Is Your Gut Conscious? Is an Extraterrestrial?

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0.0 Abstract:

This paper speculates on questions intending to be taken scientifically rather than metaphysically: “Can the human gut (enteric nervous system) be conscious?”; “Can your immune system think?”; “Could consciousness be coded in DNA?”; “What do we mean when asserting that an Extraterrestrial is Thinking, or is Conscious?

We explore through reference to theory, experiment, and computational models by Christof Koch (Caltech), Barbara Wold (Caltech), and Stuart Kauffman (University of Calgary, Tampere University of Technology, Santa Fe Institute).

We use a tentative new definition of thinking, designed to be applicable for humans, cetecea, corvids, artificial intelligences, and extraterrestrial intelligences of any substrate (i.e. Life as We Do Not Know It):

"Thinking is the occurrence, transformation, and storage in a mind or brain (or simulation thereof) of information-bearing structures (representations) of one kind or another, such as thoughts, concept, percepts, ideas, impressions, notions, rules, schemas, images, phantasms, or subpersonal representations."

We use the framework for Consciousness developed by Francis Crick and Christof Koch. We try to describe scientific goals, but discuss Philosophy sufficient to avoid naïve philosophical category errors (thus are careful not to conflate thought, consciousness, and language)

Penrose, Hameroff, and Kauffman speculate (differently) that CNS consciousness is a macroscopic quantum phenomenon. Might intestinal, immune system, or genetic regulatory network dynamics exhibit emergent cooperative quantum effects?

The speculations are in the context of Evolution by Natural Selection, presumed to operate throughout the Cosmos, and recent work in the foundations of Computational Biology and Quantum Mechanics.

1.0 Is this a Joke?

It sounds like a joke: “You have a gut feeling; are you sure that you don’t have a gut thought?” Christof Koch [Koch, 2009], said that years ago he would have dismissed this as a joke, but after more than 20 years on the nature of consciousness, much with Sir Francis Crick in his post-DNA second career, now considers this a legitimate puzzle. A this question leads to similar out-of-the-box questions, such as: “Can your immune system think?” and “Could consciousness be coded in DNA?”

“The physical basis of consciousness appears to be the most singular challenge to the scientific, reductionist world view. In the closing years of the second millennium, advances in the ability to record the activity of individual neurons in the brains of

monkeys or other animals while they carry out particular tasks, combined with the explosive development of functional brain imaging in normal humans, has lead to a renewed empirical program to discover the scientific explanation of consciousness." [Koch & Crick, 1999]

If your gut is conscious then it is necessary but not sufficient to exceed a minimum dynamic complexity. This is true both according to Crick & Koch arguments for NCC (Neural Correlates of Consciousness [Noë,2004ab])., as we shall see later), which is a more evolved notion than the old metaphysics of [de Chardin, 1959/1964, p.111]: "The more complex a being is, so our Scale of Complexity tells us, the more it is centered upon itself and therefore the more aware does it become. In other words, the higher the degree of complexity in a living creature, the higher its consciousness; and vice versa. The two properties vary in parallel and simultaneously. If we depict them in diagrammatic form, they are equivalent and interchangeable."

Chomsky famously disproved Stimulus-Response (SR as in B.F. Skinner, et al.) as a viable model of human CNS, by combinatoric argument on the computational complexity of spoken language grammars. Does your gut, immune system, or DNA have a language in an analogous sense? Would an extraterrestrial necessarily have language?

A necessary but not sufficient complexity is "The Law of Requisite Variety: If a system is to be stable the number of states of its control mechanism must be greater than or equal to the number of states in the system being controlled". Ashby states the Law as "only variety can destroy variety" [Ashby, 1956, p.207]. He sees this as aiding the study of problems in biology and a "wealth of possible applications" introductory to Shannon Information Theory (1948) which deals with the case of "incessant fluctuations" or noise. The Requisite Variety condition is a simple statement of a necessary dynamic equilibrium condition in information theory terms c.f. Newton's third law, Le Chatelier's principle.

In 1970, Conant working with Ashby produced the Good Regulator theorem [Conant, 1981] requiring autonomous systems to acquire an internal model of their environment to persist and achieve stability or dynamic equilibrium. Stafford Beer defines variety as "the total number of possible states of a system, or of an element of a system" [Beer, 1981], c.f. Ludwig Boltzmann's Wahrscheinlichkeit. Beer restated the Law of Requisite Variety as "Variety absorbs variety" [Beer, 1979, p.286]. The logarithmic measure of variety represents the minimum number of choices (by binary chop) needed to resolve uncertainty. Beer allocated management resources necessary to maintain process viability.

Stuart Kauffman likewise attacks Reductionism [p.3]: The famous Turing-Church-Deutsch, TCD, principle, [Deutsch, 1985], states that any physical machine can be simulated to arbitrary accuracy on a universal Turing machine. This thesis is profoundly related to reductionism and the long held belief, since Descartes, Newton, Einstein, Schrodinger, and Weinberg [Weinberg, 1992], that there is a 'Final Theory of Everything' at the base of physics, which explains all that unfolds in the universe by logical entailment. As we shall see, this view derives from Aristotle's analysis

of scientific explanation as deduction: All men are mortal, Socrates is a man, thus, Socrates is a mortal. As Robert Rosen rightly points out, [Rosen, 1991], with Newton, we have eliminated all but one of Aristotle's four causes, formal, final, material and efficient, retaining only efficient cause in science and mathematized it as deduction. Thus, Newton's equations, in differential form, with initial and boundary conditions are 'solved' for the behavior of the system by integration, which is precisely deduction. This identity of efficient cause with deduction leads directly to the reductionist view held by Weinberg and others. There can be no unentailed events, so emergence is just wrong and there must be a final theory 'down there' from which all derives by entailment. As Weinberg famously says, [Weinberg, 1992],, the explanatory arrows all point downward, from societies to people to organs to cells to biochemistry to chemistry to physics and ultimately to particle physics and General Relativity, or perhaps String Theory, [Smolin, 2001]. Turing-Church-Deutsch holds precisely the same view - it is algorithms all the way down so entailment all the way up. In this view, the universe is a formalizable machine, and we who live in it are TCD machines. Then we, robot-like can use the inputs from our sensors and calculate all we need to flourish, machines afloat in a machine universe. But then, unfortunately, there is no selective advantage to conscious experience. Why then, did it evolve? I will present four lines of reasoning and candidate evidence suggesting that reductionism is very powerful, but powerfully inadequate."

Set aside the epistemological question: "are brains are conscious or not?" Assume that our central nervous systems are substrates for consciousness. What is the evolutionary basis for consciousness (a question addressed by Morsella et al in Sec.11)? Kauffman [p.19] asks: "Why Might Consciousness Be Selectively Advantageous? This is a very hard problem. One normally presumes that Evolution by Natural Selection is a universal principal, applicable to life throughout the cosmos, regardless of substrate (organic, metallic, emiconductor, superconductor, plasma embedded in a satr, and other more exotic possibilities). For most examples, an unconscious computerized robot would seem to do as well [see "zombie" discussion in our section 3.0]. Humphries argues that humans are conscious because awareness 'enchants us' so makes us fitter, [Humphrey, 2008]. It is an enchanting idea and may be right."

If your digestive tract is conscious, is it "private" per [Crick & Koch, 1998] "that it is inherently impossible to communicate the exact nature of what we are conscious of?"

If in any sense your digestive tract is conscious, in what way does it have meaning in its content, in the sense of representation of the external or internal world?

If in any sense your digestive tract is conscious, is it connected in a significant way to your brain and CNS (Central Nervous System)?

This problem of qualia Chalmers (1995) calls "The Hard Problem": a full account of the manner in which subjective experience arises from cerebral processes. The hard problem breaks into several questions. The first is the major problem: How do we experience anything at all? What leads to a particular conscious experience (such as the blueness of blue)? What is the function of conscious experience? Why are some aspects of subjective

experience impossible to convey to other people (in other words, why are they private)?

We believe we have answers to the last two questions [Crick and Koch, 1995c]. We have already explained, in the section "Why Are We Conscious," what we think consciousness is for. The reason that visual consciousness is largely private is, we consider, an inevitable consequence of the way the brain works. To be conscious, we have argued, there must be an explicit representation of each aspect of visual consciousness. At each successive stage in the visual cortex, what is made explicit is recoded. To produce a motor output, such as speech, the information must be recoded again, so that what is expressed by the motor neurons is related, but not identical, to the explicit representation expressed by the firing of the neurons associated with, for example, the color experience at some level in the visual hierarchy. [Crick & Koch, 1998]

I need not define “consciousness” to ask, and begin to design experiments to answer.

“Consciousness is a vague term with many usages and will, in the fullness of time, be replaced by a vocabulary that more accurately reflect the contribution of different brain processes (for a similar evolution, consider the usage of *memory*, that has been replaced by an entire hierarchy of more specific concepts). Common to all forms of consciousness is that it feels like something (e.g., to ‘see blue,’ to ‘experience a head-ache’, or to ‘reflect upon a memory’). Self-consciousness is but one form of consciousness. It is possible that all the different aspects of consciousness (smelling, pain, visual awareness, affect, self-consciousness, and so on) employ a basic common mechanism or perhaps a few such mechanisms. If one could understand the mechanism for one aspect, then one will have gone most of the way towards understanding them all.” [Koch & Crick, 1999] Other contemporary scientific philosophers have grappled with definitions of consciousness, including: [Dennett, 1991]; [Dennett, 2001], [Churchland, 1992]; [Kauffman, 2008].

2.0 Your Second Brain and a Dog’s First Brain?

Koch reminds us, your ENS (Enteric Nervous System) in your abdomen has roughly 1% as many neurons (roughly 10^9) as does your CNS (Central Nervous System) i.e. your brain and spinal cord (roughly 10^11). Hence we call your ENS a “second brain.” We each know (First Person) that we are conscious. We are rapidly learning about what Koch and Crick call NCC: the Neural Correlates of Consciousness (Third Person). What can we say about First Person and Third Person evidence in principle that your ENS is or could be conscious? Your dog’s brain has about as many neurons as your second brain, hence once asks “is your dog conscious?” We shall return to this question.

Kauffman [pp.19-20] considers the first-person versus third-person distinction important:

“The Hard Problem, Qualia. Does any of the above help? I do not think so, at least yet... It may be that it points to an avenue that might conceivably help someday, but as ever, we have no idea what consciousness ’is’. I cannot avoid one thought: reductionism is inherently third person, for deduction is mere logical entailment, verifiable by all of us in third person language. And we feel profoundly that ’objective knowledge’ must be third person sharable. Is there some kind of clue here? All our knowledge of the world is inherently first person. Something big seems missing. As Strawson noted long ago,

[Strawson, 1961], we can only be in the world as herenow oriented subjects, not objects. How trapped are we by reductionism into a third person 'knowing' view of the world? More, being in the world when we do not always know what can happen cannot be a matter only of reason or knowing. Reason and knowing are then insufficient guides to living our lives. How are we, then, in the world? Perhaps if we try to give up third person language as primary, objective, scientific, and focus on being in the world when we cannot know, that may help with the hard problem."

Kauffman argues: "that there can be no 'theory of everything' that can explain all that unfolds in the universe by logical entailment, hence that the universe and biosphere in their evolution are not machines, and that the Turing-Church-Deutsch does not hold, [Kauffman, 2000; 2008]. The evolutionary advantages of consciousness may be stunning, for if we cannot, in principle, calculate the behavior of a universe, biosphere, animal and human life that is partially lawless yet wonderfully non-random, then there may be a profound advantage to conscious experience.

It is one way we can understand a partially lawless, non-random, hence noncalculable, universe, biosphere, and free willed human life, and flourish in it. I think the scientific grounds for a quantum mind are presently weak, that it is, at present, an improbable scientific hypothesis, but that it is definitely not ruled out, as we shall see."

Kauffman [p.2] makes: "two physical hypotheses: First, the mind is a quantum coherent-reversibly decohering-recohering system in the brain. Thus, following R.Penrose [Penrose, 1989], I believe that consciousness is a problem, at least in part, of the physical basis subtending it. While the arguments I advance differ sharply from those of Penrose, and while he was strongly attacked for suggesting a quantum-consciousness connection, he was courageous, and did much to legitimize the 'C' word in serious scientific discussion. In this view I sharply differ from those who hope for an emergence of consciousness in a computational mind, [Churchland & Sejnowki, 1992], whether comprised of chips, neurons, or water buckets."

The Wold group is interested in the composition, evolution and function of regulatory networks that govern how mammalian cell fates are specified and executed during development and during regeneration. The complexity of this regulatory network leads us to speculate on emergent properties, as we do for CNS and ENS.

3.0 State versus Content

Without squarely defining "consciousness" we may usefully distinguish between the state and the content of our Central Nervous System. We later parallel this with speculations on the Enteric Nervous System.

"Consciousness is a puzzling state-dependent property of certain types of complex, adaptive systems. The best example of one type of such systems is a healthy and attentive human brain. If the brain is anaesthetized, consciousness ceases. Small lesions in the midbrain and thalamus of patients can lead to a complete loss of consciousness, while

destruction of circumscribed parts of the cerebral cortex of patients can eliminate very specific aspects of consciousness, such as the ability to be aware of motion or to recognize objects as faces, without a concomitant loss of vision in general. Given the similarity in brain structure and behavior, biologists commonly assume that at least some animals, in particular non-human primates, share certain aspects of consciousness with humans. Brain scientists, in conjunction with cognitive neuroscientists, are exploiting a number of empirical approaches that shed light on the neural basis of consciousness. It is not known to what extent artificial systems, such as computers and robots, can become conscious, so this article will exclude these from consideration." [Koch & Crick, 1999]

We distinguish between CNS state and CNS content. CNS states include at least these 6:
* normal consciousness
* asleep and unconscious
* asleep and paralyzed but conscious of dreams (REM sleep)
* stupor [A state of impaired consciousness characterized by a marked diminution in the capacity to react to environmental stimuli (American Heritage). The condition occurs in neurologic and psychiatric disorders. The person may be totally or almost totally immobile and unresponsive, even to painful stimuli. Kinds of stupor are anergic stupor, benign stupor, and epileptic stupor (Mosby's)]
* coma
* PVS (persistent vegetative state) as applies to roughly 50,000 people right now in the United States of America alone [a state of wakefulness accompanied by an apparent complete lack of cognitive function, experienced by some patients in an irreversible coma. Vegetative functions and brainstem reflexes are intact, but the cortex is permanently damaged (Mosby's)]
[Persistent vegetative state–criteria
1. No evidence of awareness of environment; inability to interact with others
2. No evidence of sustained, reproducible, purposeful, or voluntary behavioral responses to visual, tactile, auditory, or noxious stimuli
3. No evidence of language comprehension or expression
4. Intermittent wakefulness manifested by the presence of sleep-wake cycles
5. Sufficiently preserved hypothalamic and brain-stem autonomic functions to permit survival with medical and nursing care
6. Bowel and bladder incontinence [note CNS-ENS correlation]
7. Variably preserved cranial nerve reflexes (pupillary, oculocephalic, corneal, vestibulo-ocular, gag) and spinal reflexes [McGraw-Hill]

We distinguish between these states and the content of consciousness, in terms of meaning, representation, sensation, and qualia. "This problem of qualia is what Chalmers (1995) calls "The Hard Problem": a full account of the manner in which subjective experience arises from cerebral processes. As we see it, the hard problem can be broken down into several questions, of which the first is the major problem: How do we experience anything at all? What leads to a particular conscious experience (such as the blueness of blue)? What is the function of conscious experience? Why are some aspects of subjective experience impossible to convey to other people (in other words, why are they private)?" [Crick & Koch, 1998].

The term of art “zombie” [Chalmers, 1995] is a philosophical hypothetical primarily used in “zombie arguments” in the Philosophy of Mind, typically against forms of Physicalism, including Materialism and Behaviorism. A philosophical zombie (also known as p-zombie or p-zed) is a hypothetical being that is indistinguishable from a normal human being except that it lacks conscious experience, qualia, or sentience. When a zombie is pricked with a sharp object, for example, it does not feel any pain. While it behaves exactly as if it does feel pain (perhaps saying "ouch" or recoiling from the stimulus), it does not actually have the experience of pain as a 'normal' person does.

Some experts distinguish between three types of zombies, as used in different thought experiments: (1) A behavioral zombie is behaviorally indistinguishable from a human and yet has no conscious experience.(2) A neurological zombie has a human brain and is otherwise physically indistinguishable from a human; nevertheless, it has no conscious experience. (3) A soulless zombie lacks a soul but is otherwise indistinguishable from a human; this concept is used to inquire to what, if anything, the soul might amount [Theology is beyond the scope of this paper].

Philosophical zombies are primarily discussed in the context of arguments against Physicalism or Functionalism in general. Hence, a p-zombie is typically understood as a being that is physically indistinguishable from a normal human being but that lacks conscious experience. My original question: “Is your gut conscious” transforms to: “Is your gut indistinguishable from the gut of a philosophical zombie?” This same question is applicable to whether or not an extraterrestrial is conscious, i.e. is distinguishable from an extraterrestrial philosophical zombie.

Chalmers couches his philosophical thought experiments in modal logic terminology (possible worlds, primary and secondary intensions, …; Daniel Dennett [citation] finds the argument ridiculous and preposterous, but his refutations are not (to me) compelling, as he doesn’t address the deepest disagreements with Chalmers, but that’s beyond the scope of this paper.

Whether guts are conscious or zombie, what are the states (not content) of ENS function?

My “serious” research on the ENS suggests that there are 8 different myoelectrical dynamical behaviors of the human small intestine, based on mathematical modeling and simulations, including solitons (solitary waves). Some of these categories of dynamics have been clinically observed. Others remain to be seen. We speculate that this classification is clinically significant. The 8 different system dynamics that we expect to observe in the simulation:
(1) no peristalsis, or amplitude too small to matter;
(2) single wave pulse propagating;
(3) wave train (which goes at different velocity from single wave pulse);
(4) alternans (every other wave in wave-train suppressed from subtle 2nd-order interaction) (first observed and widely published-about in Cardiac modeling and in vitro, but uses same Fitzhugh-Nagumo equations, cf. GIOME);
(5) soliton;
(6) chaos (as in tetrodotoxin experiment? [Tetrodotoxin = anhydrotetrodotoxin 4-

epitetrodotoxin, tetrodonic acid, TTX, is a potent neurotoxin with no known antidote, which blocks action potentials in nerves by binding to the pores of the voltage-gated, fast sodium channels in nerve cell membranes]);
(7) reverse peristalsis;
(8) obstruction (in which peristalsis occurs only in a proper subset of the simulated gastrointestinal tract).
[there is also possibly a 9th solution to the system of differential equations, the "canard", which I suspect is a mathematical artifact not likely to be physical, or, if it occurs, probably beneath the resolution of current observational capability].

In extensive literature survey I found 28 different categories of models (some with one exemplar, some with 20-50) relevant to peristalsis, and have proposed to create a single model which identifies and unifies the parameters from the other models so they can work together. The new model, intended to be developed at the Beckman Institute (as supported in principal by Founding Director Harry Gray) has "hooks" for additional detail but captures the entire process. I have taken a systems approach to the problem, creating a tool for optimizing the onset of peristalsis after surgery by understanding the response to variations in diet (and other parameters).

I propose a Grand Unified Theory of the Gut = G.U.T. of GUT; at least that part which deals with biophysics, biochemistry, pharmacology, kinetics, neurophysics, myoelectrophysiology, rheology, fluid dynamics, control theory; in context of diagnosis, pathogenesis, risk assessment, treatment; of post-operative paralysis of the human small intestine (ileus) contrasted with normal peristaltic and regulatory function, related post-operative pathologies, in vivo and in vitro measurements, in silico computer simulations, experimental data on horse, dog, pig, guinea pig, and mouse gastrointestinal tracts.

If we estimate 8 or 9 ENS states, roughly analogous to the 6 previously listed CNS states, we may analogously ask: "can there be ENS content within one or more of those ENS states?" Such hypothetical content is beyond the scope of all known models and measurement abilities, without linkage between ENS and CNS beyond literature.

There are clues that such CNS-ENS linkage may exist and be significant. For example, digestive tract dysfunction is common in the 1% to 2% of children with autism [citations omitted; I have written extensively on the clinical literature of autism elsewhere]. Autism is a CNS dysfunction with a significant genetic component. Is ENS interacting differently with CNS is people with Autism Spectrum Disorder by comparison with a baseline population?

4.0 Is Your Immune System Conscious?

Your immune system is a complex dynamic network whose function does affect CNS function (as the Stroop Test reveals). Barbara Wold explains, when you're sick enough to feel stupid, you are measurably more stupid, with deficit linear with immune system activity. Yet we seem to have no consciousness of immune system function as such. Can the immune system have an illusion? Perhaps, if autoimmune disease is the immune

system attacking one's own cells while "thinking" that it fights an invader.

Psychology's Stroop effect affects reaction time of a specific task. When a word such as blue, green, red, etc. is printed in a color differing from the color expressed by the word's semantic meaning (i.e. the word "red" printed in blue ink), naming the color of the word takes longer and is more error prone than when the meaning of the word is congruent with ink color. John Ridley Stroop first published the effect in English in 1935 [Stroop, 1935], previously been published in 1929, in German. The original paper has been one of the most cited papers in the history of experimental psychology, exceeding 700 replications [MacLeod, 1991].

The effect has been used to create a psychological test which is widely used in clinical practice and investigation. The test has also been further modified to investigate very different phenomena [MacLeod, 1991]

EEG and functional neuroimaging studies of the Stroop effect have consistently revealed activation in the frontal lobe; and more specifically in the anterior cingulate cortex and dorsolateral prefrontal cortex, two structures hypothesized to be responsible for conflict monitoring and resolution. Accordingly patients with frontal lesions obtain lower punctuations in the Stroop test when compared to those with more posterior lesions. However these frontal regions are not the only ones implicated in the effect. Stroop performance has also been associated with the correct functioning of the hippocampus or posterior brain areas [Spreen et all 2005].

Cristof Koch has done a series of exciting experiments analogous to the Stroop Test, but involving interference in CNS activity with visual input differing from eye to eye, and no conscious awareness of one of the two images (i.e. a naked woman in one image and an abstract conglomerate of colored rectangles in the other image).

What would be an experimental ENS analogue of the Stroop Effect? One suggestion comes from Rheology. The differential equation models of peristalsis suggest that an artificial non-Newtonian fluid or solid might paradoxically move in the opposite direction that an ordinary material moves in response to the waves of muscular contraction in the intestine .is a materially-induced reverse peristalsis. I suggest that this is similar to what certain visual illusions are in CNS (such as the sensation that one is in a train moving forwards when when sees out the window of the train another train which is backing up) A non-Newtonian fluid is a fluid whose flow properties are not described by a single constant value of viscosity, as is the case with many polymer solutions and molten polymers, and many commonly found substances such as ketchup, starch suspensions, paint, blood and shampoo. In a Newtonian fluid, the relation between the shear stress and the strain rate is linear (and if one were to plot this relationship, it would pass through the origin), the constant of proportionality being the coefficient of viscosity. In a non-Newtonian fluid, the relation between the shear stress and the strain rate is nonlinear, and can even be time-dependent. Therefore a constant coefficient of viscosity cannot be defined. A ratio between shear stress and rate of strain (or shear-dependent viscosity) can be defined, this concept being more useful for fluids without time-dependent behavior. Theoretically possible effects must be large to get the reverse peristalsis ENS "illusion."

5.0 Your Second Brain and a Dog's First Brain, Redux

Cristoph Koch enjoys the company of a fluctuating number of big, boisterous and friendly dogs: Bella, Trixie, and Nosy. He stated that "we know that our dogs are conscious." I asked [Koch, 2009]: "since you say that our ENS has roughly the same number of neurons as our dog's brain, and we know that our dog is conscious, yet some people deny that dogs and cats (and even chimps and dolphins) are conscious, why then is there no debate on whether or not or second brain (ENS) is conscious?"

An even crazier question: Koch cites the Nobel laureate and rare pseudocartesian dualist Sir John Eccles as saying that perhaps consciousness is NOT physically located in the brain, but located outside the brain and body, and detected by the brain (which in principal according to Nobel Laureate Brian Josephson [private communication] may enable telepathy between people). Can the ENS correlate with consciousness located outside the body? Can my gut telepathically communicate with your gut?

"At least some animal species posses some aspects of consciousness. In particular, this is assumed to be true for non-human primates, such as the macaque monkey. Consciousness associated with sensory events in humans is likely to be related to sensory consciousness in monkeys for several reasons. Firstly, trained monkeys show similar behavior to that of humans for many low-level perceptual tasks (e.g. detection and discrimination of visual motion or depth; Wandell 1995). Secondly, the gross neuroanatomy of humans and non-human primates are rather similar once the difference in size has been accounted for. Finally, functional magnetic resonance imaging of human cerebral cortex is confirming the existence of a functional organization in sensory cortical areas similar to that discovered by the use of single cell electrophysiology in the monkey (Tootell, Hadjikhani, Mendola, Marrett and Dale 1998). As a corollary, it follows that language is not necessary for consciousness to occur (although it greatly enriches human consciousness)." [Koch & Crick, 1999]

Koch speculates on whether or not the honeybee might be conscious. One part of the visual CNS of the bee has a density of neurons per unit volume an order of magnitude higher than any mammal's CNS. Yet he has a "gut feel" that a worm is not conscious, nor a plant. This brings us to the question of the complexity of various organisms, and whether that relates to their capacity for consciousness.

Here's a quotation on honeybee consciousness by Christof Koch [Koch, Dec 2008]: "Although these experiments do not tell us that bees are conscious, they caution us that we have no principled reason at this point to reject this assertion. Bees are highly adaptive and sophisticated creatures with a bit fewer than one million neurons, which are interconnected in ways that are beyond our current understanding, jammed into less than one cubic millimeter of brain tissue. The neural density in the bee's brain is about 10 times higher than that in a mammalian ce-rebral cortex, which most of us take to be the pinnacle of evolution on this planet. In humans, widespread loss of cerebral cortex, as in the vegetative patient Terri Schiavo, leads to an irreversible loss of con-scious-ness. That is not to say that a cerebral cortex is necessary for consciousness in creatures with a different evolutionary heritage."

"Bees live in highly stratified yet flexible social organizations with group decision-making skills that rival academic, corporate or government committees in efficiency. In spring, when bees swarm, they choose a new hive that needs to satisfy many demands within a couple of days (consider that the next time you go house hunting). They communicate information about the location and quality of food sources using the waggle dance. Bees can fly several kilometers and return to their hive, a remarkable navigational performance. Their brains seem to have incorporated a map of their environment. And a scent blown into the hive can trigger a return to the site where the bee previously encountered this odor. This type of associative memory was famously described by French novelist Marcel Proust in À la Recherche du Temps Perdu."

"Given all of this ability, why does almost everybody instinctively reject the idea that bees or other insects might be conscious? The trouble is that bees are so different from us and our ilk that our insights fail us. But just because they are small and live in colonies does not mean that they can't have subjective states, that they can't smell the fragrance of the golden nectar or experience the warm rays of the sun or maybe even have a primitive sense of self. I am not a mystic. I am not arguing for pan-psychism, for the notion that anything is conscious. Nor am I assuming that bees can reason or can reflect on their fate as animated cartoon bees."

"What this dilemma highlights is that there is no accepted theory of consciousness, no principled theory that would tell us which systems, organic or artificial, are conscious and why. In the absence of such a theory, we must at the very least remain agnostic about consciousness in these creatures. So the next time a bee hovers above your breakfast toast, attracted by the sweet jam, gently shoo her away. For she might be a fellow sentient being, experiencing her brief interlude in the light, shoehorned between this moment and eternity."

Wold reminds us that the human and some far "lower" animals have about the same number of genes [citations]. Further, that some plants, which we think of as simpler than people, have significantly more genes. Hence the question of complexity of genetic networks and the question of complexity of neural networks and the questions of complexity of phenotype and behavior are unlikely to have straightforward answers.

6.0 Stuart Kauffman's Physics, Hammeroff and Penrose, and Five Problems in the Philosophy of Mind

Stuart Kauffman reframes the heart of this paper as follows [Kauffman, 2009]:

"Since Descartes' dualism, with his res extensa and res cogitans, six fundamental problems in the philosophy and natural history of mind are these:
1. how does mind act on matter?
2. If mind does not act on matter is mind a mere epiphenomenon?
3. What might be the source of free will?
4. What might be the source of a responsible free will?
5. Why might it have been selectively advantageous to evolve consciousness?

6. What is consciousness?"

"I approach the first five of the above six problems based on two physical postulates. First the mind-brain system is a quantum coherent, but reversibly decohering and recohering system. This allows me to answer 1) above, mind does not act causally on brain at all, rather it acausally decoheres to classicity (for all practical purposes), hence has consequences for brain and body as matter. Epiphenomenalism is averted. A quantum mind, because it is acausal on Copenhagen including Born, yields a free will, but a merely random free will, not a responsible free will. Second, the most radical part of this article proposes that the quantum classical interface is not always describable by a law: specifically in a special relativity setting, no function, F, maps the present state of the system mind-brain into its future. In its place is a nonrandom yet lawless process. I seek in this non-random yet lawless process a source for a responsible free will. Finally, if the quantum-classical boundary can be non-random yet lawless, then no algorithmic simulation of the world or ourselves can calculate the real world, hence the evolutionary selective advantages for evolving consciousness to know it may be great. I make no progress on problem 6, the hard problem of qualia."

He carefully defines "Consciousness" in a way related to, but interestingly different from, that of Crick and Koch. Why does Kauffman [pp.7-9] center his model on new results in Quantum Theory? As in this paper, one first distinguishes between joke and non-joke.

"I begin with old and new opinions and facts. Had one asked a physicist twenty or even ten years ago if the human brain could exhibit quantum coherent phenomena, the response, after laughter, would have been that thermalization would have destroyed any vestige of quantum coherence, so the answer was 'No'. It is therefore astonishing and important that recent results on the chlorophyll molecule, surrounded by its evolved 'antenna protein', has been shown be quantum coherent for almost a nanosecond. Now the normal time scale for decoherence is on the order of 10 to the -15 second, or a femto-second. Yet these experiments, carried out at 77K, but thought to apply to chlorophyll in plants at ambient temperature, show quantum coherence of an absorbed photon traveling to the reaction center for over 700 femtoseconds, the length of their longest trial, [Lee, 2007]. No one expected this. The authors believe that the quantum coherence increases dramatically the quantum efficiency of the energy gathering process in photo-synthesis. More, they believe that the evolved antenna protein either suppresses decoherence or induces recoherence. No one knows at present."

"It seems safe to conclude that quantum coherence for on the order of a billionth of a second, a nanosecond, is possible and observerable at body or ambient temperature. The evolved role of the antenna protein is testable by mutating its sequence. The time scale of neural activities is a million times slower, in the millisecond range. But it takes light on the order of a millisecond to cross the brain, so if there were a dispersed quantum decohering-recohering mind-brain, reaching the millisecond range is probably within grasp of a quantum theory of the mindbrain system."

"The second recent fact, now widely studied by quantum chemists working on proteins,

is that quantum coherent electron transfer within and between proteins is possible and almost certainly real. Because two proteins may coordinate two water molecules, and the electron can pass between the proteins by two pathways, in analogy with the two slit experiment, quantum interference can happen, [Salahub, D., Personal communication, 2009.]."

"The next fact is that calculations of electrical conductivity between neighboring proteins as a function of the distance between them shows a plateau between 9 and 14 micron separation. The author, David Beratan [Lin, 2005], believes that this plateau reflects quantum coherent electron transfer at this separation, about right to coordinate a few water molecules between the proteins. More, quantum coherent electron transfer occurs within proteins. Now electrons are only one kind of quantum degree of freedom that may transport within and between nearby complex molecules."

"The next fact of importance is that the cell is densely crowded with macromolecules. I do not know the distribution of distances between them, but it is on the order of dozens of angstroms, probably just enough to admit and coordinate the locations of one or more water molecule that then can support quantum coherent electron transport. This is open to investigation experimentally, including the effects of alteration of osmotic effects, swelling or shrinking cells by uptake or removal of water from the cells, on electron transport in cells. Such shrinkage or swelling could surpass the 9-14 angstrom separation needed for quantum coherent electron transport, hence be visible experimentally."

"These facts raise the theoretical possibility that a percolating connected web of quantum coherent-decohering-recohering processes could form among and between the rich web of packed molecules in a cell, let alone its membrane surfaces. Hammeroff and Penrose [Hammeroff, 2006] have suggested microtubules forming the cytoskeleton of cells as loci of coherent quantum behavior. [Penrose, 1989], has suggested that quantum gravity may play a role in the transition to classicity. Others have suggested a variety of molecular bases for extended molecular structures that might support quantum coherent behavior, [Tegmark, 1999]; [Mavromatos, 2000]. As far as I know, I am the only investigator proposing a quantum coherent-decohering-recohering model of the mind brain system. In short, we can imagine a physical substrate in cells that could carry a quantum recohereing-decohering, pink and grey, process in cells and between cells. My own view of the above is that it remains scientifically unlikely, but given the chlorophyll results and quantum chemistry calculations on electron transport, not impossible at all.]

I have published, in Conference proceedings and in progress, that connect Consciousness and Quantum Mechanics in different ways, but have paid attention to the same authors that Kauffman cites above. The discussion, beyond Kauffman, of a quantum basis for consciousness, whether CNS, ENS, Immune system, or Genomic, is beyond the scope of this paper.

7.0 Final Points: Split-Brain Analogy and "Out of Body"

A companion paper, shorter in length and with different set of references deals with

the same underlying questions: “Humaniqueness Combinatorics by Jonathan Vos Post Version 4.1, 4,800 words [includes References], 13 pp. [6 text, 7 References], of 29 September 2009, which critiques Marc Hauser, Psychology, Human Evolutionary Biology, and Organismic and Evolutionary Biology at Harvard University [Hauser, 2009], in a Scientific American’s literature review of 4 factors that make human thought unique among all species.

Test my imagined split between CNS and ENS cognition, with two analogies, one to an illusory split between mind and body, and one to an actual split of brain hemisphere from brain hemisphere. It is now verifiable scientific experiment, and no longer “fringe” parapsychology, that the human CNS can have its state or content manipulated Third Person to produce what subjects report (First Person) as an “out of body experience.”

Science reports twice in one issue [Ehrsson, 2007];[Lenggenhager, 2007] that while normal brain function integrates sensory data from sight, sound, and touch, sometimes an anomaly occurs in which humans experience the illusion that they have left their physical bodies, and float 6 to 10 feet above them, looking back at their bodies. The states in which this occurs are those associated with drug intoxication, migraine, epileptic fit, or stroke.

Ehrsson showed in Stockholm’s Karolinka Institute, that for each of 18 healthy adult subjects, when their backs were stereoscopically viewed by video goggles, and the experimenter touched both their physical chest with one rod and the region in space where their virtual chest would be (with a second rod), all subjects felt that they were where the video goggles projected them to be, six and a half feet behind their actual location. In follow-up experiment, once the subjects were spatially relocated, the experimenter swung a hammer towards where the virtual faces would be based on the virtual chests (again with the two rods touching and virtually touching), the subjects, now outfitted with skin electrical conductance sensors, responded with third-party verified anxiety (spike in skin conductance, a proxy for sweating) and reported (first person) emotional arousal and anxiety.

Lenggenhager et al (including medical doctor Olaf Blanke, who had treated stroke and epileptic out of body patients) at Lausanne, Switzerland’s Ecole Polytechnique Federale, positioned a videocamera six and a half feet behind the backs of 14 subjects wearing 3-D videogoggles. She stroked their backs with a big pen, which they could both feel and see. She guided them backwards, asked them to return to original position, and found that they overshot by a mean of 10 inches. In follow-up, she projected the video’d back of a mannequin onto the goggle image of their backs. All reported that they perceived the mannequin’s body to be their bodies.

Where are we really in space and time? CNS integrates, and sometimes miscomputes our location, and reveals a distinction between sensation and perception of the very location of our body. I ask these related questions:

(1) Is there an ENS equivalent to the CNS out of body experience?

(2) Can one have a stomach ache which seems to be someplace far away from the abdomen (as we can have a heart attack where the pain seems far from the chest) and even altogether away from the body?
(3) Can one have "intestinal urgency" which does not appear to be in the intestines at all, but far away?
(4) Nausea to me sometimes seems to be an existential property of the environment and not associated with my digestive system; can one vomit and perceive it as elsewhere?
(5) Is there anything beyond superficial similarity between the experimentally induced out of body experience, and the parapsychological phenomena associated with Catholic saints said to have been observed (third person) miraculously bilocating (being into two places at once), also attributed to Asian yogis?
(6) Is there anything beyond superficial similarity between the experimentally induced out of body experience, and the parapsychological phenomena of "remote viewing" by subjects of locations far from physically explained as viewable?
(7) To what extent can laboratory experiment determine interference (positive or negative) between CNS and ENS in perceived location of one's body?

We make a final point: It is not in principle absurd that there is consciousness in other human systems than the CNS (Central Nervous System) such as the ENS (Enteric Nervous System), Immune System, or Genome. No, it is not, given the following "existence proof."

Lateralization and Split-brain

Pioneering Split-brain research of Roger Sperry and Michael Gazzaniga [Gazzaniga, 1995] demonstrates that the mind of the CNS is not unitary, but can be broken into two personalities in the two hemispheres of the human brain, surgically. Roger Wolcott Sperry (20 August 1913-17 April 1994) was a neuropsychologist, neurobiologist, who, together with David Hunter Hubel and Torsten Nils Wiesel, won the 1981 Nobel Prize in Medicine for his work with split-brain research.

This results when the corpus callosum connecting the two hemispheres of the brain is severed, or otherwise has its bandwidth degraded. Surgically producing this condition is called corpus callosotomy. It is a rare last resort for otherwise intractable epilepsy, to reduce the severity and violence of epileptic seizures. A split brain patient (for convenience, let's say a right-handed patient), upon being shown an image in his or her left visual field, cannot name what he or she has seen. This is because the speech-control center is in the left side of the brain in most right-handed people. The image from the left visual field is sent only to the right side of the brain. Conversely, those with the speech control center in the right side will experience similar symptoms when an image is presented in the right visual field. Since communication between the two sides of the brain has been significantly degraded, the patient is simply unable name what the right side of the brain is seeing. The person can, however, touch, manipulate, pick up and show recognition of such an object with his or her left hand, since that hand is controlled by the right side of the brain.

Some of the earliest split-brain research was carried out by Sperry and continued when he was joined by Gazzaniga. They led to important theories of lateralization of brain function. “Split-brain patients may sometimes confabulate a rational account of their behavior, if the true motivations cannot be reported since they may depend on processing in the linguistically inaccessible left side of the brain. There are some theories that the different hemispheres may have different ‘personalities’ and contradictory goals.”

My analogy is that a normal human being, self-conscious that their CNS is conscious, may be self-unconscious that their gut (or immune system or genetic regulatory network) is conscious. A normal human may be metaphysically much like an abnormal split-brain patient. Hence I speculate on ENS, Immune System, or Genomic consciousness, of which the CNS may be unaware, confabulate to deny, and/or differ in evolutionary origin and function.

8.0 References:

The American Heritage® Medical Dictionary Copyright © 2007, 2004 by Houghton Mifflin Company. Published by Houghton Mifflin Company. All rights reserved.

Ashby, W.R. 1956, Introduction to Cybernetics, Chapman & Hall, 1956, ISBN 0-416-68300-2

Mary Bath-Balogh, Biol 241 Lecture Notes, Chapter 15: Sensory, Motor, and Integrative Systems, Pierce College, retrieved 30 July 2009.

Bechtel, W. (1994). Levels of description and explanation in cognitive science. Minds and Machines, 4, 1-25. 129

Bechtel, W., & Richardson, R. C. (1992). Emergent phenomena and complex systems. In A. Beckermann, H. Flohr, & J. Kim (Eds.), Emergence or reduction? Essays on the prospects of nonreductive physicalism (pp. 257-288). Berlin: de Gruyter.

Beer, S. 1979, The Heart of Enterprise, John Wiley, London and New York. Reprinted with corrections 1988.

Beer, S. 1981, Brain of the Firm; Second Edition (much extended), John Wiley, London and New York. Reprinted 1986, 1988.

Chalmers, D. J. (1996). The conscious mind. Oxford: Oxford University Press.

Chalmers, D. J. (2000). What is a neural correlate of consciousness? In T. Metzinger (Ed.), Neural correlates of consciousness (pp. 17-39). Cambridge, MA: MIT Press.

Churchland, P. and Sejnowski, T. J., ComputationalMind, (Computational Neuroscience) MIT Press, Cambridge MA, 1992.

Conant, R. 1981 Mechanisms of Intelligence: Ross Ashby's papers and writings Intersystems Publications ISBN 1127197703.

Crick FC and Koch C, Towards a neurobiological theory of consciousness. Seminar in the Neuroscience 2: 263-275, 1990.

Crick FC and Koch C, The problem of consciousness. *Scientific American* 267(3): 153-159, 1992.

Crick FC and Koch C, Are we aware of neural activity in primary visual cortex? *Nature* 375: 121-123, 1995.

Crick FC and Koch C, Why Neuroscience may be able to explain consciousness." In: Explaining Consciousness: The Hard Problem, Shear J, ed., pp. 237-240. MIT Press: Cambridge, MA, 1997.

Crick FC and Koch C, Towards a Neurobiological Theory of Consciousness. In: *The Nature of Consciousness,* Block N, Flanagan O and Güzeldere G, eds. pp. 277-292. MIT Press: Cambridge, MA, 1997.

Crick FC and Koch C, Consciousness and Neuroscience. *Cerebral Cortex* 8: 97-107, 1998.

Crick FC and Koch C, The Unconscious Homunculus. In: *The Neural Correlates of Consciousness,* Metzinger T, ed., pp. 103-110. MIT Press, Cambridge, MA, 2000.

Crick FC and Koch C, The unconscious homunculus. With commentaries by multiple authors. *Neuro-Psychoanalysis* 2: 3-59, 2000.

Crick FC and Koch C, A framework for consciousness. *Nature Neuroscience* 6: 119-27, 2003.

Crick FC and Koch C, Consciousness, the Neural Correlates of. In: *The Oxford Companion to the Mind*. Gregory R, ed., pp. 220-222. 2-nd edition. Oxford University Press: Oxford, United Kingdom, 2005.

Crick FC and Koch C, What are the neuronal correlates of consciousness. In: *Problems in Systems Neuroscience.* van Hemmen L and Sejnowski TJ, eds., pp, 474-490. Oxford University Press: New York, NY, 2006.

Crick FC and Koch C, A neurobiological framework for consciousness. In: *The Blackwell Companion to Consciousness*. Velmans M and Schneider S, eds., pp. 567-579. Blackwell, Oxford, UK, 2007.

Pierre Teilhard de Chardin L'Avenir de l'Homme (1959) essays written 1920–52, on the evolution of consciousness (noosphere), in French; The Future of Man (1964) Image 2004: ISBN 0-385-51072-1, in English.

Darwin, C. (1859). On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life. 1st edition. London: John Murray. Retrieved June 4, 2008, from http://www.talkorigins.org/faqs/origin.html

Decety, J. (1996). Do imagined and executed actions share the same neural substrate? Cognitive Brain Research, 3, 87-93.

Dennett, D. C. (1976). Are dreams experiences? Philosophical Review, 73, 151-171.

Dennett, Daniel, Consciousness Explained, Little, Brown and Co. Boston MA. 1991.

Dennett, Daniel, Freedom Evolving, Viking, N.Y. 2003.

Deutsch, D., Quantum theory, the Church-Turing Principle, and the universal quantum computer, Proc. R. Soc. Lond. A vol 400. 97-117, 1985; Bassett, P. Personal Communication, 2009.

Ehrsson, H. Henrik, The Experimental Induction of Out of Body Experiences, Science, 24 Aug 2007.

Farthing, W. G. (1992). The psychology of consciousness. New York: Prentice Hall.

Freud, S. (1900/1965). The interpretation of dreams. New York: Avon Books. (Original work published 1900.)

Gazzaniga, M. S. (1995). Consciousness and the cerebral hemispheres. In M. S. Gazzaniga (Ed.), The cognitive neurosciences (1391-1400), Cambridge, MA: MIT Press.

Hammeroff, S. and Penrose, R., 1996, Orchestrated reduction in quantum coherence in brain microtubules: a model for consciousness. In: toward a Science of Consciousness - The First Tucson Discussions and Debates. Eds S. Hameroff, A. Kaszniak, A Scott, MIT Press Cambridge, MA.

Marc Hauser, “The Origin of the Mind”, Scientific American, September 2009, pp.44-51.

Humphrey, N., Getting the Measure of Consciousness, Prog. of Theo. Physics. Sup. 173, 264-269, 2008.

Jeannerod, M. (1995). Mental imagery in the motor context. Neuropsychologia, 33, 1419-1432.

Jensen AR, Rohwer WD (1966). "The Stroop color-word test: a review". Acta

psychologica 25 (1): 36–93. PMID 5328883.

Jung, C. G. (1933). Modern man in search of a soul. New York: Harcourt.

Jung, C. G. (1965). Memories, dreams, reflections. New York: Vintage books.

Jung, C. G. (1974). Dreams. Princeton, NY: Princeton University Press.

Jouvet, M. (1999). The paradox of sleep: The story of dreaming. MIT Press; Cambridge, MA.

Kahan, T. L., & LaBerge, S. (1996). Lucid dreaming as metacognition: Implications for cognitive science. Consciousness and Cognition, 3, 246-264..

Kauffman, S. A., Investigations, Oxford University Press, NY 2000.

Kauffman, Stuart A., Reinventing the Sacred, Basic Books, N.Y. 2008.

Stuart Kauffman, Physics and Five Problems in the Philosophy of Mind, http://arxiv.org/abs/0907.2494

Koch, C., personal communication, Caltech Seminar Day, 2009

Koch C, and Roberts *The Quest for Consciousness: A Neurobiological Approach*. Publishers, Denver, Colorado, 2004. (http://www.questforconsciousness.com) Translated into Japanese, French, Spanish, Korean, and German.

Koch C, Sleeping and Dreaming. A review of "Brainstem Control of Wakefulness and Sleep" by M. Steriade and R. W. McCarley and "Thalamic Oscillations and Signaling" by M. Steriade, E. G. Jones and R. Llinas. *Science* 251: 326-327, 1991.

Koch C, Computational approaches to cognition: The bottom-up view. *Current Opinion in Neurobiology* 3: 203-208, 1993.

Koch C and Crick FC, Some Further Ideas Regarding the Neuronal Basis of Awareness. In: *Large-Scale Neuronal Theories of the Brain*, Koch C and Davis J, eds., pp. 93-110, MIT Press: Cambridge, MA, 1994.

Koch C, A neuronal correlate of consciousness? *Current Biology.* 6: 492, 1996.

Koch C, Hard-headed dualism. A review of "The Conscious Mind: In Search of a Fundamental Theory" by D. Chalmers. *Nature* 381: 123-124, 1996.

Koch C, Qualia. *Current Biology* 14: R496, 2004.

Koch C and Crick FC, The neurobiology of consciousness. In: *The MIT Encyclopedia of the Cognitive Sciences,* Wilson RA and Keil FC, eds., pp. 193-195. MIT Press: Cambridge, MA, 1999.

Koch C and Crick FC, The neural basis of consciousness. In: *Intl. Encyclopedia of the Social & Behavioral Sciences*, Smelser N and Baltes P, eds., Vol. 4, pp. 2600-2604. Elsevier, Oxford, United Kingdom, 2001.

Koch C, Introduction to Consciousness. In: *The Cognitive Neurosciences*, 3-nd edition, Gazzaniga, MS, editor. pp. 1107-1109. MIT Press, Cambridge, MA, 2004.

Koch C, Thinking about the conscious mind. A review of *Mind – A Brief Introduction* by J. Searle. *Science* 306: 979-980, 2004.

Koch C, The inchoate science of Consciousness. *The Scientist* 19: 14-17, 2005.

Koch C, The movie in your head. *Scientific American Mind*, in press.

Koch, C., "Exploring Consciousness through the Study of Bees", December 2008 Scientific American Mind, "Bees display a remarkable range of talents—abilities that in a mammal such as a dog we would associate with consciousness."
This article was originally published with the title, "What Is It Like To Be a Bee?"
http://www.scientificamerican.com/article.cfm?id=exploring-consciousness

Koch C and Hepp K, Quantum mechanics and higher brain functions: Lessons from quantum computation and neurobiology. *Nature* 440: 61161-2, 2006.

Koch C and Poggio T, Artificial Intelligence. In: *Encyclopedia of Neuroscience*. G. Adelman, ed., pp. 77-80. Birkhauser, Boston, 1987.

LeDoux, J. E. (1996). The emotional brain: The mysterious underpinnings of emotional life. New York: Simon & Schuster.

Lehar, S. (2003). The world in your head. Mahwah, NJ: Lawrence Erlbaum.

Lenggenhager, Bigna, et al., Video Ergo Sum: Manipulating Bodily Self Consciousness, Science, 24 Aug 2007.

Lee. H., Cheng, Y.C. and Fleming, G.R., Coherence Dynamics in Photosynthesis: Protein Protection of Excitonic Coherence, Science 316, 1462-1467, 2007.

Lin, J. Balabin, I, Beratan, D.N., The Nature of Aqueous Tunneling Pathways Between Electron Transfers for Proteins. Science, 1310-1313, 2005.

LeSauter et al. Stomach ghrelin-secreting cells as food-entrainable circadian clocks. Proceedings of the National Academy of Sciences, 2009; 106 (32): 13582

DOI: 10.1073/pnas.0906426106

McGraw-Hill Concise Dictionary of Modern Medicine. © 2002 by The McGraw-Hill Companies, Inc.

MacLeod CM (March 1991). "Half a century of research on the Stroop effect: an integrative review". Psychological bulletin 109 (2): 163–203. PMID 2034749. http://content.apa.org/journals/bul/109/2/163.

Mahowald, M. W., Woods, S. R., & Schenck, C. H. (1998). Sleeping dreams, waking hallucinations, and the central nervous system. Dreaming, 8, 89-102.

Mavromatos, N., 2000, Cell Microtubules as Cavities: Quantum Coherence and Energy Transfer? arxiv.org.pdf.quant-ph/0009089.

Ezequiel Morsella et al,. The Essence of Conscious Conflict: Subjective Effects of Sustaining Incompatible Intentions. Emotion, October 2009

Mosby's Medical Dictionary, 8th edition. © 2009, Elsevier.

Noë, A., & Thompson, E. (2004a). Are there neural correlates of consciousness? Journal of Consciousness Studies, 11 (1), 3-28.

Noë, A., & Thompson, E. (2004b). Sorting out the neural basis of consciousness. Journal of Consciousness Studies, 11(1), 87-98.

O'Regan, J. K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. Behavioral and Brain Sciences, 24(5), 939-1031.

Penrose, R., The Emperor's New Mind: Concerning Computers, Minds and the Laws of Physics, Oxford University Press, N.Y. 1989.

Jonathan V. Post, "Analysis of Enzyme Waves: Success through Simulation", Proc. Summer Computer Simulation Conference, Seattle, WA, 25-27 August 1980, pp.691-695, AFIPS Press, 1815 North Lynn Street, Suite 800, Arlington, VA 22209

Jonathan V. Post, "Simulation of Metabolic Dynamics", Proceedings of the Fourth Annual Symposium on Computer Applications in Medical Care, Washington, DC, 2-5 November 1980

Jonathan V. Post, "Enzyme System Cybernetics", Proceedings of the International Conference on Applied Systems Research and Cybernetics, Acapulco, Mexico, 12-15 December 1980

Jonathan V. Post, "Enzyme System Cybernetics", Applied Systems Research and Cybernetics, ed. G.E. Lasker, Pergamon Press, 1981, Vol.IV, pp.1883-1888, ISBN: 0-08-027196-0 (set), ISBN: 0-08-0271201 (Vol.IV)

Jonathan V. Post, "Alternating Current Chemistry, Enzyme Waves, and Metabolic Chaos", NATO Workshop on Coherent and Emergent Phenomena in Biomolecular Systems, Tucson, AZ 15-19 January 1991

Jonathan V. Post, "Nonlinear Enzyme Waves, Simulated Metabolism Dynamics, and Protein Nanotechnology", poster session, 2nd Artificial Life Workshop, 5-9 Feb 1990, Santa Fe, NM

Jonathan V. Post, "Continuous Semigroups, Nonlinear Enzyme Waves, and Simulated Metabolism Dynamics", accepted for Semigroup Forum (Mathematics journal), 15 May 1990 not published as employer accidentally erased only digital file of paper]

Jonathan V. Post, "Is Functional Identity of Products a Necessary Condition for the Selective Neutrality of Structural Gene Allele?", Population Biologists of New England (PBONE), Brown University, Providence, RI, June 1976

Jonathan V. Post, "Enzyme Kinetics and Selection of Structural Gene Products -- A Theoretical Consideration", Society for the Study of Evolution, Ithaca, NY, June 1977

Jonathan V. Post, "Birth of the Biocomputer", color-videotaped lecture to audience of 200, at opening of A.P.P.L.E.'s new world headquarters, Kent, WA, 15 Mar 1983

Jonathan V. Post , et.al., "Part Human, Part Machine", panel discussion on cyborgs, prosthesis, robots, nanotechnology, Westercon 37, Portland Marriott, Portland, OR, 30 Jun 1984

Jonathan V. Post (moderator), Prof. Vernor Vinge, Paul Preuss, Greg Bear, F. Eugene Yates (Director, Crump Institute for Medical Engineering, UCLA), "New Machines, New Life Forms", UCLA Extension's Symposium on Science and Science Fiction, Westwood, CA, 9 Nov 1986

Jonathan V. Post, Dean R. Lambe, Laura Mixon, Walter John Williams, "Nanotechnology", panel discussion, Nolacon: 46th World Science Fiction Convention, Sheraton Grand B, New Orleans, LA, 4 Sep 1988

Jonathan Vos Post, "The Evolution of Controllability in Enzyme System Dynamics", Proc. 5th Int. Conf. on Complex Systems, Boston, Massachusetts, 16-21 May 2004.

Purcell, S., Moffit, A., & Hoffmann, R. (1993). Waking, dreaming, and selfregulation. In A. Moffit, M. Kramer, & R. Hoffman (Eds.), The functions of dreaming (pp. 197-260). New York: State University Press.

Revonsuo, A. (1999). Binding and the phenomenal unity of consciousness. Consciousness and Cognition, 8(2), 173-185.

Rizzolatti, G., & Graighero, L. (2004). The mirror-neuron system. Annual Review

in Neuroscience, 27, 169-92.

Rosen, R., Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life, Columbia University Press, N.Y. 1991.

San Francisco State University (2009, October 2). Consciousness Is The Brain's Wi-Fi, Resolving Competing Requests, Study Suggests. ScienceDaily. Retrieved October 3, 2009, from http://www.sciencedaily.com- /releases/2009/09/090930141537.htm

Sen Sarma et al. Distance-Responsive Genes Found in Dancing Honey Bees. Genes Brain & Behavior, 2010; DOI: 10.1111/j.1601-183X.2010.00622.x http://www.sciencedaily.com/releases/2010/08/100818131611.htm

Searle, J. R. (1992). The rediscovery of the mind. Cambridge, MA: MIT Press.

Smolin, L., Three Roads to Quantum Gravity, Basic Books, N.Y. 2001.

Solms, M. (2003). Brain and the inner world: An introduction to the neuroscience of the subjective experience. New York: Other Press.

Spreen, Otfried; Strauss, Esther; Elisabeth M. S. Sherman (2006). *A compendium of neuropsychological tests: administration, norms, and commentary*. Oxford [Oxfordshire]: Oxford University Press. pp. 477-499. ISBN 0-19-515957-8. http://books.google.es/books?id=dvE1mzbqI14C&pg=PA477&lpg

Stapp, H., Mind, Matter, and Quantum Mechanics, Springer Verlag, 1993.

Strawson, P. F., Lectures Oxford University, 1961.

Stroop, John Ridley (1935). "Studies of interference in serial verbal reactions". *Journal of Experimental Psychology* **18**: 643-662. http://psychclassics.yorku.ca/Stroop/

Tegmark, M., (1999) The importance of quantum decoherence in brain processes. Phys. Rev.E. 14194-4206. arxiv.org/abs/quant-ph/9907009.

Thompson, E., & Varela, F. J. (2001). Radical embodiment: neural dynamics and consciousness. Trends in Cognitive Sciences, 5(10), 418-425.

Tooby, J. & Cosmides, L. (1990). The past explains the present: Emotional adaptations and the structure of ancestral environments. Ethology and Sociobiology, 11, 375-424.

Tooby, J., & Cosmides, L. (1992). The Psychological Foundations of Culture. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), The Adapted Mind (pp. 19-136). New York: Oxford University Press.

Tooby, J., & Cosmides, L. (1995). Mapping the Evolved Functional Organization of

Mind and Brain. In M. S. Gazzaniga (Ed.), The Cognitive Neurosciences (pp. 1185-1197). Cambridge, MA: MIT Press.

Tye, M. (1995). Ten problems of consciousness. A representational theory of the phenomenal mind. Cambridge, MA: MIT Press.

Weinberg, S., Dreams of a Final Theory: the search for the fundamental laws of Nature, Pantheon Books, N.Y. 1992.

Yaguez, L., Nagel, D., Hoffman, H. Canavan, A.G., Wist, E., & Homberg, V. (1998). A mental route to motor learning: improving trajectorial kinematics through imagery training. Behavioral Brain Research, 90, 95-106.