

Cosmological Foundations of Consciousness

An Overview

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Abstract: This paper explores the cosmological foundations of subjective consciousness in the biological brain, from cosmic-symmetry-breaking, through biogenesis, evolutionary diversification and the emergence of metazoa, to humans, presenting a new evolutionary perspective on the potentialities of quantum interactions in consciousness, and the ultimate relationship of consciousness with cosmology.

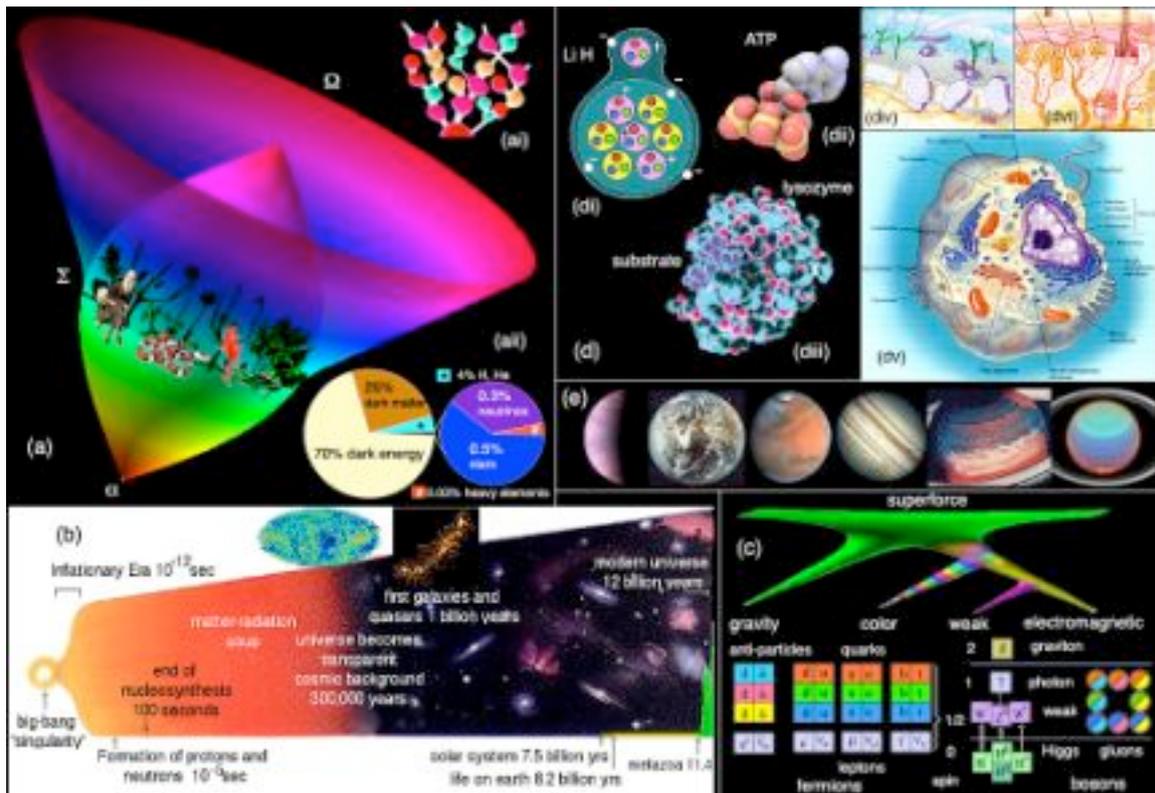


Fig 1: Cosmic symmetry-breaking and its interactive fractal and chaotic effects leading to biogenesis. (a) Life is the consummation of interactive complexity (Σ) resulting from symmetry-breaking of the fundamental force of nature in the big-bang (α), whatever ultimate fate is in store (Ω). Inset (i) fractal inflation model, (ii) the distribution of dark energy and matter and the matter of stars and planets. (b) Logarithmic time scale of cosmological events showing life on earth existing for a third of the universe's lifetime. (c) Symmetry-breaking of the forces of nature results in the color and weak forces, generating 100 atomic nuclei, while gravity and electromagnetism govern long-range structure determining biogenesis, from fractal chemical bonding, to solar systems capable of photosynthetic life in the goldilocks zone of liquid water. (d) Interactive effects of cosmic symmetry-breaking lead to hierarchical interaction of the forces, generating hadrons, atomic nuclei and molecules (i). Non-linear energetics of chemical bonding lead to a cascade of cooperative weak-bonding effects, which generate fractal molecular complexity, from the molecular orbitals of simple molecules (ii), through the 3D structures of complex proteins and nucleic acids (iii) to supra-molecular cell organelles (iv), cells (v), and tissues (vi) and organisms. (e) Chaotic effects of gravity as a non-linear force, results in extreme planetary variation, generating a diversity of potential conditions for biogenesis, similar to dynamic variations surrounding the Mandelbrot set.

1: Introduction: Scope and Design

This overview explores the cosmological foundations of consciousness as evidenced in current research and uses this evidence to present a radical view of what subjective consciousness is, how it evolved, and how it might be supported through quantum processes in the biological brain.

To do full justice to this very broad topic within the confines of the special issue and its planned book edition, I have prepared this paper as a short review article, referring to the full research monograph (King 2011b), as supporting online material, containing all the detailed references, a more complete explanation of the ideas and the ongoing state of the research in the diverse areas covered.

2: Non-linear Quantum and Cosmological Foundations of Biogenesis

While it is well understood that the fundamental forces of nature appear to have differentiated from a superforce in a founding phase of cosmic inflation, the interactive implications of cosmic symmetry-breaking for the chemical basis of life and its evolution into complex sentient organisms are equally as striking, and central to our existence. Cosmic symmetry-breaking and the ensuing preponderance of matter over anti-matter results in the hierarchical arrangement of quarks into neutrons and positively charged protons and then the 100 or so stable atomic nuclei, through the interaction of the strong and weak nuclear forces with electromagnetic charge, providing a rich array of stable, electromagnetically polarized, atoms with graduated energetics.

The non-linear molecular orbital charge energetics that results in strong covalent and ionic bonds also leads to a cascade of successively weaker bonding effects from H-bonds, to van-der-Waal's interactions, whose globally cooperative nature is responsible for the primary, secondary, and tertiary structures of proteins and nucleic acids, and in a fractal manner to quaternary supra-molecular assemblies, cell organelles, cells, tissues and organisms. Thus, although genetic coding is a necessary condition for the development of cell organelles and organismic tissues, this is possible only because the symmetry-broken laws of nature can give rise to such dynamical structures. In this sense, tissue, culminating in the sentient brain, is the natural interactive full-complexity product of cosmic symmetry-breaking.

Despite the periodic quantum properties of the *s*, *p*, *d* and *f*-orbitals, which form the basis of the table of the elements, successive rows have non-periodic trends because of non-linear charge interactions, which result in a symmetry-breaking determining the bioelements pivotal to biogenesis. Life as we know it is based on the strong covalent bonding of first row elements C, N and O in relation to H, stemming from the optimally strong multiple -CN-, -CC-, and >CO bonds, which are cosmically abundant in forming star systems and readily undergo polymerization to heterocyclic molecules, including the nucleic acid bases A, U, G, C and a variety of amino acids, as well as optically active cofactors such as porphyrins.

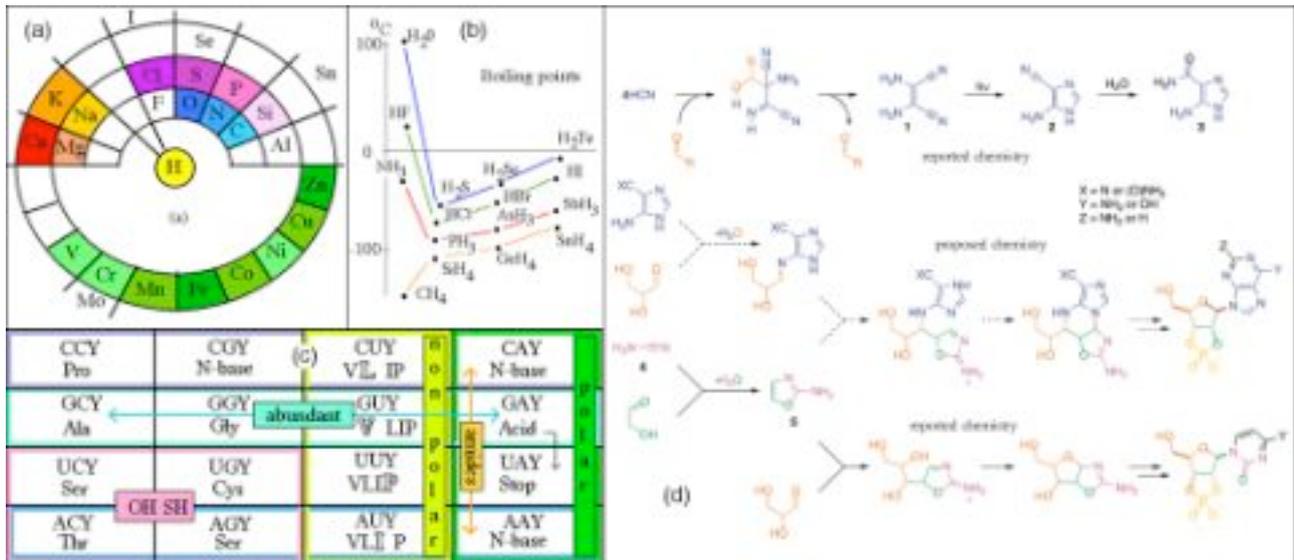


Fig2: (a) Symmetry-breaking quasi-periodic table of the bioelements displays covalent optimality. (b) Optimality of H₂O in terms of internal weak-bonding expressed in its high boiling point. (c) Evidence for a symmetry-breaking origin of the genetic code. (d) Realized and proposed direct synthesis paths from primordial precursors such as HCN to nucleotides (Powner et. al. (2010).

This interactive symmetry-breaking continues in a cascade. As we trend from C > N > O the electronegativity increases from non-polar C-H, to highly electronegative O, resulting in H₂O having extreme optimal properties as a polar hydride, bifurcating molecular dynamics into polar and non-polar phases, in addition to pH, and H-bonding effects, which define the aqueous structures and dynamics of proteins, nucleic acids, lipid membranes, ion and electron transport. Following on are secondary properties of S in lower energy -SH and -SS- bonds and the role of P as oligomeric phosphates in the energetics of biogenesis, cellular metabolism, dehydration polymerization and the nucleic acid backbone. We then have bifurcations of ionic properties K⁺/Na⁺ and Ca⁺⁺/Mg⁺⁺ and finally the catalytic roles of transition elements as trace ingredients.

This does not imply that this is the only elemental arrangement possible for life, as organisms adapted to use arsenic in the place of phosphorus (Wolfe-Simon et. al. 2010) demonstrate, but it does confirm that life as we know it has optimal symmetry-breaking properties cosmologically. Many of the fundamental molecules associated with membrane excitation, including lipids such as phosphatidyl choline and amine-based neurotransmitters, also have potentially primordial status (King 1996). Effects of symmetry-breaking may also extend to the genetic code (King 1982).

Recent research has begun to elucidate a plausible 'one-pot' route (Powner et. al. 2010) from simple cosmically abundant molecules such as HCN and HCHO to the nucleotide units making up RNA, giving our genetic origin a potentially cosmological status. There have also been advances with inducing selected RNAs to self-assemble from precursors and assume catalytic functions (see King 2011b).

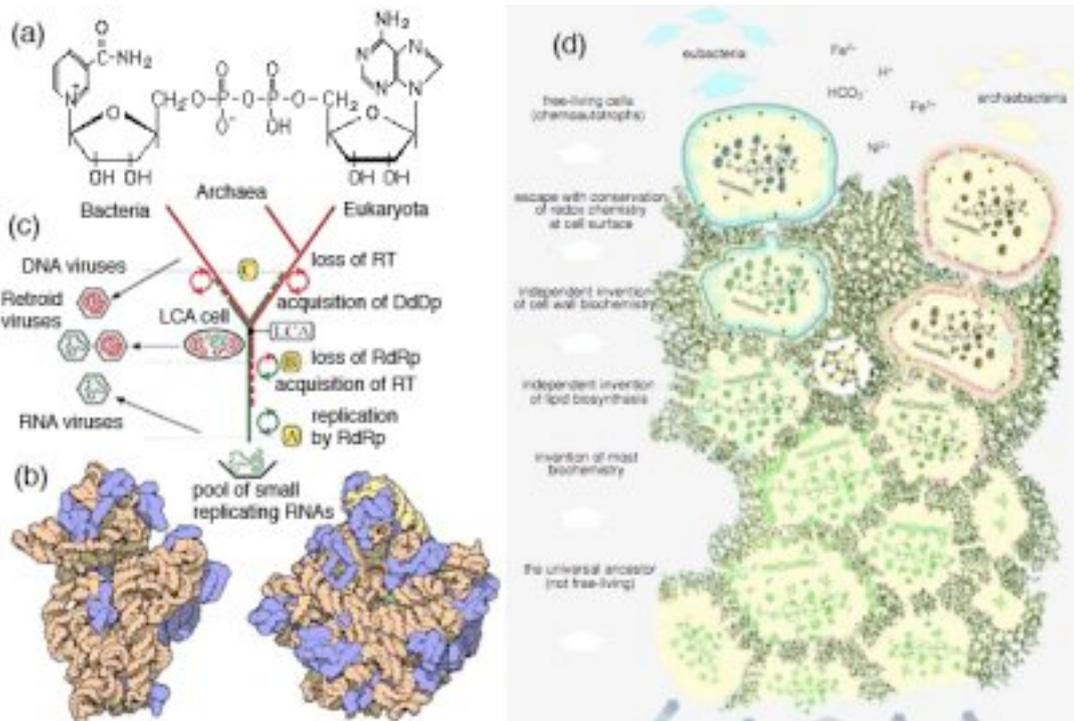


Fig 3: (a) Catalytic nicotine-adenine dinucleotide is essential in respiration. (b) Large and small subunits of the ribosome are centrally and functionally RNA [pink] (c) Molecular fossil evidence for a viral-based cellular transition from the RNA world to DNA based chromosomes, through cellular cooption of viral RNA-directed RNA-polymerase, followed by reverse transcriptase and finally DNA-dependent DNA-polymerase. (d) Independent evolution of archaean and bacterial cellular life from a non-cellular form of life at the interface of olivine and acid, iron-rich sea water forming 'lost city' undersea vents able to solve the concentration and encapsulation problems (Martin and Russell 2003).

3: Emergence of the Excitable Cell: From Universal Common Ancestor to Eucaryotes

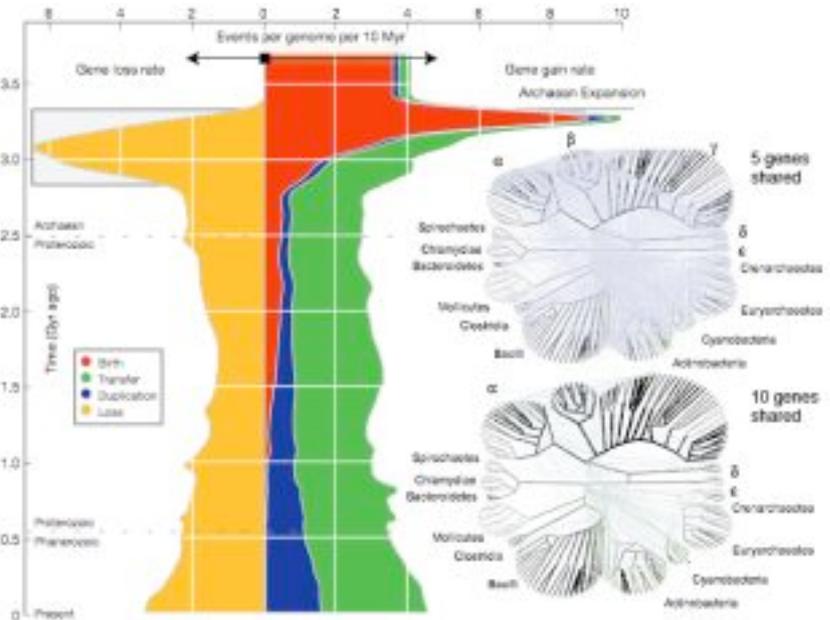
Looking back at the universal common ancestor of life, likewise indicates a transition through an era in which RNA functioned as both catalyst and replicator, through the establishment of the genetic code, whose ribosomal protein translation units are still RNA-based, to the eventual emergence of DNA-based life, probably through viral genes (King 2011 a). However the genetic picture of cell wall proteins is consistent with independent cellular origins of bacteria and archaea, implying more than one evolution of cellular life from a protected environment conducive to naked nucleotide replication (Martin and Russell 2003).

Nevertheless, once the branches of cellular life evolved, excitability based on ion channels and pumps rapidly became universal. It has recently been discovered that as early as 3.3 billion years ago there was a massive genetic expansion, which gave rise to the genes common to all forms of life (David and Alm 2010) facilitated by high levels of horizontal gene transfer, promoted by viruses (Dagan et. al. 2006).

Estimates of the adaptive computational power of the collective bacterial and archaean genome (King 2011 a) give a presentation rate of new combinations of up to 10^{30} bits per second, compared with the current fastest computer at about 10^{17} bit ops per second. Corresponding rates for complex life forms are much lower, around 10^{17} per second, because they are fewer in total number and have lower reproduction rates and longer generation times. This picture of bit rates coincides closely with the Archaeian expansion scenario

and suggests that evolution has been a two-phase process of genetic algorithm super-computation, which arrived at a global solution to the notoriously intractable protein-folding problems of the central metabolic and electro-chemical pathways, which are later capitalized on by eukaryotes and metazoa.

Fig 4: (Left) Archaean genetic expansion around 3.3 billion years ago generated most critical genes common to life (David and Alm 2010) (Right) Evidence of ubiquitous horizontal transfer of genes between bacterial species at different trigger levels (Dagan et. al. 2006).



Horizontal transfer, endosymbiosis and gene fusion led to a situation where sexuality and excitability, along with all the critical components for neural dynamics including ion-channels specific for Ca^{++} , K^{+} and Na^{+} , G-protein linked receptors, microtubules, and fast action potential became common to the spread of eucaryote cell types, from giardia and paramecium to metazoa. Ion channel structure appears to have been established during the soup of lateral gene transfers that drove bacterial evolution, with all major classes arising before the metazoa, with several showing homology to bacterial versions. This means we can find neurotransmitter receptors from GABA a, b, and glutamate, through opioid, to dopamine, epinephrine, serotonin and melatonin in single-celled eukaryotes. This universality continues up the evolutionary tree, so that chemicals psychoactive in humans also affect the web building of spiders, implying that the very different nervous system designs of arthropods and vertebrates mask a deeper common neurodynamic basis.

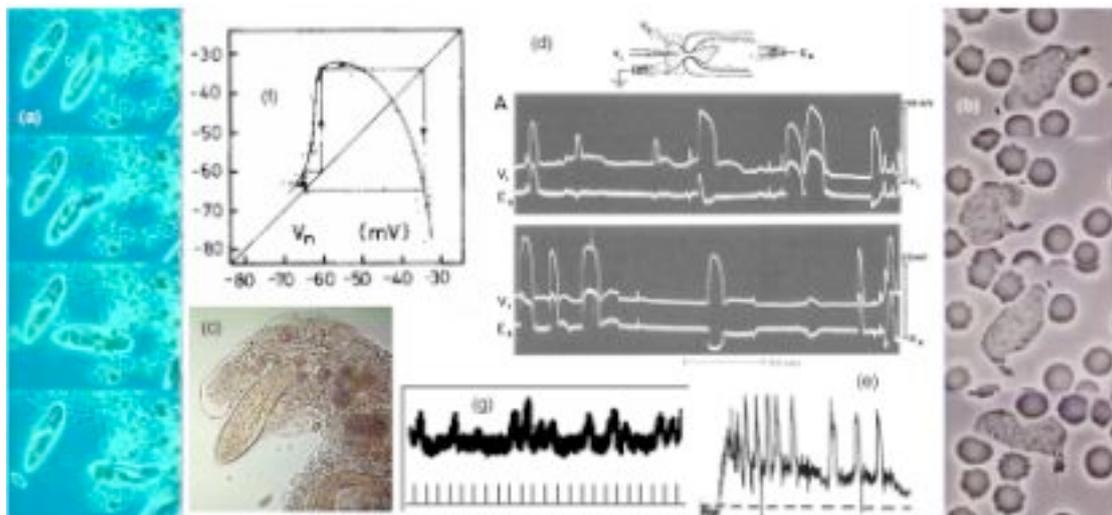


Fig 5: Real-time purposive behavior in single cells (a) *Paramecium* reverses, turns right and explores a cul-de-sac. (b) Human neutrophil chases an escaping bacterium (black), before engulfing it. (c) *Chaos chaos* engulfs a *paramecium*. Action potentials in *Chaos chaos* (d) and *paramecium* (e). Period 3 perturbed excitations in alga *Nitella* indicate chaos. (g) Frog retinal rod cells are sensitive to single quanta in an ultra-low intensity beam.

The evolutionary key to sentient consciousness lies in the survival advantage it could provide in anticipating existential threats and strategic opportunities. Since key genes for neurophysiology evolved up to six times as long ago as the Cambrian radiation, the key to the emergence of conscious sentience may be sourced in the evolution of excitable single cells. Chaotic excitation provides a eucaryote cell with a generalized quantum sense organ. Sensitive dependence would give a cell feedback about its external environment, perturbed by a variety of quantum modes - chemically through molecular orbital interaction,

electromagnetically through photon emission and absorption, electrochemically through the perturbations of the fluctuating fields generated by the excitations, and through acoustic, mechanical and osmotic interaction.

As we move to founding metazoa, we find *Hydra*, which supports only a primitive diffuse neural net, in continuous transformation and reconstruction, has a rich repertoire of up to 12 forms of 'intuitive' locomotion from snail-like sliding to somersaulting (King 2008), as well as coordinated tentacle movements. This is consistent with much of the adaptive capacity of nervous systems arising from cellular complexity, rather than neural net design alone. Pyramidal neurons for example engage up to 10^4 synaptic junctions, having a diversity of excitatory and inhibitory synaptic inputs involving up to five types of neurotransmitter, with differing effects depending on receptor types, and their location on dendrites, cell body, or axons.

In the complex central nervous systems of vertebrates, we see the same dynamical features, now expressed in whole system excitations, such as the EEG, in which interacting excitatory and inhibitory neurons provide a basis for broad-spectrum oscillation, phase coherence and chaos in the global dynamics, with the synaptic organization enabling the dynamics to resolve complex context-sensitive decision-making problems. Nevertheless the immediate decision-making situations around which life or death results, in the theatre of conscious attention are qualitatively similar to those made by single celled organisms, based strongly on sensory input, and short term anticipation of immediate existential threats and opportunities, in a context of remembered situations that bear upon the current experience.

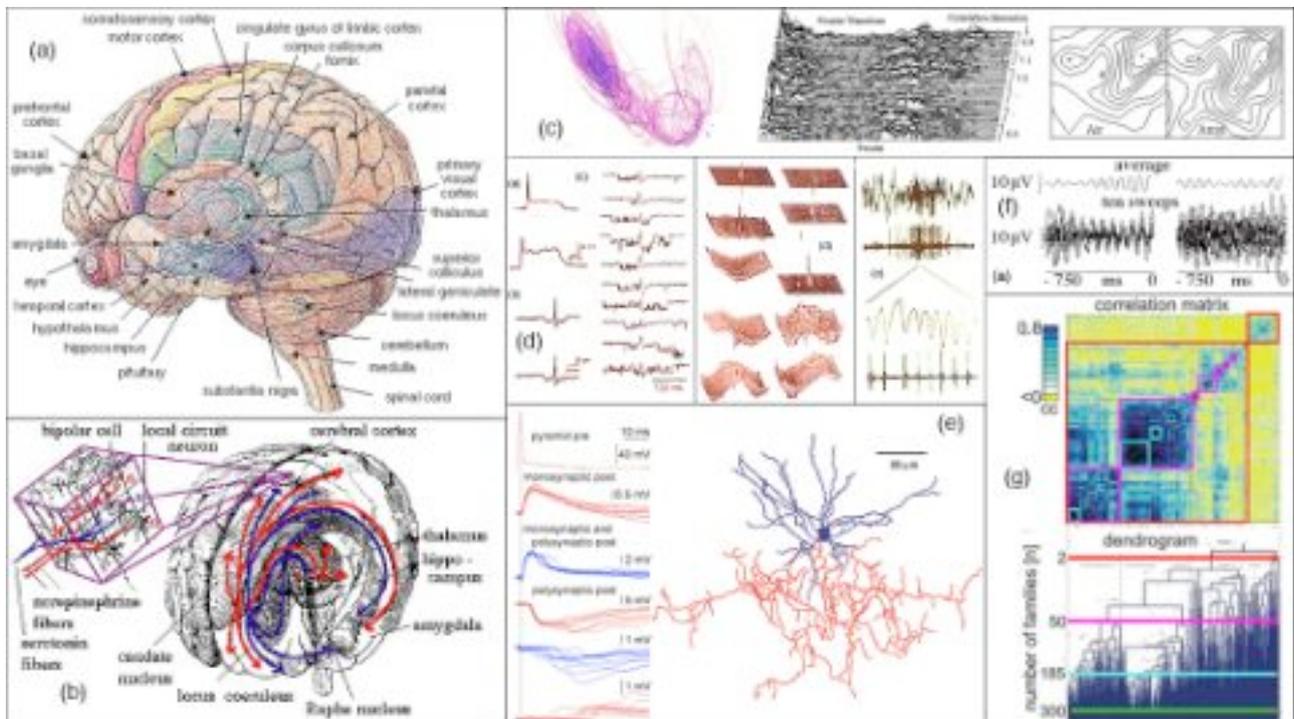


Fig 6: Structural overview of the brain as a dynamical organ. (a) Major anatomical features including the cerebral cortex, its underlying driving centres in the thalamus, and surrounding limbic regions involving emotion and memory, including the *cingulate cortex*, *hippocampus* and *amygdala*. (b) Conscious activity of the cortex is maintained through the activity of ascending pathways from the thalamus and brain stem, including the reticular activating system and serotonin and nor-adrenaline pathways involved in light and dreaming sleep. Processes which enable global dynamics to be affected by small perturbations. (c) Evidence for dynamical chaos includes modulated strange attractors (Freeman 1991), and broad spectrum excitations with moderate fractal (correlation) dimensions (Basar et. al. 1989). These dynamics are complemented by holographic processing across the cortex illustrated in an experimental representation of olfactory excitations corresponding to recognized odors (Skarda and Freeman 1987). (d) Stochastic resonance enables fractal instabilities to grow from ion channel to neuron to hippocampal excitation (Liljenström and Uno 2005). (e) Chandelier cells can facilitate an spreading of excitation to many pyramidal cells (Molnar et. al. 2008, Woodruff and Yuste 2008). (f) Wave front coherence in processing becomes manifest when a cue is recognized by the subject (left) (g) Correlation matrix and dendrogram of cortical slice is consistent with fractal self-organized criticality (Beggs and Plenz 2004).

4: A Dynamical View of the Conscious Brain

Although long distance axons involve pulse coded action potentials, the brain appears to utilize dynamic processing involving broad-spectrum oscillations, rather than discrete signals. Unlike the digital computer, the human brain is a massively parallel organ with only the order of 10 synapses between input and output,

despite having some 10^{10} neurons and 10^{14} synapses. Such design is essential to enable quick reactions to complex stimuli in real time and avoid the intractability problem of serial computers, which neural nets and genetic algorithms do solve effectively.

The cerebral cortex consists of six layers of cells organized in a sheet of functional columns about 1 mm square. These have a fractal modular architecture, with each column representing one aspect of experience, from primary processing of lines at given angles, color, motion and auditory tones, through to cells recognizing individual faces. Major areas of the cortex also follow a modular pattern centered on the primary senses and our coordinated motor responses to our ongoing situation. Frontal areas are involved in abstractions of motor events, strategic planning and execution, parietal areas between touch and visual cortices are involved in spatial abstractions, with the temporal lobes extending laterally beyond visual and auditory areas representing attributes with specific meaning, such as specific faces and complex melodies, semantic and symbolic process, such as language, and the temporal relationships between experiences. This is consistent with a 'holographic' model – each experience being represented collectively, like a Fourier transform, in terms of its attributes – consistently with the many-to-many connections neurons provide.

No single cortical area has been identified as the seat of consciousness. The most successful proposal (Ananthaswamy 2009, 2010) is that conscious processes correspond to the coordinated activity of the whole brain engaging active communication in 'working memory' between the frontal cortex and major sensory and association areas, while activity confined to regional processing is subconscious. This tallies with Bernard Baars' (1997) model of the Cartesian theatre of consciousness as 'global workspace'.

While major input and output pathways pass through thalamic nuclei underlying the cortex, two other systems modulate the dynamics of brain activity. The cortex is energized by ascending pathways from the brain stem, involving the reticular activating system, and dopamine, nor-adrenalin and serotonin pathways, fanning out across wide areas of the cortex, modulating active wakefulness, dreaming and sleep. Our emotional experiences are modulated through the limbic system, a lateral circuit, passing through the hypothalamus regulating internal and hormonal processes, the cingulate cortex dealing with emotional representations, and the hippocampus and amygdala, setting down sequential memories and dealing with flight and fight survival.

There is also evidence active conscious processing corresponds to (30-80 Hz) EEG oscillations in the gamma band, driven by mutual feedback between excitatory and inhibitory neurons in the cortex, and that phase coherence distinguishes 'in-synch' neuronal assemblies forming conscious thought process from peripheral pre-processing (Basar et. al. 1989, Crick & Koch 1992).

While the brain may be 'holographic' spatially, it appears to use phases of dynamical chaos in the time domain. Modulated transitions at the edge of chaos can explain many phenomena, from perception to insight learning in a 'eureka' brain wave. In olfactory perception, the brain appears to enter high energy chaos, which frees the dynamic from getting inappropriately locked-in, as annealing does in formal networks, fully-exploring dynamical space, followed by a reduction of energy, causing the dynamic to fall, either into a recognized state, represented by a strange attractor, or to form a new attractor through an adaptive change in the potential energy landscape, through learning (Skarda and Freeman 1987). The same idea fits with the 'eureka' of insight, where an unstable dynamic generated by the problem is resolved in a single bifurcation from chaotic instability into lucidity.

Non-linear mode-locking, common to oscillating chaotic systems, has the potential to facilitate the coherent excitations that characterize coupled neurosystems, going a good way towards resolving the 'binding' problem – how the brain 'brings it all back together'. By modulating the coupling between oscillating neurosystems, mode-locking could selectively bring related systems into phase coherence, just as the heartbeat is mode-locked to its local and brain pacemakers.

Chaos also makes the brain state arbitrarily sensitive to small perturbations, which is essential for a dynamical brain to be sensitive to small changes in its environment, and to its local instabilities. If the global state is critically poised at a tipping point, an unstable chaotic dynamic could become sensitive to perturbations at the level of the cell, synapse, or ion channel. There are several additional ways in which such sensitivity could come about. Stochastic resonance has been demonstrated to facilitate sensitivity, from ion channel, to cell, to global dynamic (Liljenström and Uno 2005). Fractal self-organized criticality has been found in cortical slices (Beggs and Plenz 2004). Chandelier cells have been shown to facilitate lateral spreading of local excitations to multiple pyramidal cells (Molnar et. al. 2008, Woodruff and Yuste 2008).

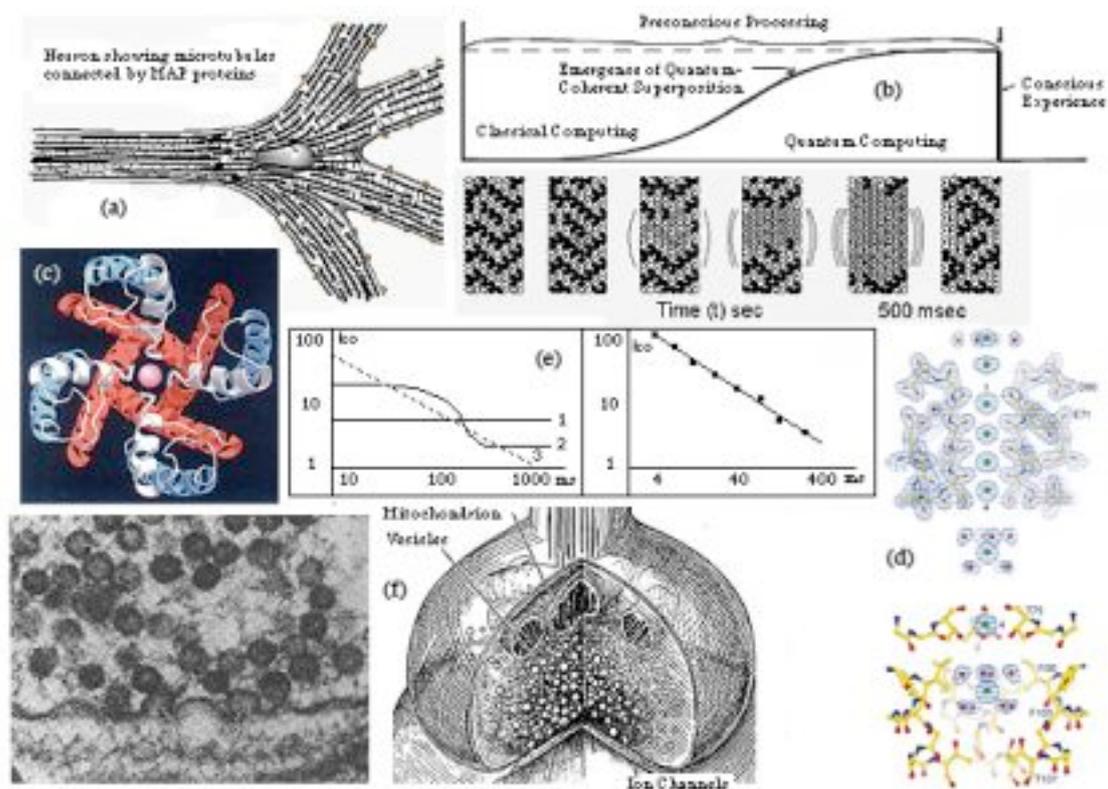


Fig 7: Features of quantum processing in proposed models. (a) Microtubule MAP proteins as envisaged in the OOR model (Hameroff and Penrose 2003). (b) The ensuing relationship between classical and quantum computing and consciousness. (c, d) gated K⁺ ion channels from MacKinnon's group (Zhou et. al. 2001). (e) Fractal kinetics in the channels (Liebovitch et. al.) (f) Synaptic junction may invoke uncertainty of position of the vesicle.

5: Quantum Dynamics and Conscious Anticipation

The two key questions confounding science about the brain are (1) how and why brain function generates subjective experience, and (2) whether there is any basis for our subjective conscious intentions having physical consequences in 'free-will'.

We thus explore how central to neurodynamic processes might exploit quantum effects to enhance survival prospects of the organism. To develop a realistic quantum theory of consciousness, we have to consider how whole brain states might become capable of quantum interaction and how this could arise from neurophysiological processes common to excitable cells.

We have seen that various forms of global instability, from chaos, through tipping points to self-organized criticality could make the global brain state ultimately sensitive to change at the cellular, molecular or quantum level. Ion channels, such as for acetyl-choline display non-linear (quadratic) concentration dynamics, being excited by two molecules. Many aspects of synaptic release are also highly non-linear, due to biochemical feedback loops. A single vesicle excites up to 2000 ion channels, providing extreme amplification of a potentially quantum event. In addition to being candidates for quantum coherence, voltage gated ion channels display fractal kinetics (Liebovitch 1987).

How interacting systems respond to the quantum suppression of chaos, in processes such as scarring of the wave function (Gutzwiller 1992), received clarification (Chaudhury et. al. 2009, Steck 2009), when it was discovered that an electron in an orbit around a Cs atom in a classically chaotic regime enters into entanglement with nuclear spin. This illustrates how the chaotic 'billiards' of molecular kinetics, and chaotic membrane excitation, might become entangled with other states at the quantum level. One characteristic of time-dependent quantum 'chaos' is transient chaotic behavior ending up in a periodic orbital scar as wave spreading occurs. This would suggest that chaotic sensitivity, with an increasing dominance by quantum uncertainty over time, would contribute to which entanglements ultimately occur in a given kinetic encounter.

The evolutionary argument is a potent discriminator of models of consciousness. Quantum attributes making subjective consciousness possible need to evolve in confluence with essential physiological processes, thus

potentially dating back to the epoch when the central components of modulated excitability evolved. Many theories of consciousness have been devised invoking quantum processes which emphasize unusual interpretations of physics, esoteric forms of quantum computation invoking properties extraneous to the known physiological functions of biological organelles, or hypothetical fields in addition to known physiology, raising questions as to whether they pass the evolutionary test. One of the most famous is Hameroff and Penrose's (2003) OOR theory combining objective reduction of the wave function with hypothetical forms of quantum computing on microtubules, which might be extended between cells through gap junctions. These are extensively discussed in the supporting online material, (King 2011b).

One idea fitting closely with neurophysiology is Bernroder's (2003, 2005) proposal that quantum coherence may be sustained in ion channels long enough to be relevant for neural processes and that the channels could be entangled with surrounding lipids and proteins and with other channels in the same membrane. He suggests that the ion channel functions through quantum coherence. MacKinnon's group (Zhou et. al. 2001) have shown that the K⁺-specific ion channel filter works by holding two K⁺ ions bound to water structures induced by protein side chains. These have similarities to models of quantum computing using ion traps. The solitonic nature of action potentials could provide such entangled connectivity between channels.

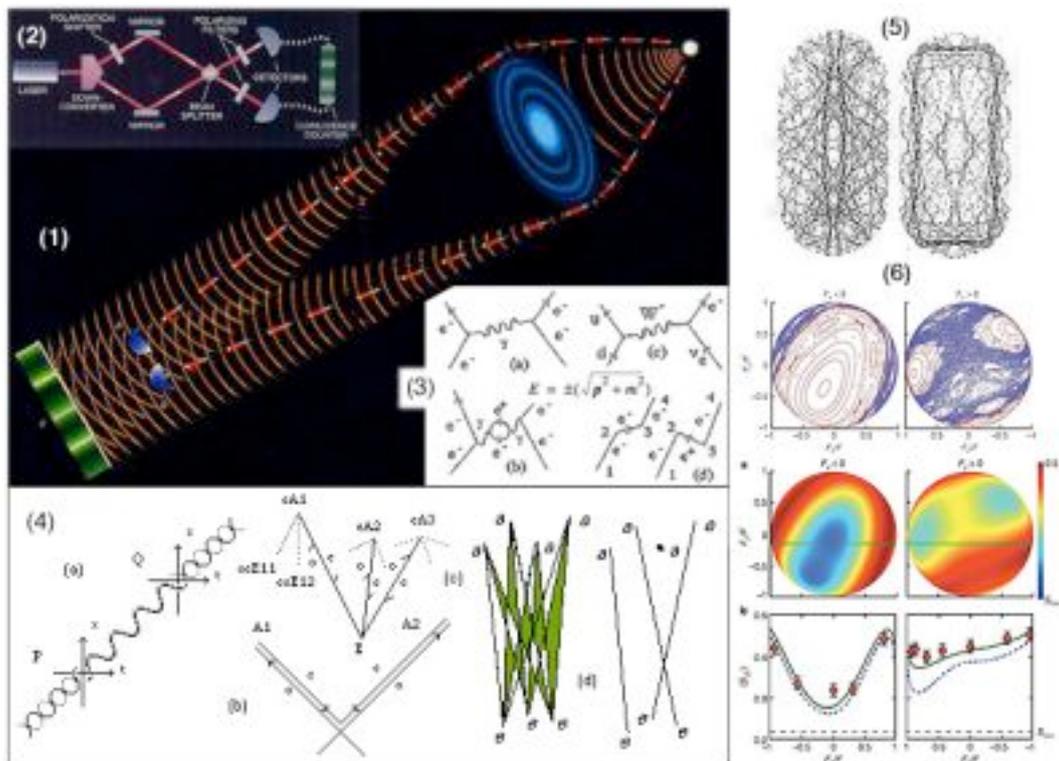


Fig 8: Wheeler delayed choice experiment (1) shows that a decision can be made after a photon from a distant quasar has traversed a gravitationally lensing galaxy by deciding whether to detect which way the photon traveled or to demonstrate it went both ways by sampling interference. The final state at the absorber thus appears to be able to determine past history of the photon. Quantum erasure (2) likewise enables a distinction already made, which would prevent interference, to be undone after the photon is released. Feynman diagrams (3) show similar time-reversible behavior. In particular time reversed electron scattering (d) is identical to positron creation-annihilation. (4a) In the transactional interpretation (Cramer 1983), a single photon exchanged between emitter and absorber is formed by constructive interference between a retarded offer wave (solid) and an advanced confirmation wave (dotted). (b) Experiments of quantum entanglement involving pair-splitting are resolved by combined offer and confirmation waves, because confirmation waves intersect at the emission point. Contingent absorbers of an emitter in a single passage of a photon (c). Collapse of contingent emitters and absorbers in a transactional match-making (d). (5) Scarring of the wave function of the quantum stadium along repelling orbits (Gutzwiller 1992). (6) Generation of quantum entanglement by quantum chaos in the quantum kicked top (Chaudhury et. al. 2009, Steck 2009).

While decoherence theories and objective reduction do not provide an active role for will, several physicists have suggested consciousness could play a part in the way the wave function representing a superposition of states, collapses to one real instance of the particle. Quantum theory predicts Schrödinger's cat subjected to cyanide if a radioactive scintillation occurs, is in a shadowy superposition - both alive and dead. In our conscious experience of the real world, we find the cat is either alive or dead. This suggests subjective consciousness could play an intervening role within quantum reality, reducing the superabundance of

quantum probability multiverses to the historical process we experience. If so, consciousness may have a direct window on the entangled sub-quantum realm. We thus explore a model of quantum anticipation, which could extend back to single celled evolution.

Feynman diagrams of quantum interactions show that the quantum interaction is time-reversible. The diagram for electron scattering, when the scattered electron path is time-reversed, becomes positron creation and annihilation. Moreover in real quantum experiments, such as quantum erasure and the Wheeler delayed-choice experiment, it is possible to change how an intervening wave-particle behaves by making different measurements after the wave-particle has passed through the 'apparatus'. All forms of quantum entanglement possess this time-symmetric property.

John Cramer (1983) incorporated time-symmetry into the 'transactional interpretation' of quantum mechanics, in which space-time handshaking between the future and past becomes the basis of each real quantum interaction. The emitter of a particle sends out an offer wave forwards and backwards in time, whose energies cancel. The prospective absorbers respond with confirmation waves, and the real quantum exchange arises from constructive interference between the retarded component of the chosen emitter's offer wave and the advanced, time-reversing component of the chosen absorber's confirmation wave. The boundary conditions defining the exchange thus involve both past and future states of the universe. Upon wave function collapse, the exchanged real particle traveling from the emitter to the absorber is identical with its negative energy anti-particle traveling backwards in time.

The transactional interpretation is a heuristic device, which is not essential to the argument, since its predictions coincide, largely, or exclusively with conventional quantum mechanics, but it does highlight future boundary conditions, which could play a part in conscious anticipation. Regardless of the interpretation of quantum mechanics we use, an exchanged particle has a wave function existing throughout the space-time interval in which it exists, so any process involving collapse of a wave function has boundary conditions extending in principle throughout space-time, involving future prospective absorbers. Advanced entanglement becomes clear in experiments creating two entangled particles (Aspect 1981), where subsequent measurement of the polarization of one photon immediately results in the other having complementary polarization, although neither had a defined polarization beforehand. The only way this correlation can be maintained within quantum reality is through a wave function extending back to the creation event of the pair and forward again in time to the other particle.

If subjective consciousness has a complementary role to brain function, correlated with entangled, quanta emitted and absorbed by the biological brain, it is then correlated with a superposition of possible states in the brain's future, as well as having access to memories of the past. In pair-splitting experiments, the boundary conditions do not permit a classically-causal exploitation. This does not result in a contradiction here, because the brain state is quantum indeterminate and the conscious experience corresponding to the entangled collapse provides an intuitive 'hunch', not a causal deduction.

A possible basis for the emergence of subjective consciousness, which could also be pivotal in explaining the source of free-will, is thus that the excitable cell gained a fundamental form of anticipation of threats to survival as well as strategic opportunities, through anticipatory quantum non-locality induced by chaotic excitation of the cell membrane, in which the cell becomes both an emitter and absorber of its own excitations. Non-locality in space-time is a fundamental quantum property shared by all physical systems, including macroscopic systems with coherent resonance. The coherent global excitations in the gamma range associated with conscious states, could thus be the 'excitons' in such a quantum model. Unlike quantum computing, which depends on not being disturbed by decoherence caused by interaction with other quanta. Stringent requirements, avoiding decoherence, may not apply to transactions, where real particle exchange occurs even under scattering.

Quantum phenomena abound in biological tissues. Entanglement has been observed in healthy tissues in quantum coherence MRI imaging and bird navigation has been suggested to use entangled electrons. Excitations in photosynthetic antennae have also been shown to perform spatial quantum computing. Enzyme activation energy transition states and synaptic transmission also use quantum tunneling.

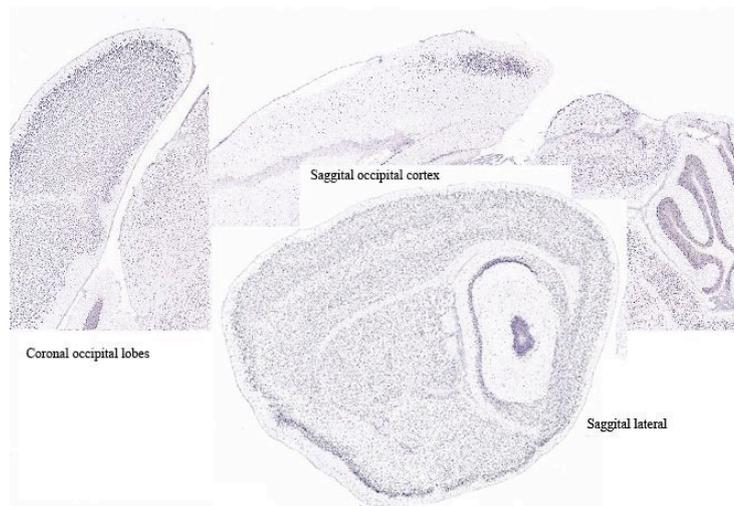
By making the organism sensitive to a short envelope of time, extending into the immediate future, as well as the past, subjective consciousness could thus gain an evolutionary advantage, making the organism sensitive to anticipated threats to survival as well as hunting and foraging opportunities. It is these primary needs, guided by the nuances of hunch and familiarity, rather than formal calculations, that the central

nervous systems of vertebrates have evolved to successfully handle. Such temporal anticipation need not be of causal efficacy but just provide a small statistical advantage, complemented by computational brain processes associated with learning, which edge-of-chaos wave processing is ideally positioned to do.

These objectives are shared in precisely the same way by single-celled organisms and complex nervous systems. Because of the vastly longer evolutionary time since the Archaean expansion, than the Cambrian metazoan radiation, and the fact that all the components of neuronal excitability were already present when the metazoa emerged, quantum anticipation could have become an evolutionary feature of single celled eukaryotes, before metazoa evolved.

6: Quantum Sensitivity, Sensory Transduction and Subjective Experience

Fig 9: Expression of rhodopsin in the CNS shows both strong selective neuronal activity and a focal expression in the occipital cortex consistent with function in primary visual areas (King 2007).



One of the mysteries that distinguish the richness of subjective conscious experience from the colorless logic of electrodynamics is that sensory experiences of vision, sound, smell and touch are richly and qualitatively so different that it is difficult to see how mere variations in neuronal firing organization can give rise to such qualitatively different subjective affects. How is it that when dreaming, or in a psychedelic reverie, we can experience ornate visions, hear entrancing music, or smell fragrances as rich, real, intense and qualitatively diverse as those of waking life?

Since the senses are actually fundamental quantum modes by which biological organisms can interact with the physical world, this raises the question whether subjective sensory experience is in some way related to the quantum modes by which the physical senses communicate with the world. Clearly our senses are sensitive to the quantum level. Individual frog rod cells have been shown to respond to individual photons, the quietest sound involves movements in the inner ear of only the radius of a hydrogen atom and single molecules are sufficient to excite pheromonal receptors.

Many genes we associate with peripheral sensory transduction in several senses are also expressed in the mouse brain (King 2007) at least in the form of RNA transcripts, including stomatin-like protein 3 associated with touch, epsin, otocadherin and otoferlin associated with hearing, and several types of opsin, including rhodopsin and encephalopsin. This suggests the brain could harbour an 'internal sensory system' which might play a role in generating the 'internal model of reality', although these ideas are speculative and it is a major challenge to see how such processes could be activated reversibly in the CNS.

Several researchers (Pocket 2000, McFadden 2002) have proposed that neural excitation is associated with electromagnetic fields, which might play a formative role in brain dynamics. Attention has recently been focused on biophotons as a possible basis of processing in the visual cortex based on quantum releases in mitochondrial redox reactions (Rahnama et. al. 2010, Bókkon et. al. 2010). Microtubules have also been implicated (Cifra et. al. 2010).

All excitable cells have ion channels, which undergo conformation changes associated with voltage, and orbital or 'ligand'-binding, both of internal effectors such as G-proteins and externally via neurotransmitters, such as acetyl-choline. They also have osmotic and mechano-receptive activation, as in hearing, and in some species can be also activated directly and reversibly by photoreception. Conformation changes of ion channels are capable of exchanging photons, phonons, mechano-osmotic effects and orbital perturbations, representing a form of quantum synesthesia. Since the brain uses up to 40% of our metabolic energy for functions with little or no direct energy output, it is plausible that some of the 'dissipated' energy could be generating novel forms of interaction.

7: Complementarity, Symmetry-breaking, Subjective Consciousness, and Cosmology

This leads to the most perplexing chasm facing the scientific description of reality. What is the existential nature of subjective consciousness, from waking life, through dreaming to psychedelic and mystical experience, and does it have cosmological status in relation to the physical universe?



Fig 10: Psychedelic and dreaming states provide conscious experiences as intense and subjectively veridical as real world sensory experiences, but with very different structure and dynamics (Andrew Ostin <http://psion005.deviantart.com/>, *Memory of the Future* Oscar Dominguez 1939).

The key entities forming the physical universe manifest as symmetry-broken complementarities. Quanta are wave-particles, with complementary discrete particle and continuous wave aspects. The fundamental forces are symmetry broken in a manner that results in complementary force-radiation bearing bosons and matter forming fermions. In the standard model these have symmetry broken properties, with differing collections of particles. Supersymmetry proposes each boson has a fermion partner to balance their positive and negative energy contributions, but E8's 112 'bosonic' and 128 'fermionic' root vectors, suggest symmetry-breaking could be fundamental (Fielder and King 2010).

Further symmetry-broken complementarities apply to the biological world, where the dyadic sexes of complex organisms and many eukaryotes are both complementary and symmetry broken, with themes of discreteness and continuity even more obviously expressed at the level of sperm and ovum than in our highly symmetry-broken human bodily forms, involving pregnancy, live birth and lactation.

The relationship between subjective consciousness and the physical universe displays a similar complementarity, with profound symmetry breaking. The 'hard problem of consciousness research' (Chalmers 1995) underlines the fundamental differences between subjective 'qualia' and the participatory continuity of the Cartesian theatre on the one hand, and the objective, analyzable properties of the physical world around us.

Although we depend on a pragmatic acceptance of the real world, knowing we will pass out if concussed and could die if we cut our veins, from birth to death, the only veridical reality we experience is the envelope of subjective conscious experience. It is only through the consensual regularities of subjective consciousness that we come to know the real world and discover its natural and scientific properties. As pointed out by Indian philosophy, this suggests that mind is more fundamental than matter. The existential status of subjective consciousness thus also has a claim to cosmological status.

A further cosmological interpretation of consciousness we have noted in association with the cat paradox is that it may function to solve the problem of super-abundance, by reducing probability multiverses to the unique course of history we know and witness. This view of consciousness in shaping the universe is consistent with several of the conclusions of biocentrism (Lanza 2009).

The lessons of quantum and fundamental particle complementarity and symmetry-breaking, sexuality and the Yin-Yang complementarity of the Tao and of Shakti-Shiva in Tantric mind-world cosmologies, lead to a cosmology of consciousness, as symmetry-broken complement to the physical universe.

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