Article

Cosmological Foundations of Consciousness

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ABSTRACT

How the biological brain generates subjective consciousness remains the principal abyss in the scientific description of reality, a problem complementary to the cosmological theory of everything, and equally as challenging, because it takes the scientific model beyond the confines of objective reality. This paper examines the cosmological basis of consciousness and subjective experience in biological organisms. It draws on principles of symmetry-breaking and interactive non-linear dynamics to establish the cosmological status of biogenesis, and biological tissues as fractal forms of interactive symmetry-breaking. It then investigates the Archaean genetic expansion as a source of the envelope of functional machinery forming the basis of neural activity, based on the universal excitability of all living cells. Finally it examines the biophysical basis for consciousness, both in single cells, and in the human brain and its 'Cartesian theatre' of consciousness, to elucidate cosmological principles underlying the mind-body relationship.

Key Words: cosmological foundation, consciousness, reality, subjective experience.

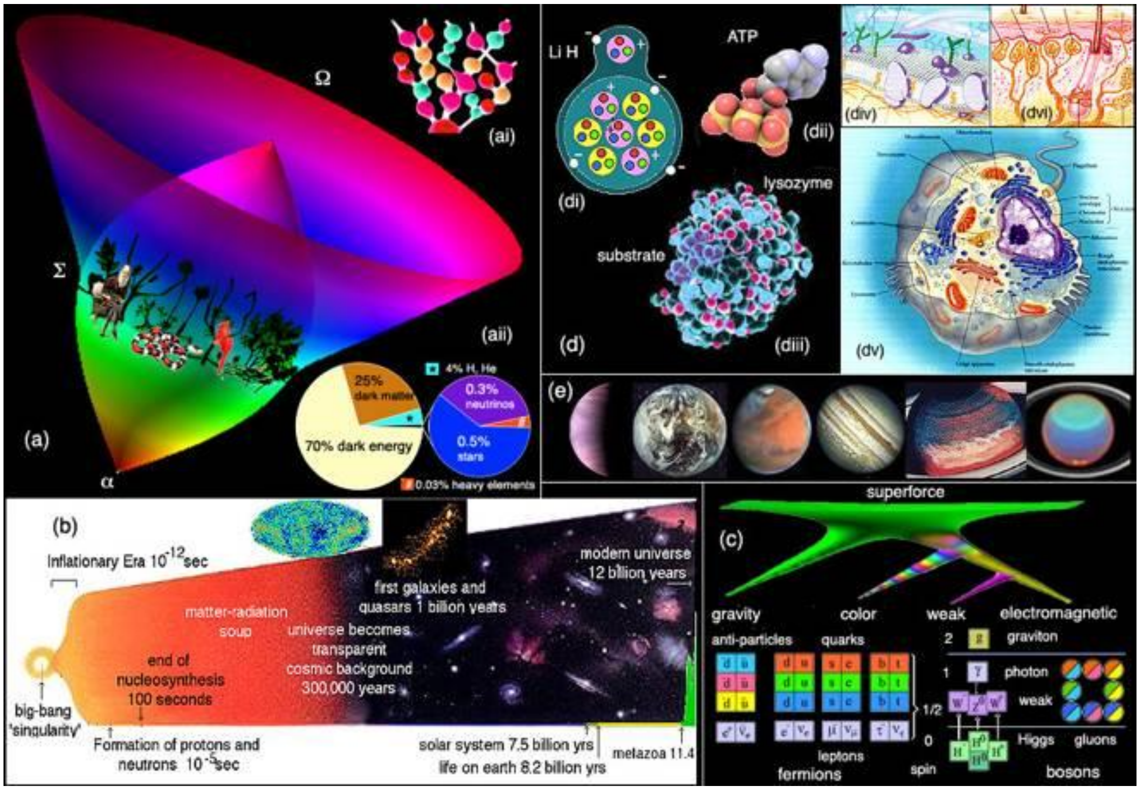

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Fig 1: Cosmic symmetry-breaking and its interactive fractal and chaotic effects leading to biogenesis. (a) Life portrayed as the consummation of interactive complexity (Σ) resulting from symmetry-breaking of the fundamental force of nature in the big-bang (α), whatever ultimate fate is in store (Ω). Inset (i) possible fractal inflation , (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 current 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) These fractal effects are complemented by the chaotic effects of gravity as a non-linear force, resulting in extreme variation of the planets, generating a diversity of potential conditions for biogenesis, similar to the dynamic variations surrounding the Mandelbrot set.

1. Introduction: Scope and Design

This is the full version of a pair of twin papers, comprising a compact overview (King 2011b) which refers extensively to this paper as supporting online material. The overview presents the general principles, while this paper contains all the references and a full discussion of all the research developments and ideas.

2. Non-linear Quantum and Cosmological Foundations of Biogenesis

Although it is now well-known science that the universe appears to have begun in an explosive 'big-bang' possibly accompanied by a phase of cosmic inflation and that these events are also associated with symmetry-breaking of the forces of nature into the highly asymmetric weak and strong nuclear forces, electromagnetism and gravity we experience today, the cosmological implications of this for the existence of life and hence consciousness (King 1978) are far less well-understood and not fully recognized.

Two preconceptions have tended to cloud this recognition of the cosmic role of biogenesis. The first is that life is fragile and insignificant by comparison with the maelstrom forces of stellar energies, let alone black-holes or the cosmic big-bang. This is criticism of life's cosmological status is incorrect because life is sine-qua-non the ultimate interactive consequence of cosmic symmetry-breaking. Nowhere else do the forces of nature enter into such complete fractal expression in complexity. Furthermore, although life's energetics are miniscule on a cosmic scale, they are robust over cosmological time, to the extent that life has continued on Earth for a full third of the universe's lifetime.

The second is that chemistry has been incorrectly perceived as a matter of ball-and-stick molecules, of almost arbitrary structure, generally driven by highly determined reaction conditions suited to push the process towards a few desired products. This approach does not deal well with situations where very simple reactants lead to increasingly complex and diverse products. In a Nature article for the current 'Year of Chemistry', Ball (2011) notes the demise of such notions, toward a dynamic view of chemical bonding, but this misconception led to a slowing of prebiotic discovery the 20th century, so that, despite Miller and Urey's (1959) founding work on spark syntheses mid century, the key biogenetic pathways to replication are only beginning to be elucidated, nearly a decade into the third millennium.

The realities of non-linear quantum interaction are that, due to the charge interactions of electron wave functions and atomic nuclei, molecular orbitals form as a non-linear perturbation of the basic linearity of Hamiltonian dynamics. The non-linear energetics that results in strong covalent and ionic bonds does not stop there, but leads to a cascade of successively weaker H-bonding, hydrophobic and 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 interactions, cell organelles, cells, tissues and organisms.

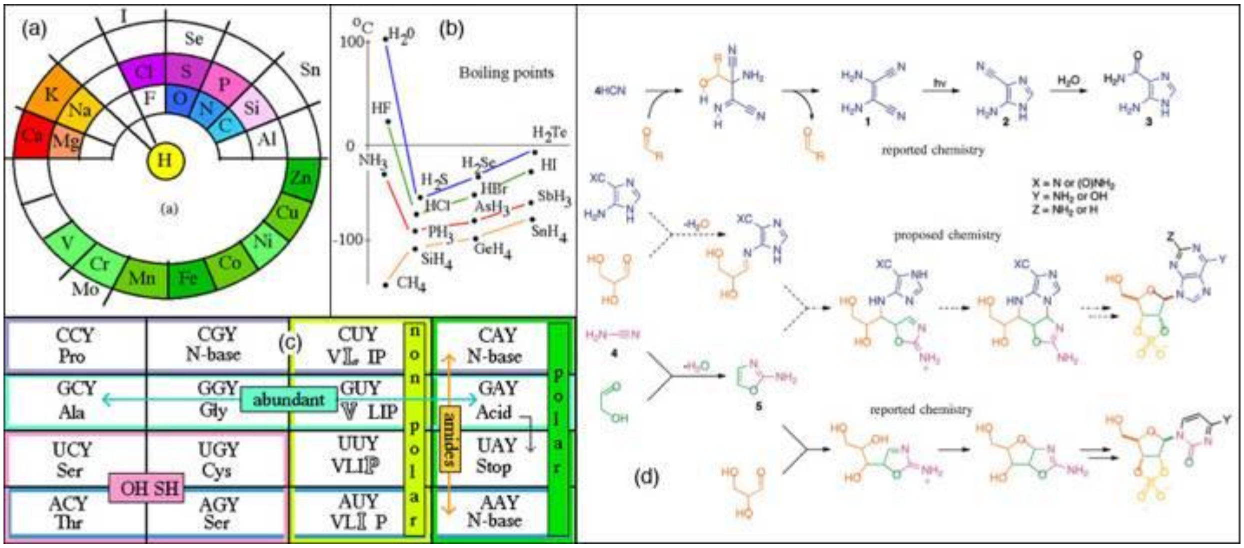

Fig2: (a) Symmetry-breaking quasi-periodic table of the bioelements displays covalent optimality. (b) Optimality of H_20 in terms of internal weak-bonding expressed in its high boiling point. (c) Evidence for a symmetry-breaking origin of the genetic code. (d) Realized and proposed direct synthesis paths from primordial precursors such as HCN to nucleotides (Powner et. al. (2009, 2010).

Thus, while genetic coding and regulation is necessary for organizing the structures of the tissues that make up our bodies and brains, it is certainly not sufficient and can only encode organismic development because the fundamental laws of molecular interaction, upon which such coding depends, are non-linear and fractal. In this sense, tissue is the natural interactive full complexity product of cosmic symmetry-breaking. The tissue of the conscious human brain represents the Copernican pinnacle of integrated functional complexity in the universe and lays a claim to a cosmological status, as fundamental as the big-bang.

Fractal molecular energetics combines with chaotic gravitational dynamics to cause an extreme variety of local conditions in varying solar systems, which give our own planets and their satellites an extreme diversity from one another, and each of the many hundreds of extra-solar planets discovered and the billions of estimated planets in our galaxy their own bewildering extremes. These conditions lead to a situation similar to the Mandelbrot set of the quadratic iteration, in which local states form an endlessly varying fractal domain in the phase space of possible conditions. A Mandelbrot universe virtually guarantees a goldilocks biogenesis cosmologically, through the dense exploration of dynamical space by the chaotic system.

The distribution of the bioelements shows very clear evidence of symmetry-breaking optimizations that are a direct result of the non-linear nature of the periodic table of the elements in which the symmetry-breaking of charge in atomic matter, leads to a series of quantum periodicities of the *s*, *p*, *d* and *f* orbitals and their hybrids which is not periodic energetically so that the second row elements CNO are optimally covalent. This causes the covalent basis of life to be founded on the splitting of H with CNO, stemming from the high energy optimally strong multiple -CN, -CC-, and >CO bonds, which are cosmically abundant in forming star systems (Buhl 1974) 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.

The covalent symmetry-breaking of periodicity is complemented by a series of other optimalities. The increasing electronegativity of the first row sequence CNO leads to the optimality H_2O as an extreme polar structure-invoking medium, bifurcating molecular dynamics between hydrophilic and non-polar phases, in addition to pH, polar and H-bonding effects, which define the structures and dynamics of proteins, nucleic acids, membrane, ion and electron transport - all fundamentally essential to the existence of life. The alkali and alkaline earth elements K^+/Na^+ and Ca^{++}/Mg^{++} are bifurcated in their ionic relationships e.g. in cell membrane potentials. Second row elements S and P also become involved contributing unique properties of third row element elements, weaker S-S bonds and Fe-S interactions critical for electron transport, and the energetics of oligomeric PO_4^{3-} ions, in cellular energetics as ATP, and in catalyzing nucleic acid polymerization and forming its backbone. Finally the electron-transferring properties of the transition elements enter into major catalytic roles.

This does not imply that this arrangement of bioelements is the only one in which life could exist, as the discovery of organisms adapted to using arsenic in the place of phosphorus, even in the DNA backbone (Wolfe-Simon et. al. 2010) demonstrates, but it does confirm that life as we know it does have optimal properties of a symmetry-breaking nature cosmologically. These may extend as far as the establishment of the genetic code, where major assignments of the first and second codon appear to be based on cosmic abundance and hydrophilicity versus non-polarity, as well as other generic features (King 1982).

The critical transition, for the origin of replicative life to take place, is a stable context in which the four nucleotides comprising RNA can be generated from primordial cosmically-abundant molecules such as HCN and HCHO and then polymerize and become able to catalyze their own replication.

Although the first syntheses produced the purines adenine and guanine readily, cytosine and uracil, the complementary pyrimidine bases, making up the other half of the pairs A-U and G-C, were not at detectable levels. However Stanley Miller, 43 years after his original pioneering experiment, with Michael Robertson, discovered a way for the primordial pond to make them in high yield. When he added more urea than was produced in the spark synthesis, it reacted with cyanoacetaldehyde, another by-product, producing large amounts of pyrimidines. (Cohen 1996, Horgan 1996).

A major stride has recently been made which put the direct primal synthesis in a more definitive perspective. Sutherland's group (Powner et. al. 2009, 2010) have both produced a prebiotically plausible route for synthesizing pyrimidine nucleotides and have a putative pathway that could also lead to the synthesis of the purine complements in a 'one-pot' process. Critically in the presence of phosphate is necessary to the polymerization pathway.

Ferris (1996) added montmorillonite, a positively charged clay believed to be plentiful on the young Earth, to a solution of negatively charged adenine nucleotides, spawning RNA 10-15 nucleotides long. When these chains, clinging to the surface of the clay, were repeatedly washed with the solution, they grew up to 55 nucleotides long. The discovery that RNA appears to be the catalyst of peptide-bond synthesis in the modern ribosome (Guthrie 1992, Pace 1992, Noller et. al. 1992) and the capacity of modified ribozymes to act as amino-acyl esterases (Picarilli et.al. 1992), the first step in protein synthesis, establish RNA has the capacity to act as synthetase as well as transfer, messenger and ribosomal functions.

Szostak's group (Szostak et. al. 1995, Wilson and Szostak 1996) have evolved ribozymes capable of a broad class of catalytic reactions. Co-researcher David Bartel has evolved RNAs that are as efficient as some modern protein enzymes. His ribozymes can stitch small pieces of RNA together without breaking larger molecules apart, using high-energy tri-phosphate bonds similar to ATP (Cohen 1996). Zhang and Cech (1997, 1998) isolated RNAs that could efficiently link specific amino acids together from a random pool of 10^{15}synthetic RNAs. They also found that a small region of many of the RNAs they selected was 70 per cent identical to some regions of the ribosomal RNA. Lincoln and Joyce (2010) have also demonstrated RNA ligation processes using complementary catalytic RNAs which provide a plausible basis for RNA to 'pull itself up by its bootstraps' into reproductive autonomy.

Many of the fundamental molecules associated with membrane excitation, including lipids such as phosphatidyl choline and amine-based neurotransmitters, have potentially primordial status (King 1996). Amine-based neurotransmitters, from acetylcholine to the catecholamines and serotonin as well as simple amino acids glutamate and GABA may have the capacity to modify membrane dynamics directly, through polar interactions with the terminals of membrane lipids, and have later been coopted by evolution into protein binding to ion channels and receptors as a result of these properties.

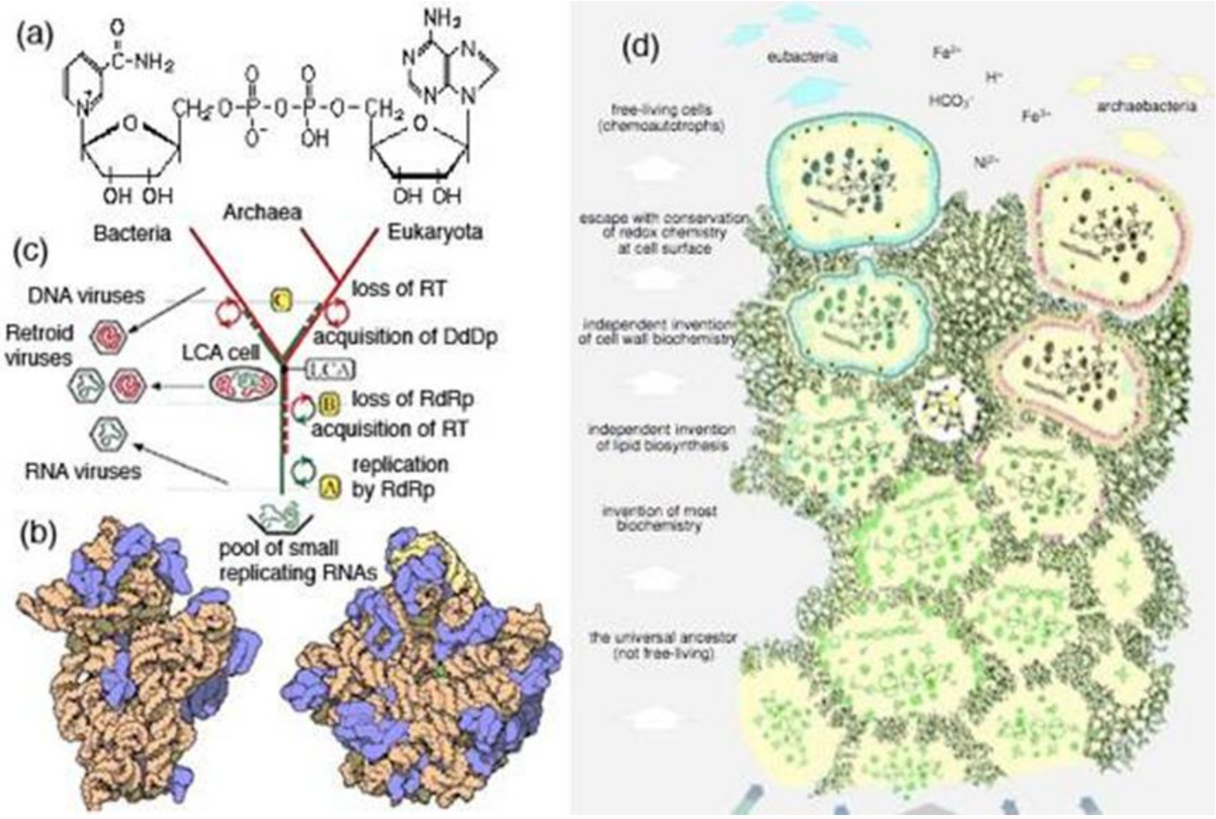

Fig 3: (a) Catalytic nicotine-adenine dinucleotide is essential in respiration. (b) Large and small subunits of the ribosome are centrally and functionally RNA [pink] (c) Molecular fossil evidence for a viral-based cellular transition from the RNA world to DNA based chromosomes, through cellular cooption of viral RNA-directed RNA-polymerase, followed by reverse transcriptase and finally DNA-dependent DNA-polymerase. (d) Independent evolution of archaeal 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.

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

There is abundant genetic evidence for an era when RNA played the roles of both an informational molecule and a protein-like catalyst through its tertiary structure. The ribosome is still centrally an RNA-based functioning unit common to all life forms, implying that protein translation evolved during the RNA era. Eucaryote nuclear chemistry is still very much RNA-based with extensive RNA processing. Cellular metabolisms also depend extensively on nucleotide-based cofactors from NAD through to cyano-cobalamin, or vitamin B12. The evidence is consistent with the polymerases for this transition coming from viral genomes and with DNA replication evolving independently in bacteria and archaea/eukaryotes.

Likewise both fermentation and the cell walls and membranes of bacteria and archaea/eukaryotes differ genetically, implying two independent evolutionary origins. A novel unstable interface phenomenon may provide a plausible explanation for how cellular life originated, well into the RNA era after ribosome-based protein translation was in place (Martin and Russell 2003). 'Lost city' undersea vents generate a gigantic chemical garden of porous carbonate columns at the interface of cosmically-abundant crustal mineral olivine interacting chemically with [then acid carbonate and iron-rich] sea water, releasing hydrogen, alkaline fluids and heat. These vents have been found to provide a unique pore-filled active interface, conducive to the coexistence of complex organic molecules, lipid membranes and iron-sulphur complexes, with a proton gradient, and capable of concentrating nucleotides exponentially. This provides a plausible environment for an open RNA-era protoplasm to survive, and for autonomous cellular life to evolve (Lane 2009).

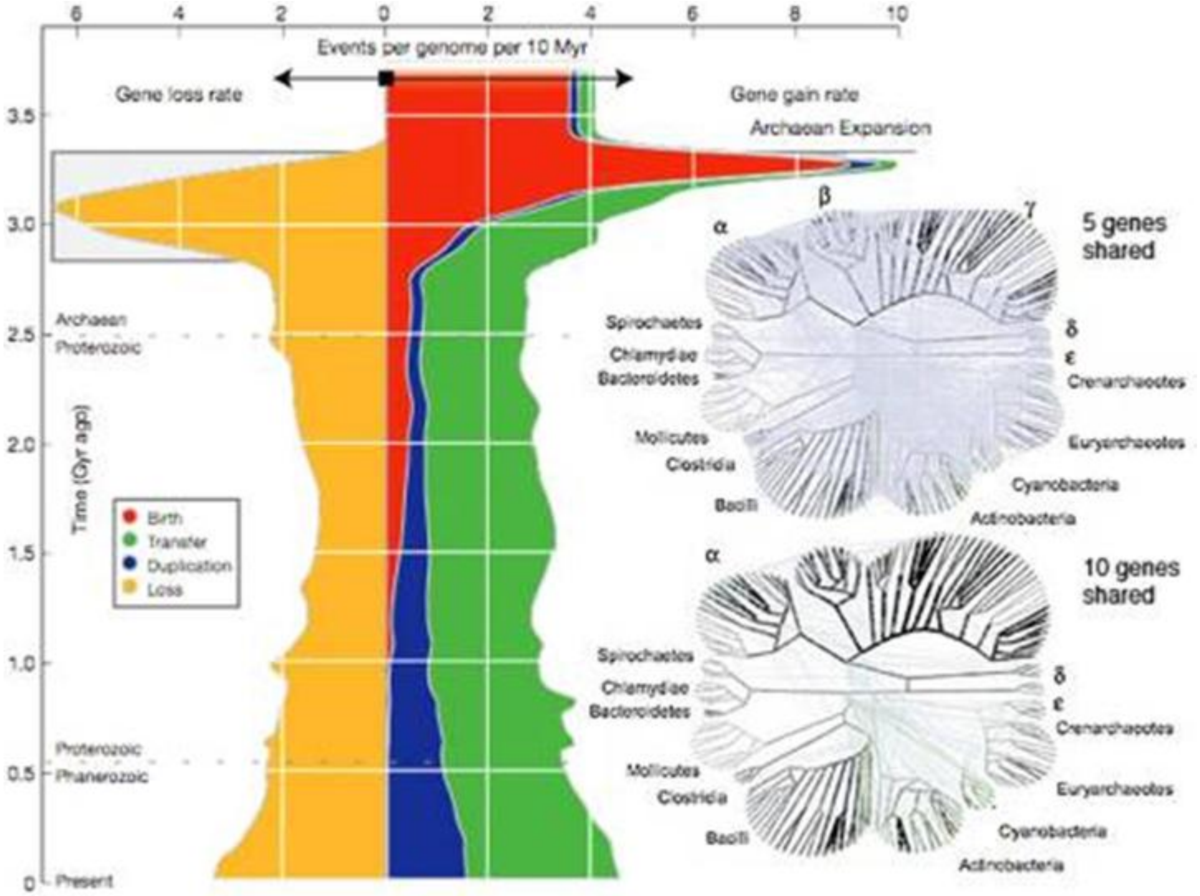

Fig 4: (Left) Archaean genetic expansion around 3.3 billion years ago generated most critical genes common to life (David and Alm 2010) (Right) Evidence of ubiquitous horizontal transfer of genes between bacterial species at different trigger levels (Dagan et. al. 2006).

Once the branches of cellular life evolved, cell excitability based on ion channels and pumps rapidly became universal. As early as 3.3 billion years ago there was a massive genetic expansion, which gave rise to the majority of critical genes necessary to all forms of life over a remarkably short period in evolutionary time (David and Alm 2010). This was also accompanied by high levels of horizontal gene transfer driven by a cross-species pan-sexuality promoted by viruses and plasmid conjugation and transfer.

Estimates of the computing power of the collective bacterial and archaeal genome contain some almost astronomical figures (King 2009). To give a very rough idea of the computing power of the combined bacterial genome alone, taking into account bacterial soil densities ($\sim 10^9$/g), effective surface area ($\sim 10^{18}$ cm^2), genome sizes ($\sim 10^6$), combined reproduction and mutation rates ($\sim 10^{-3}$/s) gives a combined presentation rate of new combinations of up to 10^{30} bits per second, roughly 10^{13} times greater than the current fastest computer at 2 petaflops or about 10^{17} bit ops per second. Corresponding rates for complex life forms would be much lower, at around 10^{17} per second because they are fewer in total number and have lower reproduction rates and longer generation times, but they are still vying with the computation rates of the fastest supercomputer on earth.

This picture of bit rates coincides closely with the Archaean expansion scenario noted above and suggests that evolution has been a two-phase process in which the much higher bit rates of the collective single-celled genome, under promiscuous sexuality and horizontal transfer, has arrived at a global genetic solution to the notoriously intractable protein folding problems of the central metabolic, electro-chemical and root developmental pathways, which are then later capitalized on by multi-celled organisms, through gene duplication and loss, as well as the creation of new specialized genes at a much lower rate. The excitability associated with chaotically sensitive cells and conscious brains might thus have cosmological status if evolution has successfully explored the phase space of catalytic processes making excitability and quantum sensation possible.

The eukaryotes appear to have evolved through a number of pivotal gene fusions, which dramatically enriched their genomes and ultimately led to the plants, fungi and animals. Both the respiring mitochondrion, common to eukaryotes, and the plasmid of plants, are bacterial endosymbionts, engulfed by ancestral cells of eukaryotes. There is further evidence that only the informational nucleic acid-processing genes of eukaryotes originated with them and that the majority of metabolic genes have been inherited from mitochondrial, or other bacterial genetic fusions (Horiike et. al. 2001).

Horizontal transfer and gene fusion has led to a situation where both 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 (Perez 2003) and a fast action potential are common to the spread of eucaryote cell types, from giardia and paramecium to metazoa. Meech and Mackie (2007) note that ion channel structure appears to have been established during the soup of lateral gene transfers that drove bacterial evolution and that all major classes arose before the metazoa, with several showing homology to bacterial versions.

A fundamental question arises. Is the sort of dynamics we associate with the conscious brain essentially a product of the complex interconnectivity of circuitry, as artificial neural nets and computational approaches might suggest? Or is it a fundamental aspect of living cells, which evolved with the earliest eukaryotes?

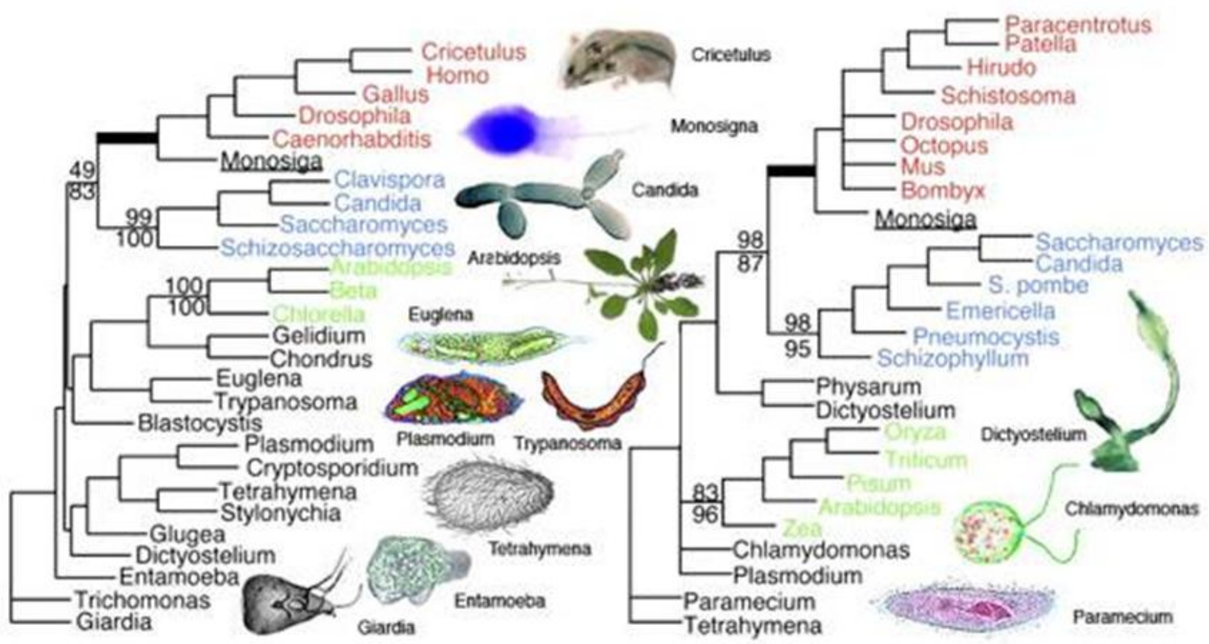

Fig 4b: Evolutionary trees of transcriptional elongation factor EF-2 and b-tubulin outlining the spread of eucaryote evolution in relation to the animals and humanity (King and Carrol 2001). The spread of genes governing excitability, including ion-channels, neurotransmitters and G-linked proteins are universal to the eucaryote tree.

Pyramidal and other neurons are very complex dynamical systems, far from the trivial additive units which formal McCulloch-Pitts ‘neurons’ present in theoretical artificial networks. They engage up to 10^4 synaptic junctions, having a variety of excitatory and inhibitory synaptic inputs involving up to four or five different types of neurotransmitter, with differing effects depending on individual receptor types, and their location on dendrites, the cell body, or axon-axonal connections. Neuronal synaptic connections also involve many non-linearities, feedbacks and sigmoidal tipping points. Furthermore, as noted, many critical features we associate with neurons, and their associated neuroglia, in the conscious brain, including excitability and the use of neurotransmitter molecules, are not only shared by other cells in the human body, but extend down to the earliest single-celled eukaryotes (Mackie 1990).

Amoebae, although they lack specific sense organelles, are highly sensitive to chemical and electrical signals, as well as to bright light. Earlier work demonstrated membrane potentials in *Amoeba proteus* (Bingley 1966) associated with pseudopod formation, and action potentials have been found in the amoeba *Chaos chaos* (Marshall 1965, Tasaki and Kamiya), Ciliates and Diatoms (Taylor 2009). In ciliated protozoa, such as *Paramecium* (Kung and Eckert 1972, Hennessey 2005) and *Tetrahymena* (Onimaru 1980) action potentials are associated with the coordinated motile actions of cilia in cellular locomotion, avoidance and exploration (Ramoino et. al. 2006). Paramecium utilizes Ca^{++}-dependent Na^{+} ion channels, as well as K^{+} channels, enabling osmotically neutral action potentials, as in metazoan nervous systems (Saimi & Ling 1990). Paramecia possess GABA a and b receptors (Ramoino et. al. 2004, 2006), b-adrenergic (Wiejak et. al. 2002) and glutamate receptors (Bernal-Martínez and Ortega-Soto 2004) as well as those for a variety of other molecules (Ladenburger et. al. 2006) essential for sensing their chemical environment. Single celled organisms share a need for cellular memory to sample concentration gradients, since they are too small for differential sensing spatially.

The connection between bursting and beating in excitable cells was established by the Chay-Rinzel model and ensuing experiments (Chay and Rinzel 1985), which established chaotic dynamics in neurons, pancreatic b-cell exocytosis, and inter-nodal cells in the alga *Nitella* (Hayashi et. al. 1982). The association between excitability and exocytosis spanning the eukaryotes (Lledo 1997) is significant in that synaptic vesicles are produced by exocytosis.

The aggregation of slime moulds such as *Dictyostellium* is mediated by cyclic-AMP (Halloy et. al. 1998, Goldbeter 2006). The ciliated protozoan *Tetrahymena pyriformis* (Brizzi and Blum 1970, Essman 1987) and flagellated *Crithidia jasciculata* (Janakidevi et. al. 1966) utilize serotonin, and the former also metabolizes dopamine and epinephrine (Takeda and Sugiyama 1993, Nomura 1998).*Tetrahymena pyriformis* also has circadian light-related melatonin expression (Köhida et. al. 1993).

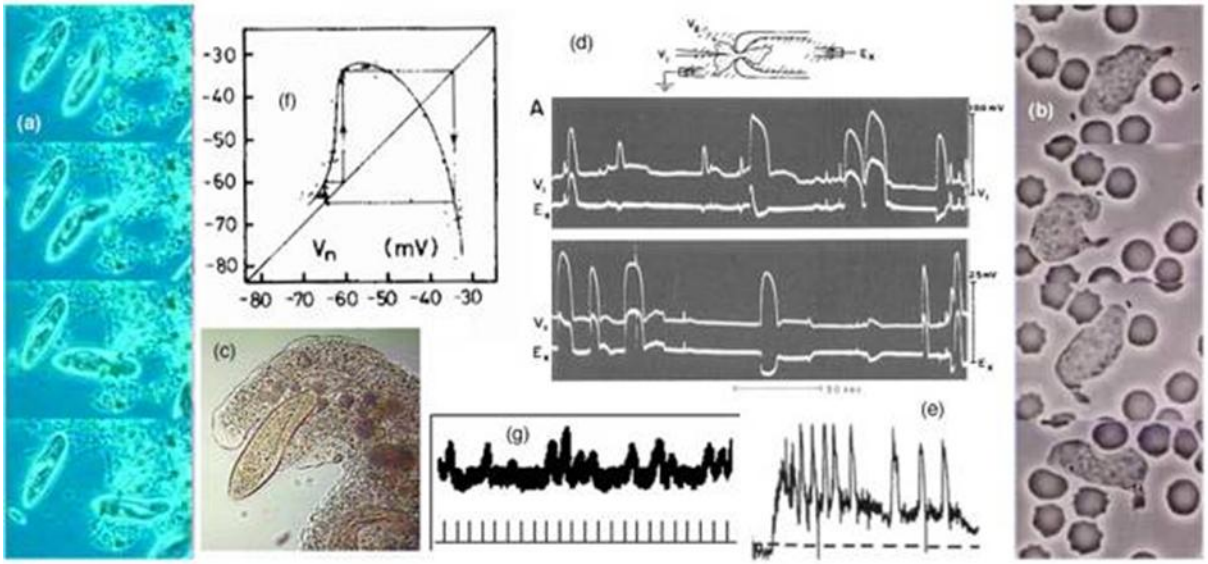

Fig 5: Real-time purposive behavior in single cells (a) *Paramecium* reverses, turns right and explores a cul-de-sac. (b) Human neutrophil chases an escaping bacterium (black), before engulfing it. (c) *Chaos chaos* engulfs a*paramecium*. Action potentials in *Chaos chaos* (d) and *paramecium* (e). Period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

Complex behavior is not confined to metazoans. Both amoebae and ciliates show purposive coordinated behaviour, as do individual human cells, such as macrophages. The multi-nucleate slime mould *Physarum polycephalum* can solve shortest path mazes and demonstrate a memory of a rhythmic series of stimuli, apparently using a biological clock to predict the next pulse (Nakagaki et. al. 2000, Ball 2008).

Chaotic excitation provides an excitable single cell with a generalized quantum sense organ. Sensitive dependence would enable such a cell to gain feedback about its external environment, perturbed by a variety of quantum modes - chemically through molecular orbital interaction, electromagnetically through photon absorption, electrochemically through the perturbations of the fluctuating fields generated by the excitations themselves, and through acoustic and mechanical/osmotic interaction.

Since such sensitivity predates the computational function of neural nets, dynamical chaos became fundamental to the evolution of neuronal computing. A single cell has no intercellular form of computation and has to rely on internal genetic regulation to provide memory and a strategy for survival, so the sensory sensitivity of the membrane in response to internal and external cues is its key function.

When we move to the earlier metazoa we find sponges, despite lacking a nervous system, sport acetylcholinesterase, catcholamines, and serotonin (Mackie 1990, Wayrer et. al. 1999). Likewise protein kinases C and in particular tyrosine kinases are universal to choanoflagellates (King N et. al. 2001, 2008) and metazoa from sponges to humans (Kruse et. al. 1997). Coelenterates represent the first group with genuine neurons. Serotonin neurons have been found in the coelenterate Renilla along with catacholamines and melatonin (Kaas 2009, Anctil et. al. 1982, 1984, 1991). GABA and glutamate receptors mediate pacemaker and feeding response in the coelenterate Hydra as well as diverse neuropeptides and putative Hox genes (Kaas 2009).

Hydra, which supports only a primitive diffuse neural net and whose tissues can dynamically reorganize themselves, and whose nervous system is in continuous transformation and dynamic reconstruction, involving inter-conversion of cell types (Koizumi and Bode 1991, Burnett and Diehl, Bode 1992), has a rich repertoire of up to 12 forms of ‘intuitive’ locomotion (King 2008), and is able to coordinate tentacle movements, tumbling, sliding and other forms of movement using similar global dynamics to those in amoebae and*Paramecium*, and much more advanced organisms.

Thus we already have the neurotransmitters, G-linked protein receptors, ion channels and essentially the entire complement of neuronal machinery we associate with vertebrate and human nervous systems. The basis of central nervous system function and dynamics is thus common to the entire animal kingdom.

This universality continues up the evolutionary tree so that chemicals psychoactive in humans, from LSD to caffeine, are also known to affect the web building of spiders (Noever et. al. 1995) implying that the very different nervous system designs of arthropods and vertebrates mask a deeper identity of dynamical basis shared by virtually all the metazoa. We can thus see that metazoan nervous systems have arisen from the adaptive dynamics of individual eucaryote cells, rather than being composed of unrelated logical networks.

As we move up the evolutionary tree to the complex nervous systems of vertebrates, we see the same dynamical features, now expressed in whole system excitations such as the EEG, in which 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, involving memories of past situations and adaptations to current ones. Nevertheless the immediate decision-making situations around which life or death results, in the theatre of conscious attention, are qualitatively similar in nature to those made by single celled organisms, such as *Paramecium*, based strongly on immediate sensory input and short term anticipation of immediate threats, in a context of remembered situations from the past that bear upon the current existential strategy.

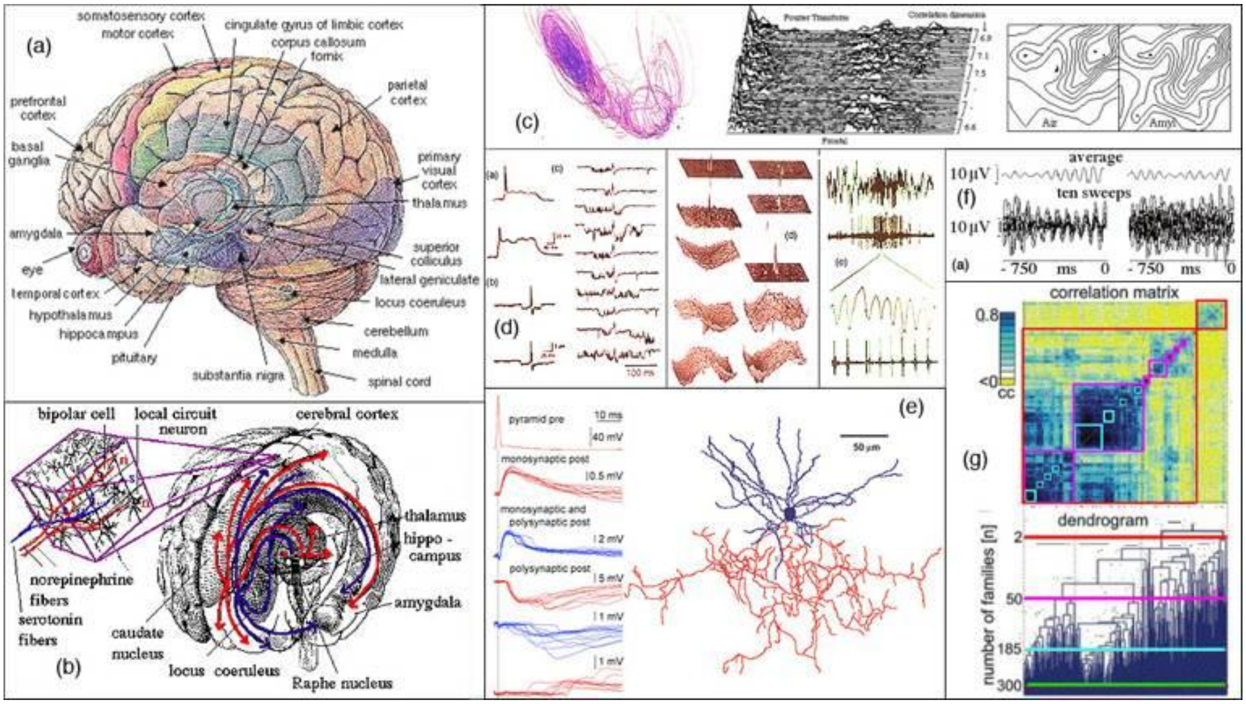

Fig 6: Structural overview of the brain as a dynamical organ. (a) Major anatomical features including the cerebral cortex, its underlying driving centres in the thalamus, and surrounding limbic regions involving emotion and memory, including the *cingulate* cortex, *hippocampus* and *amygdala*. (b) Conscious 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 2003, 2004).

4. A Dynamic View of the Conscious Brain

Here follows a brief overview of the essential features of dynamics in the conscious brain, in relation to our purpose of uncovering the cosmology of consciousness. Further details can be found in King (2008).

Structurally the mammalian brain consists of the 5 to 6 layer nerve sheet of the cerebral cortex, receiving and transmitting through the nuclei of the thalamus (with the exception of the direct sensory pathways of smell). Overall states of consciousness are modulated by ascending neural pathways from basal brain centers, sending dopamine, serotonin and nor-adrenaline pathways fanning out across the cortex, regulating conscious activity, from waking life, through sleep and dreaming, to psychedelic experience. A looping limbic system also runs around the edge of the cortex, providing emotional responsiveness, flight and fight sensitivity, and the consolidation of episodic memory.

Unlike the digital computer, which is a serial digital device based on a discrete logic of 0s and 1s, the brain is a massively parallel dynamic organ, with only some 10 or so synaptic junctions between sensory input and motor output. This is essential for the brain to be able to solve complex environmental problems and immediate threats to survival in seconds to milliseconds, which would be classically intractable problems in computational terms. Unlike a computational process, which may take days or years to complete, conscious processing has to be ready at all times for split-second reactions and the role of global consciousness is clearly to provide a dynamic conduit for integrating all the parallel attributes of the perceived context into a vital response which anticipates threats to survival and key opportunities, rather than to become stranded solving an unboundedly complex problem.

This explains why, despite some 10^{10} neurons and 10^{14} synaptic junctions, we have trouble handling mare than a simple 7 digit number in working memory, while potentially being able to recognize millions of visual images we have seen before and listen to one critical conversation over the babble of a crowded room.

Although the action potential of the long axons of pyramidal cells is a semi-discrete pulse-coded analog firing rate, many neurons and indeed those forming the organizing centre of many processes have continuously graded potentials. The electrical activity of the human brain, as expressed in the EEG consists of broad spectrum waves indicative of chaos (King 1991), rather than the discrete resonances of ordered dynamics. While some aspects of the EEG, such as the alpha rhythms of visual relaxation, may be housekeeping activities, oscillations in the gamma band have been associated with conscious thought processes (Crick and Koch 1992).

This is consistent with the brain using globally-coupled oscillations in its central conscious processing, which are chaotic in the time domain, but are ‘holographic’ transforms of the experiential envelope of senses and secondary areas spread across the regions of the cortex in functional columns spanning the cortical layers.

Chaotic dynamics both enable brain states to fully explore the phase space of possibilities without becoming stuck in an inappropriate dynamic and provide sensitive dependence on unstable inputs which provide arbitrary sensitivity to small instabilities in the event of an uncertain response. Walter Freeman (1991), based on his studies of rabbit olfaction, has given us a good model of perception, as a transition from high-energy chaos to a lower energy strange attractor which provides for learning new symbolic representations through changes in the potential energy landscape during learning, giving a clear basis for the ‘aha’ of “eureka!” in insight learning in terms of a bifurcation from the unstable chaos of the unresolved problem to the order of the clarity of the insight, explaining how a ‘brain-wave’ can come ‘out of the blue’.

The ‘holographic’ picture (Mishlove and Pribram 1998), which is consistent with the many-to-many nature of synaptic mappings results in a cortical structure in which different cortical regions represent varying aspects of conscious experience in much the same way a Fourier transform represents all the frequencies in a waveform. Sensory areas for vision, hearing, smell touch and other emotional and bodily sensations are complemented by secondary processing areas e.g. of spatial relations in the parietal cortex and time-related and semantic categories in the temporal cortex. So-called ‘Oprah Winfrey’ cells specific for a certain person or face in the temporal cortex (Reddy et. al. 2009, Callaway 2009), represent landmarks on a fractal transform space of subjective experience over time. The ongoing process is driven and organized by centres in the frontal prefrontal cortex forming our model of intentional action and future strategies of life.

This means that each experience is globally represented across the cortex in terms of the diverse characteristics, which together make up the full context of the so-called ‘Cartesian theatre’ of subjective experience, (Baars 1997, Dennett 1991), centered on our sensory views of the world around us conditioned by our past experiences and their semantic contexts - a term derived from the dualistic cosmology of Rene Descartes (1644) - *cogito ergo sum* - who closely identified ‘thought’ with subjective consciousness: "what happens in me such that I am immediately conscious of it, insofar as I am conscious of it". Thinking is thus every activity of a person of which he is immediately conscious.

Charles Darwin (1871) argued that a continuity of mind exists between humans and other animals. It is the innate capacity to have subjective experiences, and what influence these have on organismic survival, that we need to examine in the long-term evolutionary context, because these may arise from adaptive advantages running back to single celled eukaryotes. This is a completely different question from the unique properties of the human mind, in terms of language and creative intellect, that separate humanity from most, or all, other animals (Hauser 2009).

Barrs (2001) describes the theatre of the conscious in terms of global workspace - working memory and its associated backdrops. Baars' approach suggests that consciousness is associated with the whole brain in integrated correlated activity and is thus a property of the brain as a whole functioning entity rather than a product of some specific area, or system, such as the supplementary motor cortex (Eccles 1982, Fried et. al. 1992, Haggard et. al. 2005). Furthermore, the approach rather neatly identifies the distinction between unconscious processing and conscious experience in terms of whether the dynamic is confined to local or regional activity or is part of an integrated coherent global response. It is also consistent with there being broadly only one dominant stream of conscious thought and experience at a given time, as diverse forms of local processing give way to an integrated global response. A series of experiments, many by teams working with Stanislas Dehaene, involving perceptual masking of brief stimuli to inhibit their entry into conscious perception (Sergent et. al. 2005, Sigman and Dehaene 2005, 2006, Dehaene and Changeux 2005, De. Cul et. al. 2006, 2009, Gaillard et. al. 2009) studies of pathological conditions such as multiple sclerosis (Reuter et. al. 2009, Schnakers 2009) and brief episodes in which direct cortical electrodes are being used during operations for intractable epilepsy (Quiroga et. al. 2008) have recently tended to confirm the overall features of Baars' model of consciousness founded on the global work space (Ananthaswamy 2009 a,b, 2010).

This couples with a recently 'discovered' system called the 'default network' (Fox 2008), which was unearthed when background readings discarded from many brain scan studies were found to have common dynamical features. It has been proposed that the default network is an active brain process we drift into when not preoccupied in more essential tasks dominating our attention, and that it may have adaptive value in rehearsing strategic situations important for our survival. One can loosely identify the default network with the process of daydreaming, reminiscence, worrying and idle thought, but in these terms it looks clearly like a manifestation of global work space in action and hence provides another view on the global mechanisms being brought into play in conscious experience (Vanhaudenhuyse 2010).

Since Libet's original experiments (1983, 1989) in which he detected a 'readiness potential' in the supplementary motor cortex before the free decision to press a button was consciously registered by the subject, there has been debate about whether conscious free will, or subconscious brain processes, are the source of our decision-making. Recently experiments testing this question more closely have only added to the debate. Trevena & Miller (2010) allowed subjects to decide whether or not to press the button and found the same readiness potential regardless of the decision to act. They also found no correlation with the side of the brain activated when either left or right hands were used to press the button. Their results, which have been widely discussed (Ananthaswamy 2009, Geert et. al. 2010, Gomes 2010, suggest that Libet's brain states simply indicate non-specific readiness, although other studies by Brass's group (Soon et. al. 2008) do appear to show activity in the frontopolar cortex, which was statistically predictive of the decision, up to 10 s in advance of conscious decision-making, and then in the parietal cortex stretching from the precuneus into posterior cingulate cortex, relating to timing and handedness. The difficulty here is that the brain may need to anticipate rapid actions by indeed building frontal cortex models which are statistically predictive of lokely outcomes which are then called on by conscious decision-making to minimize latent response times.

We can sense the many cortical areas that come into play in the Cartesian theatre and the balance between conscious and subconscious processes from mental activities, such as recalling that it was raining when watching Oprah Winfrey start up her new TV channel, while at the same time anxiously rehearsing a talk we have to give, trying to visualize the easiest route to drive to get there, and desperately trying to remember a the name of a colleague we will meet there, which later pops into our awareness out of the blue.

The brain may distinguish attended conscious experience from fragmented sub-conscious processing and the ground-swell of competing neurological excitatory ‘noise’ by the wave-front coherence of coupled neurons oscillating together in phase, while the other unrelated out-of-phase signals do not achieve a global resonance and tend to cancel. This phase front processing is mathematically homologous to quantum measurement (Pribram 1993), where quantum uncertainty dictates that we can measure the energy of a wave-particle only by counting the number of coherent wave fronts passing over a time interval.

There are a number of processes, from the amplifying dynamics of certain dedicated cell types such as chandelier cells (Molnar et. al. 2008, Woodruff and Yuste 2008), through states of stochastic resonance (Liljenström and Uno 2005), to self-organized criticality (Beggs and Plenz 2003, 2004) and chaotic sensitivity itself, which provide a neurophysiological basis to support arbitrary sensitivity of the global dynamic, when in unstable equilibrium at a tipping point, enabling a single neuron or even a single ion channel or receptor complex to tip the global balance when the global conditions warrant it, making it potentially sensitive to quantum perturbations.

This type of wave-based dynamic processing gives the brain unique capacity to combine the sensitivity of chaos and the intrinsic uncertainty and entanglement of quantum excitations in a way that is impossible for current digital computers, and which may provide a means for direct conscious experience in real time to complement the processing power of our brains to ensure our survival, explaining how consciousness emerged in evolution.

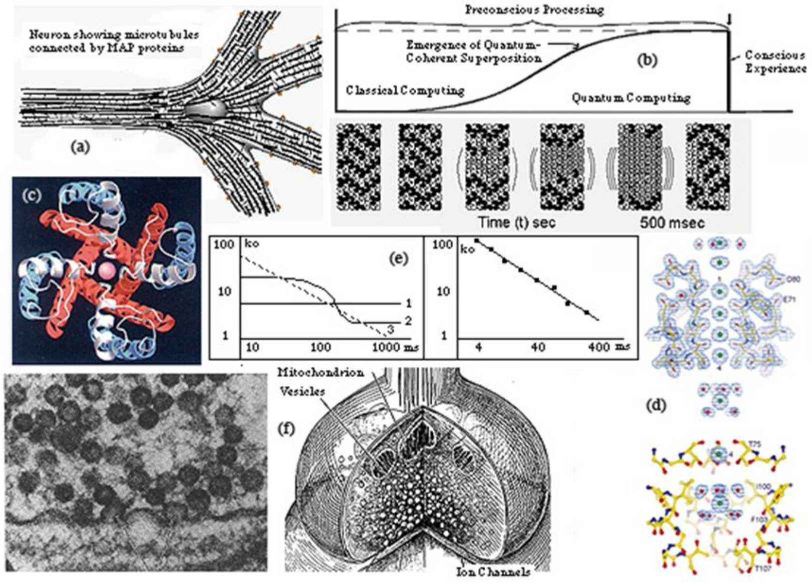

Fig 8: Features of quantum processing in proposed models. (a) Microtubule MAP proteins as envisaged in the OOR model. (b) The ensuing relationship between classical and quantum computing and consciousness. (c, d) gated K^+ ion channels from MacKinnon's group (Zhou et. al. 2001). (e) Fractal kinetics in the channels (Liebovitch et. al.) (f) Synaptic junction as in Eddington's (1935) suggestion of quantum uncertainty of the vesicle.

5. Chaos, Quantum Dynamics and Conscious Anticipation

The two most profound questions confounding science about the brain are (1) how and why brain function generates subjective experience, which would seem extraneous to computational efficiency and (2) whether there is any basis for our continuing impression that our subjective conscious intentions can actually be transformed into physical consequences in acts of 'free-will', when the physical determinacy of ongoing brain states would appear to be necessary and sufficient to determine all outcomes for the organism, leaving our subjectively conscious impressions of personal autonomy and intentionality a mere delusion.

Here we want to explore as simply and directly as possible how known functions, central to neurodynamics might be able to exploit quantum uncertainty, or quantum entanglement, to enhance survival prospects of the organism. If the brain uses transitions out of chaos in its processing, it makes it possible for an unstable brain state, poised at a tipping point, to become arbitrarily sensitive to neurons, or ion channels, in the circuits ultimately sensitive the change and hence manifest quantum indeterminacy.

The immediate question that arises is, how could quantum uncertainty or entanglement at this point aid the process and hence the survival of the organism? Is this just precipitating a random process or is there a way in which quantum sensitivity might be able to aid the survival of the organism? Physicists have struggled with this question and have come up with a variety of answers, from the 'pilot wave' theory of David Bohm et. al. (1981, 1985), to Roger Penrose's (1989, 1994) objective reduction, based on graviton interactions.

Since the birth of quantum mechanics, both physicists and prominent brain scientists have drawn attention to the fact that the quantum universe is not deterministic and that quantum uncertainty could provide a loophole through which conscious free will might not be in conflict with biology. A number of proposals have been made. Eddington (1935, 1939) and Eccles (1966, 1970) discussed the possibility of quantum-mechanical action of the vesicle and pointed out that the uncertainty of position of a vesicle of 400 ^{o}A diameter and mass 3 x 10^{-17}g is about 30^{o}A, comparable with the thickness of the membrane. Concluding that intentional volition might then be inconsistent with the chance probability-based calculations of particle statistic, Eddington then effectively suggested a form of hidden correlation in sub-quantum dynamics: a correlated behaviour of the individual particles of matter, which he assumed to occur for matter in liaison with mind. Walker (1977) noted quantum tunneling in synaptic transmission and Eccles (1986) noted the relation between mental events, neural events and quantum probability fields. David Bohm (1980) introduced the notion of 'implicate order' generating both consciousness and the physical universe. Henry Stapp (2007) described the interaction of consciousness with the physical universe in terms of mental collapse of the wave function influencing the physical brain state in a manner that involves choice. Eccles (1969) took a more direct position of emergent mentalism, resulting in an ongoing debate about how the conscious mind might interact with neurodynamics (Sperry 1987, 1989, 1992, Vandervert 1991a,b).

Central to many ideas of quantum brain dynamics is the notion of coherent excitation (Frolich 1968, Umezawa 1993) possibly through a quantum field associated with the brain. Several theories of quantum consciousness introduce additional constructs, for which there is little experimental evidence or demonstrated relevance to actual neurodynamics. Frolich's theory later elaborated by others (Jibu & Yasue 1995, Vitiello 2002) proposes that the electric dipoles of the water molecules constitute a quantum field, with 'corticons' as the quanta, in addition to coherent neuronal excitations. This cortical field is postulated to interact with quantum coherent waves generated by the biomolecules in neurons in the neuronal network as a means, for order to be maintained through long-range dipole interactions, which not only interact with the neuronal network, but can also function to control it. An even more controversial proposal involving replicatable DNA water structures has been reported (Coghlan 2011).

A pivotally influential theory developed by Roger Penrose and Stuart Hameroff makes one of the most detailed attempts to sketch out a plausible theory of quantum consciousness. Penrose (1989, 1994) first developed ideas of how 'objective' reduction might occur outside quantum measurement, through gravitational interaction, through a non-computable influence embedded in the fundamental level of space-time geometry, from which mathematical understanding and consciousness derived. This attempts to avoid the double bind of physical causality and quantum randomness of collapse, which appears to have no utility for consciousness or free will. He was then joined by Stuart Hameroff (Hameroff and Watt 1982, Haglan et. al. 2002, Hameroff 2006) who suggested that microtubules might be able to function as quantum computers at the molecular level, which might be linked to Penrose's reduction process. This led to the orchestrated objective reduction of OOR view of consciousness.

Hameroff and Penrose (2003) note that tubulin exists in two forms and could thus enter a quantum superposition of states. They thus envisage tubulin acting as a quantum cellular automation, interleaving between classical and quantum computational states. However microtubules are extensively involved in transport of essential molecules and whole organelles, as well as cytoskeletal architecture and synaptic growth, and it is unclear they have a direct role in the fast forms of excitation of the electrochemical states we associate with conscious awareness.

In the OOR model, consciousness is a passive result of a quantum computation, which occurs in the pre-conscious state and is resolved objectively by a self-energy splitting of the gravitational centres of mass of the superimposed states in objective reduction and conscious awareness emerges only subsequently, based on the outcome. The model proposes the neuron can very rapidly alternate quantum computing with normal function by temporarily isolating the microtubules from the membrane through disassociating the linking MAP proteins (to avoid quantum decoherence effects). This would mean the quantum computation is isolated from the global brain state during the quantum computation cycle.

This theory has led to more discussion and debate than any other. Tegmark (2000) made a prominent critique of the model, claiming quantum decoherence would destroy the proposed mechanisms over much too shorter time scales. Hagan, Hameroff and Tuszyński (2002), and Hameroff et. al. (2002) responded with further versions of the theory. Hameroff (2006, 2009) has further proposed that condensates in microtubules in one neuron can link with microtubule condensates in other neurons and glial cells via gap junctions and thus generate an extensive quantum state suggested to be a Bose-Einstein condensate. However these ideas have also been subject to criticisms of their viability (Georgiev 2007, 2009a,b, McKemmish et. al. 2009). As well as critiquing the OOR model, Georgiev (2003, Georgiev et al. 2007) has also investigated the role solitons could play in microtubule-based processing, and supports some of OR's conclusions.

Part of the difficulty of the overall theory is that, although it proposes very specific processes, both the unusual interpretation of quantum physics and central emphasis on microtubules in brain function, are not generally accepted ideas in their fields although an experimental test of OR has been proposed (Marshall et. al. 2003). A Bose-Einstein condensate would provide an extreme form of quantum coherence, which would present the same problems for brain state differentiation that EM field theories have. OOR itself invites an epiphenomenalistic interpretation of consciousness in which the notions of personal autonomy and free will take a passive role to objective reduction. Quantum 'cell-automaton' microtubule computing stands as an extraneous addition to existing essential biological functions. It is hard to see how microtubules can carry out these functions efficiently if they are also harnessed to arcane forms of non-algorithmic quantum 'computing' on a switch-on switch-off basis.

The evolutionary principle is an important test here. What role could such quantum computing conceivably have in Paramecium, or Hydra, which do possess fully developed microtubules? This problem does not apply to membrane excitation, where any quantum properties are integral to, and consistent with, known cellular function central to how neurodynamics operates.

Bernroider (2003, 2005) has a different model for quantum interaction closer to the prominent features of neuronal excitation - that quantum coherence may be sustained in ion channels for long enough to be relevant for neural processes. He proposes that the channels could be entangled with surrounding lipids and proteins and with other channels in the same membrane. Bernroider bases his work on recent studies of the potassium (K^+) ion channel by MacKinnon and co-workers (Jiang et. al. 2003, Zhou et. al. 2001, Morais-Cabral et. al. 2001, Doyle et. a. 1998) who have shown that the K^+-specific ion filter works by holding two K^+ ions bound to water structures induced by protein side chains that have a structure consistent with models of quantum computing using ion traps and that the correct interpretation of the action of the ion channel is through quantum coherence, possibly extending to entangled states between ion channels as well.

David Chalmers (2003) notes "collapse dynamics leaves a door wide open for an interactionist interpretation" with mind and body mutually interacting as separate entities. He suggests " the most promising version of such an interpretation allows conscious states to be correlated with the total quantum state of a system, with the extra constraint that conscious states (unlike physical states) can never be superposed."

This is where we now take the discussion. The natural complement to conscious experience and willful decision-making is not just the ion channel or microtubule, but the whole brain dynamic. To develop a realistic theory of consciousness, we thus have to consider how whole brain states might be capable of forms of quantum interaction and we need to understand how this might take place in terms of the really central neurophysiological processes common to all excitable cells. In terms of the global brain processes believed to be the signature of conscious experience, rather than subconscious processing, chaotic and unstable fractal dynamics based on self-organized criticality become key to providing a link between the global states of consciousness and the molecular and quantum level.

Non-linear chaotic dynamics provides several attributes pertinent to this process. Non-linear oscillatory couplings have a natural propensity for coherent excitation through mode-locking, providing a natural mechanism for wave-front coherence and for solving the ‘binding problem’ – how diverse cerebral processing comes together. Freeman (1991) has drawn attention to the idea that the oscillations of the EEG are driven through cyclic excitation of cortical excitatory and inhibitory neurons. Modulating the lateral connections between inhibitory neurons to enhance the non–linear feedback would provide a direct means of drawing closely related frequencies into phase synchrony on a common step of the fractal ‘devil’s staircase’ of mutually locked states. Chaotic dynamics is, by definition, arbitrarily sensitive to small perturbations, and we have seen, several neurophysiological processes, from chaos, through stochastic resonance, to self-organized criticality, which could make it possible for a critically poised global dynamic to become sensitive to local influences, down to the level of the ion channel.

Many aspects of synaptic release are highly non-linear, with many feedback loops involved in the biochemical pathways. A single vesicle excites up to 2000 ion channels, so a smaller fluctuation could set off a critically-poised ion channel and trigger a chain reaction of excitation. In addition to being candidates for quantum coherence, as noted above, voltage gated ion channels display fractal kinetics consistent with a quantum fractal model of protein conformational dynamics (Liebovitch 1987a, b, 1992). Ion channels, such as that for acetyl-choline display non-linear (quadratic) concentration dynamics, being excited by two molecules, consistent with chaotic dynamics at level of the ion channel.

The belief that quantum non-locality suppresses classical chaos, at least in closed systems, in processes such as scarring of the wave function (Gutzwiller 1992) received a timely clarification when it was discovered that systems with more than one quantum mode are liable to enter a state of quantum entanglement when one mode is in a quantum state corresponding to chaos (Chaudhury et. al. 2009, Steck 2009). The experimental system uses a suspended Cs atom, which is both in a magnetic field and hit by a laser to give a double twist to the orbits. When the atom is stimulated in a manner corresponding to the chaotic regime, the electronic and nuclear spin states become entangled. This shows that, in addition to the wave function 'scarring' the repelling unstable orbits with ‘attractive’ probabilities, suppressing chaos, the quantum system preferentially becomes entangled with a coupled system. Hence molecular kinetics, which are chaotic billiards are likely to lead to entangled quanta throughout the tissue. Chaotic brain dynamics may thus lead to a complex quantum entangled state if there is a chaotic link between the global and quantum levels. 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.

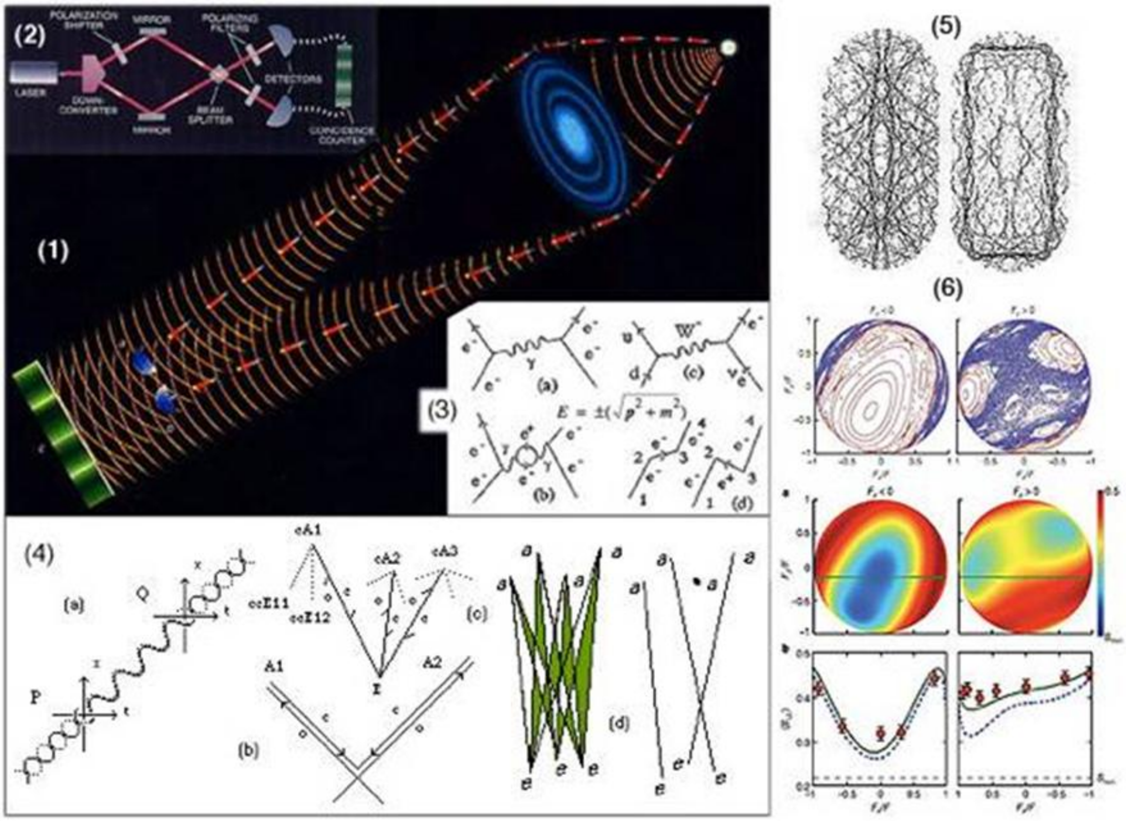

Fig 9: Wheeler delayed choice experiment (1) shows that a decision can be made after a photon from a distant quasar has traversed a gravitationally lensing galaxy by deciding whether to detect which way the photon traveled or to demonstrate it went both ways by sampling interference. The final state 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) EPR 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).

The evolutionary argument is a potent discriminator of models of consciousness. We need to think of forms of generation of consciousness, which fit naturally into the emergence of most, if not all, key genetic pathways long before the emergence of metazoa. This means the essential biophysical or quantum attributes making consciousness possible should be shared, not just by humans or higher levels of computation we associate only with human cognition, but common at least to all mammals, probably all metazoa and plausibly all eukaryotes. If we have theories of consciousness, which can have a basis only in forms of quantum computing which would only be meaningful in a human cognitive context, and require radical redirections of essential cellular structures to achieve this, but have no basis in the survival of simple animals or single cells, the theory doesn't fulfill the evolutionary test.

Hence the point of view in this report is based on central neurodynamic processes emerging from the excitability of single celled eukaryotes and fundamental properties of quantum theory. The explanation uses a version of quantum theory called the 'transactional interpretation'. However this is not essential to the argument, since its predictions coincide largely or exclusively with those of conventional quantum mechanics (Afshar 2005, 2206, Afshar et. al. 2007, Unruh 2007, Georgiev 2007, 2008), but it does emphasize future boundary conditions, which could play a part in conscious anticipation. It also has an attribute in common with Penrose's idea of non-algorithmic computing, shared with pair-splitting EPR quantum entanglement experiments (Aspect 1981, 1982a,b), in that the boundary conditions do not permit a classically-causal exploitation, but this would not result in a contradiction, because the brain state will be uncertain, and the mind's anticipatory insight comes 'out of the blue' as a coincidental 'hunch'. However, if subjective consciousness has a complementary role to brain function, correlated with coherent, or entangled, quanta emitted and absorbed by the biological brain, it is then correlated with events in the brain's future states, as well as having access to memories of the past.

The Feynman diagrams of quantum interactions point out a fundamental issue of quantum field theory, in that it is temporally reversible. We have a space-time diagram and interconnections by real or virtual particles across space-time, but in principle the process is micro-reversible and indeed the Feynman diagram for electron scattering, when the electron path is time reversed, becomes precisely that for 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'. Indeed all forms of quantum entanglement also possess this time-symmetric property.

Feynman's absorber theory (Davies 1974), which noted that the predictions of quantum mechanics were preserved if we instead considered the time-reversed interactions of the absorbers, was subsequently extended by John Cramer (1983,1986) 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.

Here the emitter of a particle sends out an offer wave forwards and backwards in time, whose energies cancel. The potential absorbers respond with a 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 determining 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.

Regardless of the particular interpretation of quantum mechanics, 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 consisting of potential absorbers extending in principle throughout space-time involving future boundary conditions. The subtle involvement of advanced interactions in entanglement becomes abundantly clear in pair-splitting experiments involving two entangled particles where measurement e.g. of the polariztion of one particle immediately results in the other having complementary polarization although neither had a defined polarization beforehand. The only way this correlation can be maintained within the sub-quantum realm is through the wave function extending back to the creation event of the pair and forward again in time to the other particle. To the extent that consciousness might be involved in the collapse of wave functions of emitted and absorbed excitons, it is sampling a nascent 'history' extending into the futures of the emission events.

This could be a universal quantum phenomenon, which is not understood, because quantum measurement generally depends on detecting absorbed particles, either individually in counters, or statistically in spectra. Emission events are generally detected by sampling the emitted quantum, effectively an absorption, resulting in decoherence. However, if subjective consciousness has a complementary role to brain function, correlated with coherent, or entangled, quanta emitted and absorbed by the biological brain, it is then correlated with events in the brain's future states, as well as having access to memories of the past.

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 excitable cell becomes both an emitter and absorber of its own excitations, modulated by the global constraints of the process into distinct quantum modes.

Unlike quantum computing, which depends on not being disturbed by decoherence caused by interaction with other quanta, the transactional principle applies to all real particle exchanges, and the boundary conditions remain, even if a more elaborate interaction, involving particle scattering, takes place, so stringent arguments in terms of decoherence may not apply. This may be a fundamental quantum property shared by all physical systems, including macroscopic systems with coherent resonance. The coherent global excitations in the gamma range researchers associate with ongoing conscious states, may thus be precisely the anticipatory 'excitons' in the quantum model.

Such excitation sensitivity could nevertheless also prime the organism for related processes, including quantum entanglement and quantum computing. Quantum entanglement has been observed in healthy tissues, in quantum coherence imaging (Warren 1998, Samuel 2001) and has been proposed to play a possible role in bird navigation (Buchanan 2008), with entangled electrons lasting up to 100 microseconds (Courtland 2011). Excitations in photosynthetic antennae have also been shown to perform spatial quantum computing (Engel et. al. 2007, McAlpine 2010), and finally quantum vibration. and not merely molecular shape fitting to receptors, has been shown to mediate olfactory preferences in fruit flies (Courtland, Rachel 2011 *Fly sniffs molecule's quantum vibrations* New Scientist 14 Feb) opening the field to similar effects in nervous systems, bringing enzyme activation energy transition states and synaptic transmission using quantum tunneling (Walker 1977) and Bernroider,Äôs (2003, 2005) ion-channel channel proposals into natural context. The solotonic nature of the action potential and potentially coherent EEG excitations could lead to entangled dynamics of individual ion channels giving the cell and coupled neurosystems a basis for global entanglement.

By making the organism sensitive to a short envelope of time extending from the present into the immediate future, as well as the past, the subjective consciousness of complex animals could thus gain an evolutionary advantage making the organism acutely 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 complex formal calculations, that the highly complex central nervous systems of vertebrates have evolved to successfully handle – catching prey and being sensitively wary of the shadows on the forking paths down to the water hole. Such temporal anticipation (Dunne 1962) need not be of causal efficacy but just provide a small statistical advantage, as noted in Darryl Bem’s recent experiments on anticipation (Aldhous 2010), particularly if complemented by computational brain processes providing the context for such ‘intuition’.

These objectives are shared in precisely the same way by single-celled organisms and single cells in our own bodies. 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, the logical conclusion is that quantum anticipation was an evolutionary feature of single celled eukaryotes, long before the metazoa evolved.

It may be hard to comprehend the notion of ‘cellular consciousness’, but it is equally difficult to directly envisage the consciousness of another human or animal, and we do so, only through common insights about our reported mental states and the enhancements to our own consciousness that come from the rich presence of mirror neurons in our own brains (Rizzolatti & Craighero 2004) giving our subjective model of reality a sense of attunement with others, particularly mammals with whom we share an emotional resonance. This view of consciousness could be associated with other quantum sensitive phenomena whose outcomes are unpredictable, including the uncertainty of fundamental particles. If the ‘free-will’ theorem (Conway & Kochen 2006, Goldstein et. al. 2010) has any validity, will would also extend to quanta.

6. Quantum Sensitivity, Sensory Transduction and Subjective Experience

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?

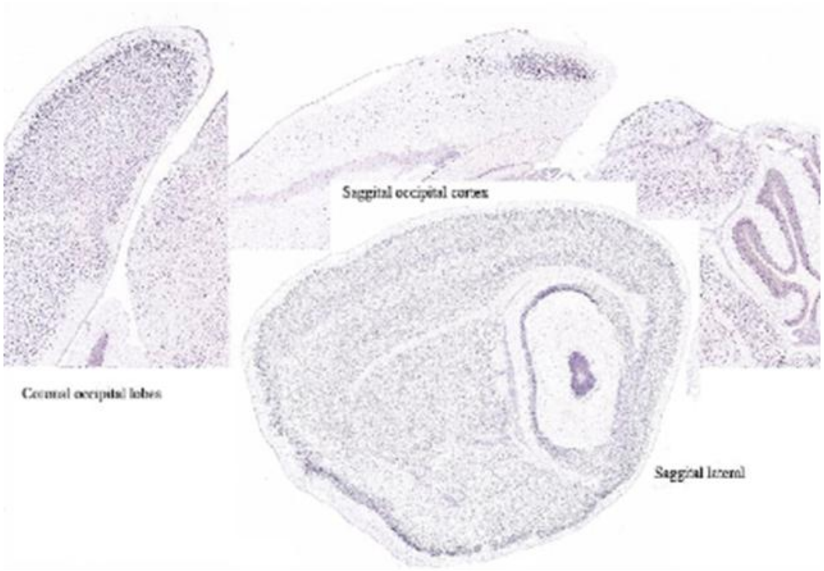

Fig 7**:** Expression of rhodopsin in the CNS shows both strong selective neuronal expression and a focal expression in the occipital cortex consistent with expression in the primary visual areas.

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.

Similar modes of quantum interaction may occur in the central nervous system. At a basic level, 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 can be also activated directly and reversibly by photoreception in certain species. At a ground level, all 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 very plausible that some of the ‘dissipated’ energy could be involved in generating novel forms of interaction.

Research on gap junctions (Dermietzel 1998, LeBeau et. al. 2003, Hormuzdi et. al. 2004) has also shown that these direct electro-conductive junctions may play a part in maintaining excitations in the gamma range thought to be coupled to active thought processes and even higher frequencies up to 100 kHz, detected in the hippocampus (Draghun et. al. 1998, Buhl et. al. 2003). Electrical junctions do not occur among pyramidal cells but have been found to occur in fast-spiking and low threshold spiking populations of inhibitory neurons in the cortex (Galaretta et. al. 1999, Gibson et. al. 1999, Fries et. al. 2002).

Recent research in whole genome mapping of the mouse brain (Lein et. al. 2007, Allen Brain Atlas) has made it possible to investigate the potential central nervous function of genes that might otherwise be associated primarily with peripheral sensory transduction. All of the following molecules are expressed in the mouse brain (King 2007) at least in the form of RNA transcripts, as well in their role in sensory organs. The first putative transduction molecule for mammalian touch, stomatin-like protein 3 (SLP3, or Stoml3) has been reported (Wetzel et. al. 2007), and putative molecules in the auditory transduction pathway, epsin, and cadherin 23 or otocadherin (Parkinson & Brown 2002, Di Palma et. al. 2001) have only been reported in the last five years and otoferlin in 2006 (Parsons 2006, Roux et. al. 2006). In parallel with the usual cilia-based photo-transducer molecule c-opsin are retinal ganglion cells, which use melanopsin, or r-opsin related to insect opsins, which depolarize rather than hyperpolarize (Fernald 2006, Su et. al. 2006). Both types of opsin also work in opposition in the reptile parietal (pineal) eye. Encephalopsin has also been found in the brain and other tissues (Blackshaw & Snyder 1999).

The occurrence of putative sensory transduction genes in the central nervous system is consistent with a novel biophysical model (King 2007) - that the distributed functioning of the central nervous system provides an 'internal sensory system' which can generate abstracted experiences forming an 'internal model of reality' using the same physical principles as are involved in sensory transduction in a bi-directional manner, enabling coherent generation and reception of biophysical excitations. There are however problems with this picture. While vision and olfaction mediate excitation indirectly through G-protein linked receptors, hearing occurs directly through the stereocilia of the inner ear deforming mechanically sensitive ion channels. It is far from obvious how these processes could be activated reversibly in the CNS.

Nevertheless the idea that additional modes of quantum communication may occur in the brain receives continuing interest. Several consciousness researchers have proposed that neural excitation is associated with electromagnetic fields, which might play a formative role in brain dynamics (Pocket 2000, McFadden 2002). McFadden proposes that the digital information from neurons is integrated to form a conscious electromagnetic information (cemi) field in the brain. Such a field could help explain how consciousness is bound together into one coherent state, however it remains unclear whether a coherent electromagnetic field would retain the complexity required for brain function and why coherent synaptic activation of coupled neurosystems wouldn't achieve the same result. Nevertheless Gray (2004) claims there is little or no real evidence for such effects.

Attention has recently been focused again on biophotons (Popp et. al. 1988, 1992, 2002) 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).

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

This leads us to the ultimate questions and paradoxes of what is the deepest and most perplexing chasm facing the scientific model of reality in the third millennium. What is the existential nature of subjective consciousness, including its many manifestations, from waking life, through dreaming to psychedelic and meditative experience, and does it have a cosmological status in relation to the physical universe?

The key entities forming the existential cosmos all appear to be symmetry-broken complementarities. Quanta manifest as wave-particles with complementary discrete particle and continuous wave aspects, which cannot both be sampled simultaneously. 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 strongly symmetry broken properties, with completely differing collections of particles. Supersymmetry attempts to assert a deeper symmetry between bosons and fermions in which each boson has a fermion partner to balance their positive and negative energy contributions, broken by fundamental force diversification, but other theories, capitalizing on E8's 112 'bosonic' and 128 'fermionic' root vectors completing E8's 240 dimensions, suggest this symmetry-breaking could be fundamental (Fielder and King 2010). In a real sense the conscious brain forms the culminating interaction in complexity of cosmic symmetry breaking so could require a theory as complicated to solve the dimensions of consciousness.

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 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 continuity of the Cartesian theatre on the one hand, and the objective, analyzable properties of the physical world around us. This leads Chalmers to discount both conventional theories and quantum theories of consciousness as adequate as they stand to give rise to consciousness, although this position would not appear to discount conscious free-will being complementary to a quantum process whose outcome was unpredictable.

The existential status of subjective consciousness also displays properties that have the potential to put it on a cosmological footing. Although we depend on a pragmatic view of the real world, knowing we will pass out if concussed and 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 and accept the real world and discover its natural and scientific secrets. As pointed out by Indian philosophy, this suggests that, in some sense, mind is 'finer' or more fundamental than matter, despite the appearance of annihilating forces in the universe at large.

Some interpretations of quantum theory (Wigner 1970) suggest that the consciousness of the observer may be necessary for reduction of the wave packet, from a quantum superposition of states, to one outcome or another e.g. in Schrödinger's 'cat paradox'. Certainly, although quantum predictions give only superimposed probabilities, we always witness real outcomes – the cat is alive or dead – not hovering uncertainly between. One cosmological interpretation of consciousness is that it functions to solve this problem of super-abundance, by reducing the probability multiverses to the unique course of history we know and witness. This view of the consciousness supports many of the conclusions of biocentrism (Lanza 2009).

Similar 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 complementary discreteness and continuity even more obviously expressed at the level of sperm and ovum than in our nevertheless highly symmetry broken human organismic sexual forms.

We also have other manifestations, dynamical in the complementarity of chaos and order in generating complexity, and strategically in the complementarity of cooperation and defection in the Prisoners' Dilemma of game theory, which leads to logical paradox, in which neither can be fully eliminated and successful strategies, such as tit-for-tat, involve a mix. For this reason we give the name Sexual Paradox (Fielder and King 2004, 2010) to these forms of symmetry-broken complementarity.

Introducing a further assumption, such as Bohm's implicate order, or Penrose's platonic realm, is not without its rationale, as the current description of the quantum-relativistic universe is incomplete, and a variety of pre-theories have been proposed such as the preons, or rishon triplets, which could make up both quarks and leptons, but as things stand the principle of symmetry-broken complementarity appears to lie at the very source of our cosmology.

The mental viewpoint leads to a perspective on consciousness as cosmological complement to the physical universe, however, taking either side of this complementarity as paramount appears to lead to paradox. The lessons of quantum and fundamental particle complementarity and symmetry-breaking, sexuality and with it the Yin-Yang complementarity of the Tao and of Shakti-Shiva in Tantric mind-world cosmologies, let alone the essential respect for the physical universe for our own survival, places the source of the cosmological mystery in the symmetry-broken complementarity of objective universe and subjective consciousness.

8. Conclusion

This leads to a view of the cosmology of consciousness as a chain of events in which (1) the symmetry-breaking of the forces of nature in our 'inflationary' origin, leads interactively (2) to biogenesis on planets in the goldilocks zone of sun-like stars, and (3) over evolutionary time to a genetic solution to the excitable cell, which then (4) through fractal elaboration becomes tissues and ultimately the integrated excitations of brain tissue manifesting (5) the ultimate expression of cosmology in mind-world complementarity, thus enabling the universe itself over its own evolutionary process (6) to come to terms of accommodation with its own relativities of space, time and existence during the brief periods that each of the sexual individuals in this chain of events have an opportunity to manifest this cosmic paradox within their own subjective experience, discovering that, in a fundamental sense, subjective consciousness is a cosmological complement to the objective physical universe.

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