubules inside neurons and other cells could process information related to consciousness. But when I read *The Emperor's New Mind* by Sir Roger Penrose in 1991 I realized that consciousness may be a specific process on the edge between the quantum and classical worlds. Roger and I teamed up to develop a theory of consciousness based on quantum computation in microtubules within neurons. Roger's mechanism for an objective threshold for quantum state reduction connects us to the most basic, "fundamental" level of the universe at the Planck scale, and is called objective reduction (OR). Our suggestion for biological feedback to microtubule quantum states is orchestration (Orch), hence our model is called orchestrated objective reduction, Orch OR.⁶⁴

Thus, we begin from this perspective one set of ideas.

Quantum mechanics describes the seemingly bizarre behavior of matter and energy at microscopic scales, e.g. that of atoms and sub-atomic particles. At that level particles may be in two or more places at the same time (quantum superposition), and particles widely separated in distance may nonetheless be intimately connected (quantum entanglement). These properties are used in quantum computation which offers potential solutions to the enigmatic features of consciousness. However quantum computation is disrupted by interactions with the environment ('decoherence'), and neurons and synapses seem too large for delicate quantum effects.'

He continues:

If an atom in such a state interacts with its environment--by being bumped or prodded by nearby atoms, for instance-its waveform can 'collapse', ending the superposition by forcing the atom to commit to one of its possible states... To some investigators, this process of coherence and collapse seems strikingly similar to what goes on in the mind. Multiple ideas flit around below the threshold of awareness, then somehow solidify and wind up at the front of our consciousness.

He also writes:

If we look inside neurons and other cells, we see highly ordered networks (the 'cytoskeleton') comprised of microtubules and other filamentous structures which organize cellular activities. Microtubules are cylindrical polymers of the protein tubulin arranged in hexagonal lattices comprising the cylinder wall. Cooperative interactions among tubulin subunits within microtubules have been suggested to process information, as in molecular scale 'cellular automata.' As the states of tubulin are controlled by quantum mechanical internal forces (van der Waals London forces), they may exist in quantum superposition of multiple states ('quantum bits', or 'qubits'), and microtubules may be seen as quantum computers involved in cellular organization.⁶⁵

It is interesting how computer metaphors move back and forth between being inadequate to reflect mind and then later, after a "quantum jump" in thought is made, new computing paradigms become operative

metaphors. To my mind we still need a broader perspective --- one that enfolds the senses and environment, extending even models of quantum computing into new realms. Along with the quantum affects articulated by Hameroff and Sir. Penrose, other interesting phenomena have literally come to light.

10) Biophotonics

One incredibly exciting area of research was made known to me in a paper delivered by Roy Ascott, entitled *Interfacing the Biophotonic Matrix*, was presented at Cyberfest in Bilbao last year. In the paper he mentioned the exciting work of Friz-Albert Popp. Subsequently this has brought a second highly fascinating area of investigation into the fold of our model— the nature of Biophotonic process in thought and bio-functionality.

In the book *Biophotons* edited by Edited by Jiin-Ju Chang, Joachim Fisch and Friz-Albert Popp, some very exciting ideas come to light.⁶⁶ These to some degree are still being debated but the debate is fascinating none the less. In terms of the integrations and stimulation on a physical level of particular biological reactions, it may be that very weak coherent light plays a central role.

Thus, the biochemical reaction is not only controlled by the availability of specific enzymes, but even more by the presence of suitable photons within the surrounding photon field. We have to conclude that the basic regulator of chemical reactivity is a photon, and all its physical properties influence the reactivity. Moreover, only photons can give us the answer to the crucial question how all the chemical reactions in a cell can be triggered at the right place at the right time. Actually, the reaction rate in a human cell is of the order of 100,000 reactions per second. One may object that a few “biophotons” are not enough to always provide the necessary activation energy for all these reactions. However, a rough estimation shows that even a few photons, and nothing else realistically, can provide the necessary activation energy to all the biochemical reactions which take place in a cell.⁶⁷

Thus, biophotons need to be understood and folded into our new model for an electrochemical computer. One wonders also how differing qualities of resonance play into our model.

One can say therefore that if the DNA (and possibly also other biomolecules) works as the resonator of biophotons in the cell it is very likely that all the information which is necessary to trigger the chemical reactions can be transferred.⁶⁸

There are also those working on DNA computers⁶⁹ as another new computational paradigm. I am very interested in how the diversity of bio-systems inherent to thought, become integrated. This is central to our holism. I am also interested in how these biological models might be enfolded back into more traditional forms of computing. In the book *Biophotons* the authors state:

Take the case that different biological systems emit different, but species-specific, patterns of electromagnetic waves which they may compensate mutually by destructive interference. This provides the most sensitive field of communication. Actually, the organisms are able to identify each other by the control of the capacity of destructive interference of their wave patterns. At the same time, every fluctuation around the ideal destructive interference, corresponding to the vacuum state, has to be interpreted as “information” of the highest possible signal/noise-ratio.⁷⁰

They continue:

This capacity for using the phase information in order to organize the metabolic events as well as the “Gestalt”-formation of biological systems seems to be elementary for living systems.⁷¹

So each of these pattern generating devices becomes enfolded in the ongoing functionality of the human being. Another area of investigation informing pattern production that in turn informs thought is that of “volume transmission”. Scott Kelso in his book *Dynamic Patterns - The Self-Organization of Brain and*

Behavior provides the following concerning Elementary Neurons and Synapses:

Increasing evidence suggests that neurons can communicate without making intimate contact at synapses. Rather than information flowing along structured pathways like electricity flowing along wires in a circuit, such communication, called volume transmission, is more like a radio broadcast...⁷²

How can we begin to devise an approach that includes the nature of this specific form of biological functionality? What role does quantum non-locality play in volume transmission? Kelso states:

...The brain is fundamentally a pattern forming self-organized system governed by potentially discoverable, nonlinear dynamical laws. More specifically, behaviors such as perceiving, intending, acting, learning and remembering arise as metastable spatiotemporal patterns of brain activity that are themselves produced by cooperative interactions among neural clusters. Self organization is the key principle.⁷³

He continues:

I believe that only particular kinds of experimental probes are going to offer insight into self organizing processes in the brain and how these relate to behavior. One is reminded of Otto Rössler's challenge to neuroscientists that in a complex system such as the brain (with more variables than the age of the universe in seconds), it is almost a miracle to find low-dimensional dynamics. But that is, in fact, the miracle that we seek. In my view, it is the cooperative action of neurons functioning together to create dynamic patterns in the brain that permits this miracle to happen.⁷⁴

So we continue with our theme of integrated patterns. Let us return back to Haugland now:

From *The Environment*

That is, for each possible input pattern, we imagine that there is some probability that, at any given time, that pattern is impinging on the input units. This probability function may in general depend on the history of inputs to the system as well as outputs of the system. In practice most connectionist models involve a much simpler characterization of the environment. Typically, the environment is characterized by a stable probability distribution over the set of possible input patterns, independent of past inputs and past responses of the system.⁷⁵

Thus, new models need to take on a higher level granularity given the new perspectives related to actual bio-functionality. So how can we factor microtubules, biophotonics and volume transmission into our embodied model? We need to define how we can integrate the pattern assuming abilities of sensing devices and the actual functionality of the brain in terms of absorbing and operating on these patterns. Haugland offers this thought:

From *Subsymbolic Computation*

The systems we are talking about are dynamical systems, not a von Neumann machine. The mathematical category in which these formalisms live is the continuous category, not the discrete category; so we have a different kind of mathematics coming into play. The differences are dramatically illustrated in the way memory is modeled in the two formalisms. In a von Neumann machine, memory storage is a primitive operation (you give a location and a content, and it gets stored), memory retrieval is likewise primitive. In subsymbolic systems, by contrast, these processes are quite involved – they're not primitive operations at all. When a memory is retrieved, it is "addressed" by its *contents*: a fragment of previously-instantiated activation pattern is put into one part of the network (by another part of the network), and the connections fill out the remainder of that previously-present pattern. This is a much more involved process than a simple "memory

fetch”. Memories are stored in subsymbolic systems by adjusting connection strength such that the retrieval process will actually work – and this is no simple matter.⁷⁶

Thus, we seek to articulate an approach that can articulate how these processes function and become integrated over time. We also seek to understand how non-local particle qualities function and what the ramifications of these processes are for an electrochemical computer and/or human thought.

Thus our network has various speeds of reaction which are assumed and summed – the speed of light, speed of bio-mechanical reactions, the speed of biochemical reactions, synapse flows, qualities inherent to the size and shape of the body and positioning of nerve endings, speed of perturbations relative to the producing body (i.e. speed of sound), etc., all of these simultaneous processes having different speeds and qualities are enfolded and enable sentience to arise, becoming the present. Could micro-fluctuations in time, quantum time reciprocity – in other words time moving forward and backward in the endophysical realm, have some bearing on this summing?

11) Benevolence Engine | The Thoughtbody Environment - Developing an N_S.E.N.T.I.E.N.T. Entity

I will here sum up where we are in terms of the development of an initial approach to our model for an electrochemical computer. We will seek to bring all of the above researches described above under one roof (so to speak) to articulate a new paradigm. I will call the goal of this research the production of an N_S.E.N.T.I.E.N.T. entity. This acronym seeks to enfold many of the qualities described above. Our device must be:

N_S.E.N.T.I.E.N.T.

Neo-sentient
 Self-organizing
 Environmentally Embedded
 Nascent
 Temporal
 Intra-active
 Emergent
 Navigational
 Transdisciplinary

Thus, we would seek to develop a form of synthetic biologically emulated neural network, informed in part by the sub-neuronal activity described above including microtubules, biophotonics and volume transmission. Such a “neuron” farm would need direct input from a multimodal sensing environment. Communication from N_Farm to/from “Body/Environment” or Sensor/Affectors with speed of light connectivity the N_Farm might be located at a distance from the body of receptors and effectors. (What does the distance of our hand from our mind play into our coming to know the world? To what degree does the measure of the body play into meaning-becoming. This complex process space might be either bio-mimetic (human like in form) or architectural or other. This may also be connected to a more global distributed sensing system. Although mobility/navigation is seen as central to the survival of the human and thus should also be enfolded into the paradigm.

We seek to enable a meta-sensor/affecter environment⁷⁷ – a Bio-Synthetic Nervous System of sorts, extending Pask and Cariani’s research. My ongoing research into the Poly-sensing environment⁷⁸ with Ingrid Verbauwede and Mark Hansen can be enfolded into this larger research realm. It explores the building of multimodal chips and a related environment for authoring media associations.

In the Poly-sensing environment our new paradigm will enable every chip to define a "poly-sensing" "neighborhood". Another key feature of the research explores the following: the technology will be created with a flexible and adaptive means of focusing the "attention" of these multiple-sensing devices in recombinant groups of intercommunicating distributed fields. The

*"Poly-sensing" environment potentially enables the intelligent storage, triggering, and calling-up of media elements and media behaviors, images, relevant libraries, and databases, accessing both local and distributed (Internet based) memory systems as well as operative programs to be elicited by physical events in the "sensed" space. The system enables any object or behavior in the field of "attention" to become an interface through multi-modal sensing. This represents a significant paradigm shift in human/computer interface design.*⁷⁹

It is interesting to note the research that Peter Cariani has undertaken i.e. *Some Epistemological Implications of Devices Which Construct Their Own Sensors and Effectors*.⁸⁰ Cariani also wrote *To Evolve an Ear: Epistemological Implications of Gordon Pask's Electrochemical Devices*.⁸¹ His online site is filled with excellent papers that relate to the above topics.⁸² Seaman and Cariani have also begun a series of discussions around the above topics.

Seaman and Gaugusch, in their paper *(RE)Sensing the Observer. Offering an Open Order Cybernetics*⁸³, have discussed a series of issues that fold into the paradigm: These include the social, cultural, and self-reflexive nature of language acquisition and the unity of experience.

Seaman has articulated ideas surrounding an expanded linguistics in a paper entitled *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*.⁸⁴ Again, these ideas can be folded into the paradigm.

Rössler and Seaman have discussed the ethics of constructing such a device. Certainly the goal is to reflect deeply on human sentience. A nickname for the project came out of these discussions— *The Benevolence Engine*. It is clear that one would need to “bring up” such a N_S.E.N.T.I.E.N.T device with benevolence and ethics.

Seaman’s work the World Generator / The Engine of Desire (with Gideon May) explores creative patterning processes, recombinant pattern creation and meta-meaning potentials.

Rössler’s refinement of his “equation for a brain” is currently in process as are his articulations surrounding endophysical processes. His pursuit of defining attractors also informs the model.

12) The Limits of Science

The task before us is infinite. Yet we somehow choose this ever expanding path, knowing we can never fully reach our goal. We realize the process reveals to us new knowledge that folds back into our observing, the depth of our language, enriching and extending the meaning of the observations we articulate. The ‘folding back in’ alters the trajectory of the path itself. This certainly is reflected in the history of science. We are potentially on the cusp of a new paradigm.

So what are the salient issues informing us and what are the limits we come up against ?

- 1) The body functions as a coherent unity, as an environment embedded within a larger environment. Studying the part may or may not help with understanding the arising of sentience in a holistic manner. Thus we are trying to find ways to get at that which enables sentience to arise, flowing up from quantum level processes. If we contend that endophysics plays an important role in this process, then we must begin to articulate a research path that resonates across a series of biological and physical domains.
- 2) The infinite is housed in our body. The infinitely small space of endophysics enables the working perception of exophysical events. Yet, in the very human nature of finite time, how can we ever expect to point at infinite processes in a meaningful manner? Humans must always choose a point to truncate the infinite to bring it into the realm of the finite. How can we do this and still derive meaningful models?

- 3) Historically, it appears that science sought to isolate fragments of the body to study the body's workings i.e. vision was studied apart from the other senses. Certainly new imaging technologies begin to make the potential of studying the flows of a living body more tenable — multimodal sensory experience. Can new approaches to modeling technologies transcend the physical/technological limits of current imaging and modeling technologies? Certainly through exploring the Platonic 1st principles articulated by Rössler, one seeks to posit a realm that could potentially help extend and focus the potentials of new technologies — technologies yet to be created.
- 4) The potential of generating a computer model of human bio-functionality is also a daunting task. Yet, if we begin to work toward building such a model as an ongoing process, slowly the complexity of the systems can begin to be reflected. The deeper question is, can a finite state machine (the common computer) help us reflect on an infinite state machine that is unfolded over time? How can infinite state machines provide data that is relevant to our study?
- 5) Does a new paradigm of infinite computing need to be articulated? How might this be either accomplished or the need for such infinite systems be circumvented while still providing relevant data? What role will attractors play in this process?
- 6) How can we develop technologies that enable us to study the workings of multiple biophysical systems, functioning simultaneously across varying scales? What new technologies might enable such study?
- 7) How can we enable the bridging in language that needs to happen between various disciplines to help articulate this multiplicity of depths of processes where each scale is enfolded within the other, forming this coherent whole.
- 8) The body functions over time, i.e., we continue to learn over a lifetime. How can we represent differing time scales in our model? This compounds the complexity of the interfunctioning systems.
- 9) How does the reciprocity of time from the endophysical perspective inform exophysical events?
- 10) Can we somehow articulate new embodied approaches to mathematics that enable insights to arise through experiential virtual means? I believe this is at the center of an approach to Endophysics.

So it is an exciting expanding spiral that continues to get bigger, where growth is self-organizing and alters the trajectory of ongoing future research. It appears that each area of investigation enfolds and informs the others. Mind, Endophysics as a new discipline, and the formation of a model for an electrochemical computer – The Thoughtbody Environment all are intra-forming.

13) Summation of the N_S.E.N.T.I.E.N.T. Paradigm

- 1) An initial artificial life simulation / virtual world will be created to explore the “billiard ball” approach to endophysics.
- 2) A more complex set of virtual worlds will be created to bridge in a reciprocal manner between endo and exophysical processes. This will seek to inform the model for an electrochemical computer.
- 3) The environment of the N_S.E.N.T.I.E.N.T. entity is seen as embedded within a larger environment. We seek to articulate the model within a subject \leftrightarrow object unity.
- 4) A model is to be made of current human functionality on the deepest level available to us. This is by all means a transdisciplinary exercise.⁸⁵ This model will flow upward in scale from the endophysical to the exophysical and will take quantum behaviors into account as part of the model.
- 5) We will seek to define a set of bio-technologies that will work toward mimicking this functionality.⁸⁶ These may also be emulated via virtual means.
- 6) One goal is to explore new models of sentience that include:
 - a) New synaptic models
 - A. The role of microtubules
 - B. Biophotonics
 - C. Volume transmission
 - D. Situatedness and the role of the body/senses.

- E. The role of Synchronized N-dimensional flows stemming from multi-modal perturbations.
- 7) An exploration of the role of quantum behaviors as they affect the arising of thought.
 - 8) A *Synthetic Genetics* of sorts will need to be articulated to potentially inform and steer growth potentials. Other methodologies will need to be developed (bio-nanotechnological etc.) to explore the potential functionality of the electrochemical substrate.
 - 9) The electrochemical substrate is seen as potentially central to sentience arising in terms of physical/quantum behaviors. (This approach is different to historical approaches to computing that primarily employ non-biological substrates and see the electrochemical nature of the body as being irrelevant to human-like computation [A.I.]).
 - 10) Findings related to the development of the model may be abstracted and folded into non-electrochemical computing potentials.
 - 11) The system depends on multimodal sensing as an input device. This sensing may be anthropomorphic or may enfold machinic senses that glean different qualities of perturbation to that of human senses, as well as distributed sensing modalities.
 - 12) The system builds up a set of pattern flows that ‘meaningfully’ connect the system with the environment and help to establish and enable learning as well as ongoing dynamic environmental intra-action and change. An entity is already one with the environment, thus the operative concept here is the notion of learning and intra-action.
 - 13) The system uses these bio-machinic ‘perceptions’ as a means to learn a pattern flow linguistics from intra-actions with *self*, others and environment.
 - 14) The system also becomes generative of pattern flows arising out of environmental intra-action (learning).
 - 15) A projective aspect is at operation that draws on the nature of pattern flows to define context in an ongoing projective manner. Thus pattern flows meaningfully bridge the entity with environment in a bi-directional manner.
 - 16) The model will have the potential of being anthropomorphic,⁸⁷ as well as distributed/architectural.
 - 17) The nature of the model is in part contingent on the limits of technologies that enable the study of the body, as well as the limits of the potential to build functional systems at multiple scales from the nanotechnological scale on up. The model will also depend on people from different disciplines developing language to talk to each other.
 - 18) The ultimate goal is to come to better know the self through this process of articulation.
 - 19) Another goal is to fold information/ideas that arise as part of the research back into the disciplines.
 - 20) The long term goal of the research is to produce a sentient *benevolence engine*.

Conclusion

Thus, I have presented the large field of this N_S.E.N.T.I.E.N.T. paradigm. Perhaps here it makes sense to quote the end of Rössler’s book, *Endophysics: The World As Interface*:

Eventually, as the computers grow faster, a whole ice-skater will come into sight again (as opposed to a one dimensional ‘partial’ view of the ice-skater... emphasis Seaman) – but this time watched completely from the Archimedean frog’s perspective of total reversibility. The first detailed report about the properties of such a “conservative virtual reality” will come in in the year 2010, if everything goes well.

In this way, a new “hopeful suspicion” could be arrived at: the virtual reality paradigm may reveal more about our own world than the usual course of science has led us to believe. Is the whole world a rainbow world? Only after such a suspicion has taken hold do new “diagnostic tools” – to confirm and to manipulate it – have a chance to be developed seriously.

To conclude, the rainbow has not lost any of its childhood magic. To simulate it interactively, an advanced type of VR is required. At the same time, a new attitude is fostered – the walls which surround the sparkling VR-like now at every moment acquire a new tangibility. Does the

hermetic paradigm of computer-generated worlds perhaps hold the key to making our own world less hermetic? The rainbow would become a door in the sky.⁸⁸

So the poetics of “rainbow s“ point to the complexity and richness of seeking to better come to know the self. This is achieved by articulating both a simulation related to exploring the operativeness of endophysical space as well as by working toward the development of a model for an electrochemical computer — *The Thoughtbody Environment, a Benevolence Engine*.

Professor Bill Seaman, Ph.D. April 17, 2005

¹ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.32)

² “Forcing function” is engineering science term that articulates a kind of force that brings about change.

³ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd.

⁴ See Seaman, B. 2005, *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*, forthcoming in *Convergence Magazine*.

⁵ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.29)

⁶ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.127)

⁷ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.32)

⁸ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.xiii-xiv)

⁹ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.xv)

^{10 16} J. Von Neumann, *Mathematical Foundations of Quantum Mechanics* (Princeton University Press, Princeton, 1955), p.439. First German edition, 1932: p.233. as found in Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.18)

¹¹ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.33)

¹² Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.34)

¹³ Primas, H. *Endo- and Exo- theories of Matter*. In Atmanschaper, H. and G.J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.182)

¹⁴ Primas, H. *Endo- and Exo- theories of Matter*. In Atmanschaper, H. and G.J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.183-184)

¹⁵ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (23)

¹⁶ HEISENBERG, W. 1930. *The Physical Principles of the Quantum Theory*. New York: Dover Publications, Inc.

¹⁷ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd.

¹⁸ See LANGTON, C. 1995 *Artificial Life: An Overview*. Cambridge/London: MIT Press.

¹⁹ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.62)

²⁰ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.183)

²¹ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.48)

²² Pagels, H. 1988. *The Dream of Reason*. New York: Simon and Shuster.

²³ ⁴⁴ N. Campbell, "Atomic structure," *Nature (London)* **107**, 170 (1921); "Time and chance," *Phil. Mag.* **I**, 1106-1117 (1926); *Nature* **119**, 779 (1927). As found in Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.49)

²⁴ Kuhn, T. 1970. *The Structure of Scientific Revolution*. Chicago: University of Chicago Press.

²⁵ Ulmer, G. 1988. The Punctum in Grammatology. In: J. CULLER, ed. *On Puns, The Foundation of Letters*. Oxford/New York: Basil Blackwell Ltd., pp.164-189. (p.164)

²⁶ Gibson, W. 1984. *Neuromancer*. New York: Ace Books. See also JARRY, A. 1965. See also *The Selected Works of Alfred Jarry*. Edited by Roger Shattuck and Simon Watson Taylor. New York: Random House (p.192) where he defines pataphysics in relation to the "virtual". He states "Pataphysics is the science of imaginary solutions, which symbolically attributes the properties of objects, described by their virtuality, to their lineaments."

²⁷ B.J. Adler and T.E. Wainwright, "Studies in molecular dynamics," *J. Chem. Phys.* **27**, 1208-1209 (1957); *Scientific American*, Oct. 1959. as cited in Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.95)

²⁸ Seaman, Bill and Andrea Gaugush, *(RE)Sensing the Observer. Offering an Open Order Cybernetics*, Technoetic Arts, 2:1. Edited by Roy Ascott

²⁹ Kelso, J. A. Scott, *Dynamic Patterns, The Self-Organization of Brain and Behavior* A Bradford Book, MIT Press, 1988, p. 4

³⁰ Seaman, Bill, 2005, *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*, forthcoming in *Convergence Magazine "Hybrid Identities in Digital Media"*, edited by Kerstin Mey and Yvonne Spielmann, *Convergence*, Winter 2005.

³¹ See Seaman, Bill, "Recombinant Poetics: Emergent Meaning as Examined and Explored within a Specific Generative Virtual Environment," Dissertation. (The Centre for Advanced Inquiry in Interactive Art. University of Wales, Corleone Campus, 1999). Also available in PDF format from the Langlois Foundation and/or <http://billseaman.com/> Here Seaman states: "It is possible to say that it is an operational "mathematics" which in part gives rise to virtual reality, reflects incredible "changes in mathematics" as embodied within computer-based environments. Wittgenstein describes the necessity of using the term "language-games" in that "language is part of an activity, or of a form of life." As life changes through the creation of new technologies, concomitantly, new means of expression and communication are born — the nature of "language-games" extended. I am seeking to enable play in what might be called "the computer-based emergent meaning game."

³² Site texts here that speak of unity...

³³ <http://www.brainyquote.com/quotes/authors/b/buddha.html>

³⁴ Primas, H. *Endo- and Exo- theories of Matter*. In Atmanschaper, H. and G.J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.173)

³⁵ Primas, H. *Endo- and Exo- theories of Matter*. In Atmanschaper, H. and G.J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.175)

³⁶ Primas, H. *Endo- and Exo- theories of Matter*. In Atmanschaper, H. and G.J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.176)

³⁷ Primas, H. *Endo- and Exo- theories of Matter*. In Atmanschaper, H. and G.J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.178)

³⁸ Crutchfield, James, *Observing Complexity and the Complexity of Observation* as found in Atmanschaper, H. and G. J. Dalenoort, ed. 1994. *Inside Versus Outside: Endo- and Exo- Concepts of Observation and Knowledge in Physics, Philosophy and Cognitive Science*. Berlin, Germany: Springer-Verlag. (p.245-246)

³⁹ Rössler, O.E. 1974, *Adequate Location Strategies for an Organism in an Abstract Environment: A relational approach to Brain Function*. Berlin-Heidelberg: Springer-Verlag. Lecture Notes in Biomathematics 4, 342-369.

⁴⁰ Suchman, Lucy A. 1987. *Plans and situated actions: The Problem of Human-Machine Communication*. Cambridge: Cambridge University Press. (p.6)

⁴¹ Suchman, Lucy A. 1987. *Plans and situated actions: The Problem of Human-Machine Communication*. Cambridge: Cambridge University Press. (pg. 8)

⁴² Suchman, Lucy A. 1987. *Plans and situated actions: The Problem of Human-Machine Communication*. Cambridge: Cambridge University Press. (pg. 9)

⁴³ See Deutsch, David, 1997, *The Fabric of Reality*, Penguin Books, London.

⁴⁴ Suchman, Lucy A. 1987. *Plans and situated actions: The Problem of Human-Machine Communication*. Cambridge: Cambridge University Press. (pg. 11)

⁴⁵ VARELA, F., THOMPSON, E. and ROSCH, E. 1991. *The Embodied Mind, Cognitive Science and Human Experience*. Cambridge/London: MIT Press. (p. 23)

⁴⁶ Rössler, Otto, *Nonlinear Dynamics, Artificial Cognition and Galactic Export*, a paper from Rössler sent to Seaman, Division of Theoretical Chemistry, DFH University of Tübingen, Auf der Morgenstelle 8, 72076, Tübingen. F.R.G.

⁴⁷ Rössler, Otto, *An artificial Cognitive Map System*, Bio systems, 13 (1981) 203-209, Elsevier/North-Holland Scientific Publishers Ltd.

⁴⁸ Seaman, B, 2004, *The Thoughtbody Environment, Notes Toward a Model for An Electrochemical Computer* April 2004. <http://billseaman.com>

⁴⁹ D. R. Hofstadter and D. C. Dennett, *The Mind's Eye* (Basic Books, new York, 1981). Rössler suggests one can find here an anthology on computer-cognition relevant fiction.

See *Simulacron Three* by Daniel F. Galouye

⁵⁰ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.33)

See S. M. Kosslyn and S. P. Schwartz, "A simulation of visual imagery," *Cognitive Sci.* **1**, 265-295 (1977).

⁵¹ Turing, A, 1992. *Collected Works of A.M. Turing: Morphogenesis*, Edited by P.T. Saunders, North-Holland, Amsterdam, Elsevier Science Publishers (p.42)

⁵² Turing, A, 1992. *Collected Works of A.M. Turing: Morphogenesis*, Edited by P.T. Saunders, North-Holland, Amsterdam, Elsevier Science Publishers. *A diffusion Reaction Theory of Morphogenesis in Plants (with C.W. Wardlaw)* p. 44

⁵³ See Ilya Prignone, *Order from Chaos*

⁵⁴ <http://complex.upf.es/~josep/Chaos.html> **Josep Sardanyés**

⁵⁵ Pask, G. 1961. *An Approach to Cybernetics*, with a preface by Warren S. McCulloch, Harper and Brothers, MIT press (pg. 105)

- ⁵⁶ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press.
- ⁵⁷ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.5) Haugeland in an Editor's note related to this quote states: These senses of the terms 'designation' and 'interpretation', and hence also of 'symbol', are specific to computer science; they concern only relationships and processes that occur *within* a computer. In linguistics and philosophy, by contrast, these terms would usually be explained in terms of relationships *between* an intelligent system (or what's inside of it) and its environment. Most of the essays in the present volume use the terms in this latter sense.
- ⁵⁸ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.106-107)
- ⁵⁹ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.108)
- ⁶⁰ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.180)
- ⁶¹ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.181-182)
- ⁶² Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.209)
- ⁶³ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.214)
- ⁶⁴ See Stuart Hameroff, MD. <http://www.quantumconsciousness.org/>
- ⁶⁵ Stuart Hameroff, 'The Physics of Quantum Consciousness Chemistry,' http://tonydude.net/NaturalScience100/Topics/3Mind/4artificial_intel.html.
- ⁶⁶ Chang, Jiin-Ju, Joachim Fisch, Friz-Albert Popp, eds. 1998. *Biophotons*. Dordrecht, Netherlands: Kluwer Academic Publishers.
- ⁶⁷ Chang, Jiin-Ju, Joachim Fisch, Friz-Albert Popp, eds. 1998. *Biophotons*. Dordrecht, Netherlands: Kluwer Academic Publishers. (p.241)
- ⁶⁸ Chang, Jiin-Ju, Joachim Fisch, Friz-Albert Popp, eds. 1998. *Biophotons*. Dordrecht, Netherlands: Kluwer Academic Publishers. (p.243)
- ⁶⁹ See DNA Computers - http://users.aol.com/ibrandt/dna_computer.html
- ⁷⁰ Chang, Jiin-Ju, Joachim Fisch, Friz-Albert Popp, eds. 1998. *Biophotons*. Dordrecht, Netherlands: Kluwer Academic Publishers. (p.247-248)
- ⁷¹ Chang, Jiin-Ju, Joachim Fisch, Friz-Albert Popp, eds. 1998. *Biophotons*. Dordrecht, Netherlands: Kluwer Academic Publishers. (p.248)
- ⁷² Kelso, J. A. Scott, *Dynamic Patterns, The Self-Organization of Brain and Behavior* A Bradford Book, MIT Press, 1988, (pg. 229)
- ⁷³ Kelso, J. A. Scott, *Dynamic Patterns, The Self-Organization of Brain and Behavior* A Bradford Book, MIT Press, 1988, (p. 257)
- ⁷⁴ Kelso, J. A. Scott, *Dynamic Patterns, The Self-Organization of Brain and Behavior* A Bradford Book, MIT Press, 1988, (p.259)
- ⁷⁵ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.215)
- ⁷⁶ Haugeland, J. 1997. *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, Mass.: MIT Press. (p.241)
- ⁷⁷ See Seaman, B. *Interflow Architectures* at <http://digitalmedia.risd.edu/billseaman/textsInterflow.php>
- ⁷⁸ See Seaman, B. **Pattern Flows: Notes Toward a Model for an Electrochemical Computer** — The Thoughtbody Environment <http://digitalmedia.risd.edu/billseaman/textsElectroChemical.php>
See also the Poly-sensing Environment <http://www.fondation-langlois.org/html/e/page.php?NumPage=49>
And also <http://students.dma.ucla.edu/~fwinkler/PSE/>
- ⁷⁹ See *Interflow Architectures* at <http://digitalmedia.risd.edu/billseaman/textsInterflow.php>
— The Thoughtbody Environment <http://digitalmedia.risd.edu/billseaman/textsElectroChemical.php>
<http://students.dma.ucla.edu/~fwinkler/PSE/>

⁸⁰ Cariani, P. *Some Epistemological Implications of Devices Which Construct Their Own Sensors and Effectors*. In: Varela F, Bourgine P. eds. *Towards a Practice of Autonomous Systems*. Cambridge, MA: MIT Press, 1991;484-493. 9pp.

⁸¹ Cariani, P., *To Evolve an Ear: Epistemological Implications of Gordon Pask's Electrochemical Devices*. *Systems Research* 1993; 10 (3):19-33

⁸² <http://www.cariani.com/>

⁸³ Seaman, Bill and Andrea Gaugush, *(RE)Sensing the Observer. Offering an Open Order Cybernetics*, *Technoetic Arts*, 2:1. Edited by Roy Ascott

⁸⁴ See Seaman, B. 2005, *Pattern Flows | Hybrid Accretive Processes Informing Identity Construction*, forthcoming in *Convergence Magazine*.

⁸⁵ <http://weber.ucsd.edu/~gbowker/classification/>

“At this site, we present the introduction, first two chapters and concluding chapters of our book on classification systems published by MIT Press in 1999”. Susan Leigh Star and Geoffrey C. Bowker in their text *Sorting Things Out: Classification and its Consequences*, define the notion of the Boundary Object: “Drawing from earlier studies of interdisciplinary scientific cooperation, we define boundary objects as those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. In working practice, they are objects that are able both to travel across borders and maintain some sort of constant identity. They can be tailored to meet the needs of any one community (they are plastic in this sense, or customizable). At the same time, they have common identities across settings. This is achieved by allowing the objects to be weakly structured in common use, imposing stronger structures in the individual-site tailored use.”

⁸⁶ See Yoseph Bar-Cohen, *Biomimetics - Mimicking and Being Inspired by Biology*, CRC Press, to be published in 2005,

⁸⁷ See Yoseph Bar-Cohen, *Biomimetics - Mimicking and Being Inspired by Biology*, CRC Press, to be published in 2005,

⁸⁸ Rössler, Otto E. 1998. *Endophysics: The World as Interface*. Singapore: World Scientific Publishing Co. Pte. Ltd. (p.180)