BIOCOSMOLOGY 3
Quantum Cosmology and the Hard Problem of the Conscious Brain

Chris King
Mathematics Department
University of Auckland

Abstract:

The conscious brain poses the most serious unsolved problem for science at the beginning of the third millennium. Not only is the whole basis of subjective conscious experience lacking adequate physical explanation, but the relationship between causality and intentionally willed action remains equally obscure. We explore a model resolving major features of the so-called ‘hard problem in consciousness research’ through cosmic subject-object complementarity. The model combines transactional quantum theory, with chaotic and fractal dynamics as a basis for a direct relationship between phase coherence in global brain states and anticipatory boundary conditions in quantum systems, complementing these with key features of conscious perception, and intentional will. The aim is to discover unusual physical properties of excitable cells which may form a basis for the evolutionary selection of subjective consciousness, because the physics involved in its emergence permits anticipatory choices which strongly favour survival.

1: Subject-Object Complementarity and the Hard Problem

In “The Puzzle of Conscious Experience” David Chalmers (1995) summarizes some of the main points of his definition of the now renowned ‘hard problem in consciousness research’. He contrasts with the hard problem what he calls the ‘easy’ problems such as: ‘How can a human subject discriminate sensory stimuli and react to them appropriately?’ ‘How does the brain integrate information from many different sources and use this information to control behaviour?’ ‘How is it that subjects can verbalize their internal states?’ Each of these deal broadly with problems of consciousness, but in ways which could in principle be resolved by straightforward functional explanations.

The ‘hard problem’, by contrast, is the question of how physical processes in the brain give rise to subjective experience. This puzzle involves the inner aspects of thought and perception and the way things feel for the subject - all of them subjective experiences known only to the participant. This is much harder to resolve because trying to compare brain states, which are in principle objective and replicable, with subjective experiences, which, however rich for the experiencer, are unavailable to an external observer, pose a severe problem of qualitative difference, which seems almost unbridgeable.

Chalmers rejects any simple resort to neuroscience explanations about brain states in solving the hard problem. He notes for example that the 40 Hz oscillations made famous by Crick and Koch (1992) and others, which might provide an explanation for the coherent binding together of different brain regions, for example visual and auditory into one attended perception, may explain how the brain integrates different processing tasks (an easy problem) but don’t explain how any of these modes evoke the subjective conscious experiences of vision and sound. Likewise he rejects philosophical explanations such as Daniel Dennett’s (1991) ‘multiple drafts’ theory of consciousness as an explanation of ‘how we produce verbal reports on our internal states’ (an easy problem) which tells us very little about why there should be a subjective experience behind these reports.

Even when we proceed to theories which attempt to use new types of physics to bridge this chasm, Chalmers remains sceptical:

> “Some have suggested that to solve the hard problem, we need to bring in new tools of physical explanation: nonlinear dynamics, say, or new discoveries in neuroscience, or quantum mechanics. But these ideas suffer from exactly the same difficulty. Consider a proposal from Stuart R. Hameroff of the University of Arizona and Roger Penrose of the University of Oxford. They hold that consciousness arises from quantum-physical processes taking place in microtubules, which are protein structures inside neurons. It is possible (if not likely) that such a hypothesis will lead to an explanation of how the brain makes decisions or even how it proves mathematical theorems, as Hameroff and Penrose suggest. But even if it does, the theory is silent about how these processes might give rise to conscious experience. Indeed, the same problem arises with any theory of consciousness based only on physical processing.”

Following on to examine the trend in cosmology and unified field theories, Chalmers speculates that conscious experience may be a fundamental feature cosmologically:

> “If the existence of consciousness cannot be derived from physical laws, a theory of physics is not a true theory of everything. So a final theory must contain an additional fundamental component. Toward this end, I propose that conscious experience be considered a fundamental feature, irreducible to anything more basic.”

This perception of the central nature of consciousness to the cosmological description is more acute than an academic or philosophical matter. Although the scientific description is based exclusively on the objective physical universe, our contact with reality is entirely *sine que non* through our subjective conscious experience. From birth to death, we experience only a stream of consciousness through which all our experience of the physical world is gained. All scientific experiments performed on the physical world ultimately become validated by the subjective conscious experience of the experimenters, and the subsequent witnesses to the phenomena and conclusions.

Because its subjective nature makes it unavailable to objective investigation, reductionist descriptions identify subjective consciousness with functional attributes of the brain, inferring computational machines might also possess consciousness. At best in such views, the subjectively conscious mind remains an enigma considered to be merely a passive ‘epiphenomenon’. However it is the physical world which is secondary to our personal experience, a consensus of stable subjective representations we assemble into our real world view. It thus remains unclear whether a physical universe without conscious observers could exist in any more than a purely conceptual or theoretical sense. Subjective consciousness may be necessary for the actualization of physical reality, and thus fundamental to physical existence in a cosmological sense, as expressed in the ‘anthropic cosmological principle’ that ‘observers’ are significant and possibly necessary boundary conditions for the existence of the universe (Barrow and Tipler 1988).

Of course this somewhat ‘idealistic’ view of subjectivity as a cosmic complement to the physical universe has a variety of critiques. Our conscious experience, while it remains mysterious, appears to be an inner manifestation of a functioning brain. Knock us out and consciousness is interrupted. The brain is a notoriously sensitive and easily damaged organ. Moreover it is a recent development in a universe where brains are by no means a forgone conclusion, the product of an idiosyncratic process of biological evolution, which at the surface appears to have little to do with the vast energies and forces shaping the cosmology of the universe as a whole. Nevertheless an argument based on non-linear interactions arising from cosmic symmetry-breaking and evolutionary universality can make the claim that the brain is accessing universal properties of a quantum nature, which may be the basis of its capacity for conscious subjectivity.

The conscious mind can also be described functionally as an internal model of reality. While such an explanation does not address the basis of subjectivity, it does help explain some of the more bizarre states of consciousness and is supported by many actively constructive aspects of sensory processing and the modular architecture of the cerebral cortex. Such an internal model can be described functionally in terms of dynamical brain processes which undergo unstable transitions to and from chaos (Skarda and Freeman 1987). Dynamical resonance and phase coherence also provide direct means to solve the 'binding problem', how the unitary nature of mind emerges from distributed parallel processing of many brain states.

A second critical property of subjective consciousness comes into play as we move from perception into volition. To quote Sir John Eccles : "It is a psychological fact that we believe we have the ability to control and modify our actions by the exercise of 'will', and in practical life all sane men will assume they have this ability" (Hooper and Teresi 1986). However this premise, which is basic to all human action, contradicts physical determinism, because any action of mind on brain contradicts the brain functioning as a deterministic computational machine, in its own right, in the physical world.

A confluence between quantum physics and the science of mind may resolve this apparent paradox. Firstly physics has difficulty determining when collapse of the wave function from a set of probabilities into an actual choice takes place, leading to some interpretations in which the conscious observer collapses the wave function. Secondly quantum uncertainty and non-locality provide exactly the types of explanation which could enable the subjective experience of free-will to be consistent with a non-deterministic model of brain function. The unpredictability of chaos (Stewart, Schuster) due to its amplification of arbitrarily small fluctuations in what is known as 'sensitive dependence on initial conditions, could provide a means to link quantum indeterminacy to global brain states.

2: Wave-Particle Complementarity, Uncertainty and Quantum Prediction

Associated with the nature of quanta themselves are unreconciled problems, which share an intriguing logical homology with problem of conscious intent. To explore these we will first summarize some of the core ideas of quantum reality.

If we have to find the frequency of a wave using the beats we can produce by comparing it with another similar wave, without being able to measure the exact amplitude of the wave at a given time (the actual situation in root quantum interactions), we then have let a considerable time elapse, to gain enough beats for an accurate measurement so we don't know exactly when the frequency was at this value. The relationship between the frequencies and the beats is: $\Delta\upsilon\Delta t \geq 1$, a smeared-out 2-D 'interval' of time and frequency combined.

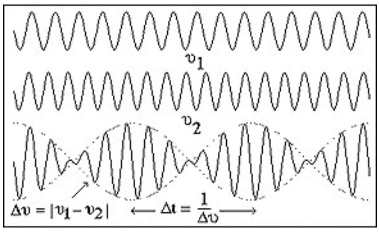


Fig 1: Measuring a wave frequency with beats has intrinsic uncertainty as to the time

Einstein's law is a fundamental equation of quantum mechanics which connects to every energetic particle a frequency $E = h\upsilon$ Measuring one is necessarily measuring the other. If we apply the above together, we immediately get the Heisenberg uncertainty relation:

$$\Delta E\Delta t = h\Delta\upsilon\Delta t \geq h$$

Each quantum can be conceived as a particle or as a wave, but not both at the same time. Depending on how we are interacting with it or describing it, it may appear as either. We can visualize the interchange between particle and wave natures by generating photons and allowing them to flow through a pair of closely spaced slits. When many photons pass through, their waves interfere as shown and the photographic plate gets dark and light interference bands where the waves from the two slits cancel or reinforce, because the photons are more likely to end up where their superimposed wave amplitude is large. The experiment confirms the wave nature of light, since the size of the bands is determined by the distance between the slits in relation to the wavelength where c is the velocity of light: $\lambda = \frac{\upsilon}{c}$

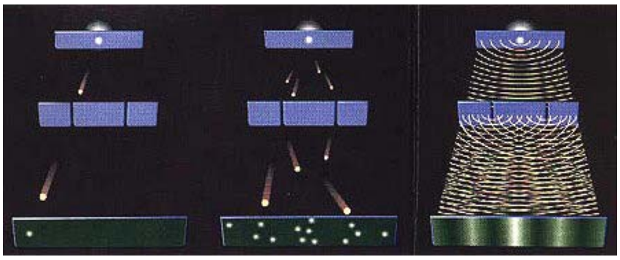


Fig 2: Two-slit interference experiment (Sci. Am. Jul 92)

We know each photon passes through both slits, because we can slow the experiment down so much that only one photon is released at a time and we still eventually get the interference pattern. Each photon released from the light bulb is emitted as a particle from a single hot atom, whose excited electron is jumping down from a higher energy orbit to a lower one. It is thus released locally and as a single 'particle' created by a single transition between two stable electron orbitals, but it spreads and passes through both slits as a wave. After this the two sets of waves interfere as shown in fig 2 to make bands on the photographic plate.

The evolution of the wave is described by an equation involving rates of change of a wave function φ with respect to space and time. For example for a massive particle in one dimension we have a differential equation:

$$\left(\frac{\partial^2}{\partial t^2} - \frac{\partial^2}{\partial x^2} + m^2\right)\varphi = 0$$

For the bands to appear, each single photon has to travel through both slits as a wave. If you try to put any form of transparent detector in the slits to tell if it went through one or both, you will always find only one particle, but now the interference pattern will be destroyed. This happens even if you use the gentlest forms of detection possible, such as an empty resonant maser chamber (a maser is a microwave laser). Any measurement sensitive enough to detect a particle alters its momentum enough to smear the interference pattern into the same picture you would get if the particle just went through one slit. Knowing one aspect destroys the other.

At the other end of the process, the photon has to be absorbed again as a particle by an atom on the photographic plate, or somewhere else if it doesn't career forever through empty space, something we shall deal with shortly. Where exactly does it go? The rules of quantum mechanics are only statistical. They tell us only that the particle is more likely to end up where the amplitude of the wave is large, not where it will actually go on any one occasion. The probability is precisely the complex square of the wave's amplitude at any point:

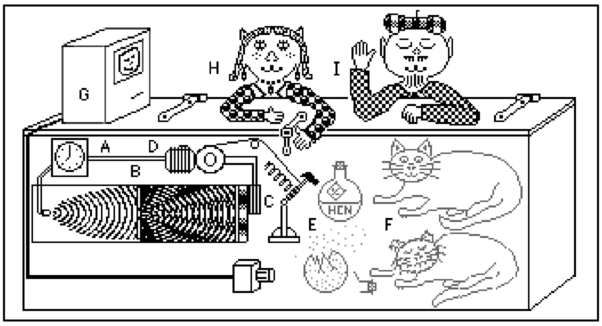
$$P = \varphi^*\varphi$$

Hence the probability is spread throughout the extent of the wave function, potentially extending throughout the entire universe at very low probabilities. Quantum theory thus describes all future (and past) states as probabilities. Unlike classical probabilities, we cannot find out more about the situation and reduce the probability to a certainty by deeper investigation, because of the limits imposed by quantum uncertainty. The photon could end up anywhere the wave is non-zero. Nobody can tell exactly where, for a single photon. However, each individual photon really does seem to end up getting absorbed as a particle somewhere, because we get a scattered pattern of individual dark crystals on the film at very low light intensities, which slowly build up to make the bands again. This is the mysterious phenomenon known as reduction of the wave packet. Effectively the photon was in a superposition of states represented by all the possible locations within the wave, but suddenly became one of those possible states, now absorbed into a single localized atom, where we can see its evidence as a silver crystal on the film. Only when there are many photons does the behaviour average out to the wave distribution. Thus each photon seems to make its own mind up about where it is going to end up, with the proviso that on average many do this according to the wave amplitude's probability distribution. So is this quantum 'free-will'?

This situation is the subject of a famous thought experiment by Schrödinger, who invented the wave equation, called the 'cat paradox'. In the cat paradox, we use an interference experiment with about one photon a second and we detect whether the photon hits one of the bright bands to the left. If it does then a cat is killed by smashing a cyanide flask. Now when the experimenter opens the box, they find the cat is either alive or dead, but quantum theory simply tells us that the cat is both alive and dead, each with differing probabilities - superimposed alive and dead states. This is very counterintuitive, but fundamental to quantum reality.

In the cat paradox experiment, fig 3, the wave function remains uncollapsed, at least until the experimenter I opens the box. Heisenberg suggested representing the collapse as occurring when the system enters the domain of thermodynamic irreversibility, i.e. at C. Schrödinger suggested the formation of a permanent record e.g. classical physical events D, E, or computer data G. However even these classical outcomes could be superpositions, at least until a conscious observer experiences them, as the many-worlds theory below suggests. Wigner's friend is a version of the cat paradox in which an assistant G reports on the result, establishing that unless the first conscious observer collapses the wave function, there will be a conscious observer in a multiplicity of alternative states, which is an omnipresent drawback of the many worlds view. In a macabre version the conscious assistant is of course the cat. According to the Copenhagen interpretation, it its not the system which collapses, but only our knowledge of its behavior. The superimposed state within the wave function is then not regarded as a real physical entity at all, but only a means of describing our knowledge of the quantum system, and calculating probabilities.

Fig 3: Varieties of forms of the 'Cat Paradox' experiment



This clash between subjective experience and quantum theory has lead to much soul-searching. The Copenhagen interpretation says quantum theory just describes our state of knowledge of the system and is essentially incomplete. This effectively passes the problem back from physics to the observer. Some physicists think the wave function never 'collapses' - all the possibilities happen and there is a probability universe for each case. This is the *many-worlds* interpretation of Hugh Everett III. The universe then becomes a superabundant superimposed set of all possible probability futures, and indeed all pasts as well, in a smeared out 'holographic' multi-verse in which everything happens. It suffers from a key difficulty. All the experience we have suggests just one possibility is chosen in each situation - the one we actually experience. Some scientists thus think collapse depends on a conscious observer. Many worlds defenders claim an observer wouldn't see the probability branching because they too would be split but this leaves us either with infinite split consciousness, or all we lose all forms of decision-making process, all forms of *historicity* in which there is a distinct line of history, in which watershed events do actually occur, and the role of memory in representing it.

Zurek (1991) describes decoherence as an inevitable result of interactions with other particles, however his theory forces the effect as an artificial parameter. Penrose in OOR, or 'orchestrated objective reduction', (Hameroff and Penrose 2003) singles out gravity as the key unifying force because of its relationship with space-time, and suggests that interaction with gravitons splits the wave function (Penrose 1989, 1994), causing reduction. Others try to discover hidden laws which might provide the sub-quantum process, for example a particle piloted within a wave as suggested by David Bohm (1952). This has difficulties defining positions when new particles, with new quantum degrees of freedom, are created. Another approach we will explore, is the transactional interpretation, which has features of all these ideas and seeks to explain this process in terms of a hand-shaking relationship between the past and the future, in which space-time itself becomes sexual in a quantum match-making. Key here is the fact that reduction is not like any other physical process. One cannot tell when or where it happens, again suggesting it is part of the 'spooky' interface between quantum and consciousness.

In many situations, people try to pass the intrinsic problems of uncertainty away on the basis that in the large real processes we witness, individual quantum uncertainties cancel in the law of averages of large numbers of particles. They will suggest for example that neurons are huge in terms of quantum phenomena and that the 'law of mass action' engulfs quantum effects. However brain processes are, by necessity, notoriously sensitive. Moreover history itself is a unique process out of many such 'unstable' possibilities at each stage of the process. Critical decisions we make become watersheds. History and evolution are both processes littered with unique idiosyncratic acts in a counterpoint to the major forces shaping the environment and landscape. Chaotic processes are potentially able to inflate arbitrarily small fluctuations, so molecular chaos may 'inflate' the fluctuations associated with quantum uncertainty.

3: The Two-timing Nature of Special Relativity

We also live in a paradoxical relationship with space and time. While space is to all purposes symmetric and multidimensional, and not polarized in any particular direction, time is singular in the present and polarized between past and future. We talk about the arrow of time as a mystery related to the increasing disorder or entropy of the universe. We imagine space-time as a four dimensional manifold, but we live out a strange sequential reality, in which the present is evanescent. In the words of the song "time keeps slipping, slipping, slipping ... into the future". There is also a polarized gulf between a past we can remember, the living present, and a shadowy future of nascent potentialities and foreboding uncertainty. In a sense, space and time are complementary dimensionalities, which behave rather like real and imaginary complex variables, as we shall see below.

A second fundamentally important discovery in twentieth century physics, complementing quantum theory, which transformed our notions of time and space, was the special theory of relativity. In Maxwell's classical equations for transmission for light, light always has the same velocity, *c* regardless of the movement of the observer, or the source. Einstein realized that Maxwell's equations and the properties of physics could be preserved under all intertial systems - the principle of special relativity - only if the properties of space and time changed according to the Lorenz transformations as a particle approaches the velocity of light *c* :

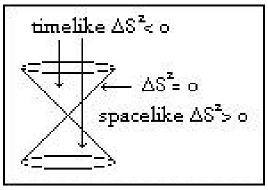
$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}, y' = y, z' = z, t' = \frac{t - (v/c^2)x}{\sqrt{1 - v^2/c^2}}$$

Space becomes shortened along the line of movement and time becomes dilated. Effectively space and time are each being rotated towards one-another like a pair of closing scissors. Consequently the mass and energy of any particle with non-zero rest mass tend to infinity at the velocity of light: $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$

By integrating this equation, Einstein was able to deduce that the rest mass must also correspond to a huge energy $E_o=m_oc^2$ which could be released for example in a nuclear explosion, as the mass of the radioactive products is less than the mass of the uranium that produces them, thus becoming the doom equation of the atom bomb. General relativity goes beyond this to associate gravity with the curvature of space-time caused by mass-energy.

In special relativity, space and time become related entities, which form a composite four dimensional space-time, in which points are related by light-cones - signals travelling at the speed of light from a given origin. In space-time, time behaves differently to space. When time is squared it has a negative sign just like the imaginary complex number $i = \sqrt{-1}$ does.

Hence the negative sign in the formula for space-time distance $\Delta S^2 = x^2 + y^2 + z^2 - c^2t^2$ and the scissor-like reversed rotations of time and space into one another expressed in the Lorenz transformations. Stephen Hawking has noted that if we treat time as an imaginary variable, the space-time universe could become a closed 'manifold' rather like a 4-D sphere, in which the cosmic origin is rather like the north pole of Earth, because imaginary time will reverse the above negative sign and give us the usual Pythagorean distance formula in four dimensions.



Space-time light cone permits linkage of 'time-like' points connected by slower-then-light communication. In the 'space-like' region, temporal order of events and causality depends on the observer.

A significant feature of special relativity is the fact that the relativistic energy-momentum equation $E^2=\boldsymbol{p}^2+ m^2$ has dual energy solutions: $E = \pm(\sqrt{\boldsymbol{p}^2 + m^2})$

The negative energy solution has reversed temporal direction. Effectively a negative energy anti-particle travelling backwards in time is exactly the same as a positive energy particle travelling forwards in time in the usual manner. The solution which travels in the normal direction (subsequent points are reached later) is called the *retarded* solution. The one which travels backwards in time is called the *advanced* solution. A photon is its own anti-particle so in this case we just have an advanced or retarded photon.

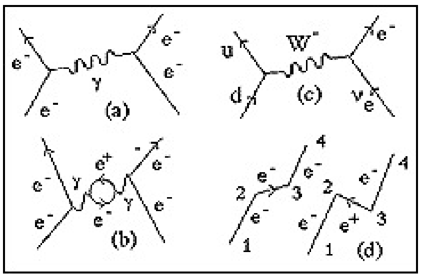


Fig 4: Quantum electrodynamics: (a,b) Two Feynman diagrams in the repulsion of two electrons. In the first a single virtual photon is exchanged between two electrons, in the second the photon becomes a virtual electron-positron pair during its transit. All such diagrams are integrated together to calculate the strength of the electromagnetic force. (c) A similar diagram shows how neutron decay occurs via the *W*- particle of the weak nuclear force, which itself is a heavy charged photon. (d) A time reversed electron scattering is the same as positron creation and annihilation.

4: Reality and Virtuality: Quantum fields and Seething Uncertainty

The theories describing force fields such as electromagnetism through the interaction of wave-particles are the most succinct theories ever invented by the human mind. Richard Feynman and others discovered the field is generated by uncertainty itself through particles propagated by a rule based on wave spreading. These particles are called *virtual* because they have no net positive energy and appear and disappear entirely within the window of quantum uncertainty, so we never see them except as expressed in the force itself. This seething tumult of virtual particles exactly produces the familiar effects of the electromagnetic field and other fields as well. We can find the force between two electrons by integrating the effects of every virtual photon which could be exchanged within the limits of uncertainty and of every other possible virtual particle system, including pairs of electrons and positrons coming into a fleeting existence. However, we can't eliminate the wave description because the amplitudes with which the particles are propagated from point to point are wave amplitudes. Uncertainty not only can create indefiniteness but it can actively create every conceivable particle out of the vacuum, and does so.

Each more complex interaction involving one more particle vertex is smaller by a factor $\frac{e^2}{hc} \sim \frac{1}{137}$ where *e* is the electron charge and *h* and *c* are as above, called the 'fine structure constant'. This allows the contribution of all the diagrams to sum to a finite interaction unlike many unified theories, which are plagued by infinities. The electromagnetic force is generated by virtual photons exchanged between charged particles existing only for a time and energy permitted by the uncertainty relation. The closer the two electrons, the larger the energy fluctuation possible over the shorter time taken to travel between them and hence the greater the force upon them. Even in the vacuum, where we think there is nothing at all, there is actually a sea of all possible particles being created and destroyed by the rules of uncertainty.

The virtual particles of a force field and the *real* particles we experience as radiation such as light are one and the same. If we pump energy into the field, for example by oscillating it in a radio transmitter, the virtual photons composing the electromagnetic field become the real positive energy photons in radio waves entering the receiver as a coherent stream of real photons, encoding the music we hear.

Relativistic quantum field theories always have both advanced and retarded solutions, one with positive and the other with negative energy, because of the two square roots of special relativity. They are often described by Feynman space-time diagrams. When the Feynman diagram for electron scattering becomes time-reversed, it then becomes precisely the diagram for creation and annihilation of the electron's anti-particle, the positron, as shown above. This hints at a fundamental role for the exotic time-reversed advanced solutions.

The weak and strong nuclear forces can be explained by similar field theories related to electromagnetism through symmetry-breaking, but gravity holds out further serious catch-22s. Gravity is associated with the curvature of space-time, but this introduces fundamental contradictions with quantum field theory. To date there remains no fully consistent way to reconcile quantum field theory and gravitation although higher-dimensional string and membrane theories show promise (Hawking 2001).

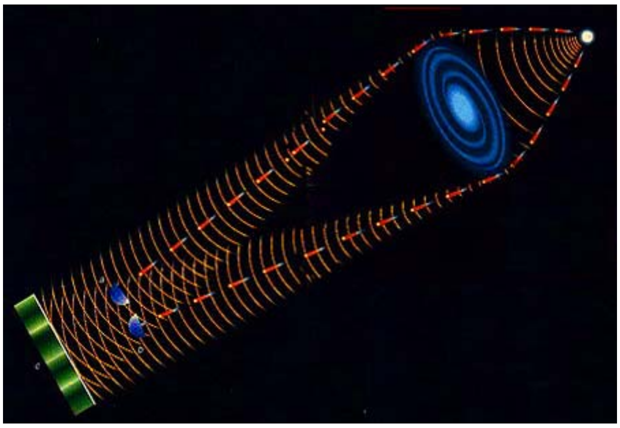


Fig 5: Wheeler delayed choice experiment: A very distant quasar is gravitationally lensed by an intervening galaxy. We can sample photons either by an interference pattern, verifying they went around both sides of the galaxy, or place separate directional detectors which will detect they went one way around only as particles (which will destroy the interference pattern. Moreover, we can decide which to perform after the photon has passed the galaxy, at the end of its path. Thus the configuration of the latter parts of the wave appear to be able to alter the earlier history.

5: The Spooky Nature of Quantum Entanglement

We have already seen how the photon wave passing through two slits ends up being absorbed by a single atom. But how does the wave avoid two particles accidentally being absorbed in far flung parts of its wave function out of direct communication? Just how large such waves can become can be appreciated if we glance out at a distant galaxy, whose light has had to traverse the universe to reach us. The ultimate size of the wave of such a photon is almost as big as the universe. Only one photon is ever absorbed for each such wave, so once we detect it, the probability of finding the photon anywhere else, and hence the amplitude of the wave, must immediately become zero everywhere. How can this happen, if information cannot travel faster than the speed of light? The same thing happens when I shine my torch against the window. The amplitude of each photon is both reflected, so I can see it, and transmitted, so that it could also escape into the night sky. Although the wave may spread far and wide, if the particle is absorbed anywhere, the probability across vast tracks of space has to suddenly become zero.

Moreover collapse may involve the situation at the end of the path influencing the earlier history, as in the Wheeler delayed choice experiment illustrated in fig 5. In this experiment we can determine whether a photon went both ways round a lensing galaxy, focusing the light from a very distant quasar long after the light has passed across the universe, by either measuring the interference between the paths as in the double slit experiment or by detecting light from one direction or another.

Because we can't sample two different points of a single-particle wave, it is impossible to devise an experiment which can test how a wave might collapse. One way to learn more about this situation is to try to find situations in which two or more correlated particles will be released coherently in a single wave. This happens with many particles in a laser and in the holograms made by coherent laser light and in Bose-Einstein condensates. It also happens in other situations where two particles of opposite spin or complementary polarization become created together. Many years ago Einstein, Rosen and Podolsky suggested we might be able to break through the veil of quantum uncertainty this way, indirectly finding out more about a single particle than it is usually prepared to let on.

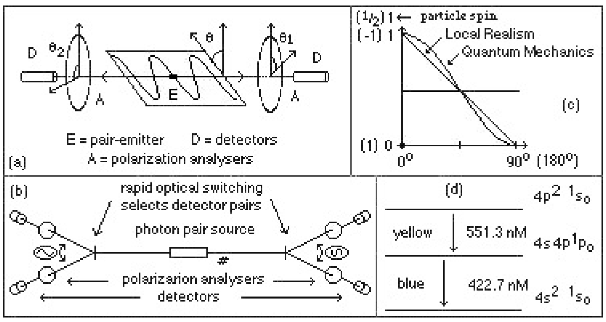


Fig 6: (a) Pair-splitting experiment for photons. (b) Time-varying analyzers are added driven by an optical switch to fast for light to cross the apparatus. (c) The results are consistent with quantum mechanics but inconsistent with Bell's inequalities for a locally causal system. (d) The calcium transition (Aspect 1982).

For example a calcium atom's electron excited into a higher orbital sometimes cannot fall back to its original orbital in one step because a photon always turns out to have spin 1 and the spins don't match. For example you can't go between two orbits of equal spin and radiate a spin-1 photon or the spins don't tally. The atom however can radiate two photons thereby cancelling one another's spins, to transit to its ground state, via an intermediate spin-1 orbit. This releases a blue and a yellow photon, each of which travel off in opposite directions, with complementary polarizations.

When we perform the experiment, it turns out that the polarization of neither photon is defined until we measure one of them. When we measure the polarization of one photon, the other immediately - instantaneously - has complementary polarization. The nature of the angular correlations between the detectors is inconsistent with any locally-causal theory - that is no theory based on information exchanged between the detectors by particles at the speed of light can do the trick, as proved in a famous result by John Bell (1966) and subsequent experiments (Clauser and Shimony 1978). The correlation persists even if the detectors' configurations are changed so fast that there is no time for information to be exchanged between them at the speed of light as demonstrated by Alain Aspect (1982). This phenomenon has been called quantum non-locality and in its various forms quantum 'entanglement', a name itself very suggestive of the throes of a sexual 'affair'.

The situation is subtly different from any kind of classical causality we can imagine. The information at either detector looks random until we compare the two. When we do, we find the two seemingly random lists are precisely correlated in a way which implies instantaneous correlatedness, but there is no way we can use the situation to send classically precise information faster than the speed of light by this means. We can see however in the correlations just how the ordinary one-particle wave function can be instantaneously auto-correlated and hence not slip up in its accounting during collapse.

Since this result in the 1980s there have been a veritable conjurer's collection of experiments, including quantum teleportation, erasure computing and encryption, all of which verify the predictions of quantum mechanics in every case and confirm all the general principles of the pair-splitting experiment. Even if we clone photons to form quartets of correlated particles, any attempt to gain information about one of such a multiple collection collapses the correlations between the related twins.

Some of the more challenging aspects of quantum entanglement arise when we consider quantum computation. Classical computation has a problem which is the potentially unlimited time it takes to check out every one of a collection of possibilities. E.g. to crack a code we need to check all the combinations, whose numbers can increase more than exponentially with the size of the code numbers and possibly taking as long as the history of the universe to compute. For example factorizing a large number composed of two primes is known to be computationally intractable enough to provide the basis for public key encryption by which banks records and passwords are kept safe. Although the brain ingeniously uses massively parallel computation, there is as yet no systematic way to boot strap an arbitrary number of parallel computations together in a coherent manner. Quantum reality is a superposition of all the possible states in a single wave function, so if we can arrange a wave function to represent all the possibilities in such a computation, superposition might give us the answer by a form of parallel quantum computation. A large number could in principle be factorized in a few superimposed steps, which would otherwise require vast time-consuming classical computer power to check all the possible factors one by one.

6: Quantum Match-making: Transactional Supercausality and Reality

For reasons which immediately become apparent, the collapse in the pair-splitting experiment has to not only be immediate, but also to reconcile information looking backwards in time. The two photons we are trying to detect are linked through the common calcium atom. Their absorptions are thus actually connected via a path travelling back in space-time from one detector to the calcium atom and forward again to the other detector. Trying to connect the detectors directly, for example by hypothetical faster-than-light *tachyons*, leads to contradictions. Tachyons transform by the rules of special relativity, so a tachyon which appears to be travelling at an infinite speed according to one observer, is travelling only at a little more than the speed of light according to another. One travelling in one direction to one observer may be travelling in the opposite direction to another. They also cause weird causality violations. There is thus no consistent way of knitting together all parts of a wave using tachyons. Even in a single-particle wave, regions the wave has already traversed also have to collapse retrospectively so that no inconsistencies can occur in which a particle is created in two locations in space-time from the same wave function, as the Wheeler delayed choice experiment makes clear.

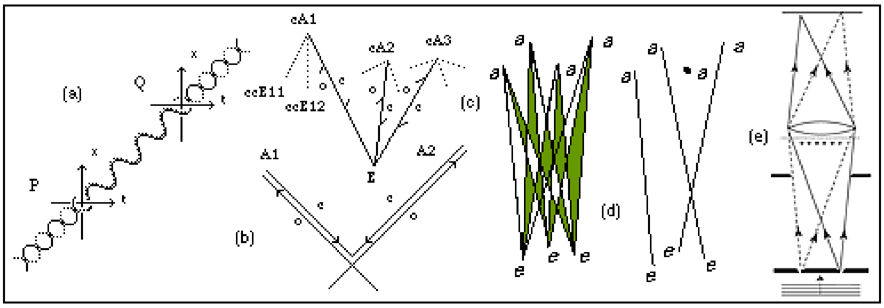


Fig 7: (a) In the transactional interpretation, a single photon exchanged between emitter and absorber is formed by constructive interference between a retarded offer wave (solid) and an advanced confirmation wave (dotted). (b) The transactional interpretation of pair-splitting. Confirmation waves intersect at the emission point. (c) Contingent absorbers of an emitter in a single passage of a photon. (d) Collapse of contingent emitters and absorbers in a transactional match-making (King). (e) Experiment by Shahri Afshar (see Chown 2004).

In the *transactional interpretation* (Cramer 1986), such an advanced 'backward travelling' wave in time gives a neat explanation, not only for the above effect, but also for the probability aspect of the quantum in every quantum experiment. Instead of one photon travelling between the emitter and absorber, there are two shadow waves, which superimposed make up the complete photon. The emitter transmits an *offer* wave both forwards and backwards in time, declaring its capacity to emit a photon. The potential absorbers of this photon transmit a corresponding *confirmation* wave. These, travelling backwards in time, send a hand-shaking signal back to the emitter, fig 7(a). The offer and confirmation waves superimpose constructively to form a real photon only on the space-time path connecting the emitter to the absorber. The transactional approach offers the only viable explanation for the apparently faster-than-light connections between detectors in pair-splitting EPR experiments in which a pair of correlated photons are emitted by a single atom as in fig 6. In fig 7(b), rather than a super-luminal connection between detectors A1 and A2, the photons' own advanced waves meet at the source in a way which enables the retarded waves to be instantaneously correlated at the detectors.

A possible confirmation of the transactional approach comes from an intriguing experiment by Shahri Afshar (see Chown 2004), fig 7e. A grid is placed at the interference minima of the wave fronts coming from two slits, just below a lens designed to focus the light from each slit into a separate detector. Measurements by detectors (top) test whether a photon (particle) passed through the left or right slit (bottom). There is no reduction in intensity when the grid is placed below the lens at the interference minima of the offer waves from the two slits. The grid does however cause a loss of detector intensity when the dashed left-hand slit is covered and the negative wave interference between the offer waves at the grid is removed, so that the non-interfered wave from the right slit now hits the grid, causing scattering. This suggests both that we can measure wave and particle aspects simultaneously, and that the transactional interpretation is valid in a way which neither many worlds (which predicts a splitting into histories where a photon from the source goes through one slit or other) or the Copenhagen interpretation of complementarity (where detecting a particle forbids the photon manifesting as a wave).

In the extension of the transactional approach to supercausality (King 1989, 2003), a non-linearity reduces the set of contingent possibilities to one offer and confirmation wave, fig 7 (c,d). Thus at the beginning, we have two set of contingent emitters and absorbers as in fig 7(c) and at the end each emitter is now exchanging with a specific absorber. Before collapse of the wave function, we have many potential emitters interacting with many potential absorbers. After all the collapses have taken place, each emitter is paired with an absorber in a kind of marriage dance. One emitter cannot connect with two absorbers without violating the quantum rules, so there is a frustration between the possibilities which can only be fully resolved if emitters and absorbers can be linked in pairs. The number of contingent emitters and absorbers are not necessarily equal, but the number of matched pairs is equal to the number of real particles exchanged, fig 7(d).

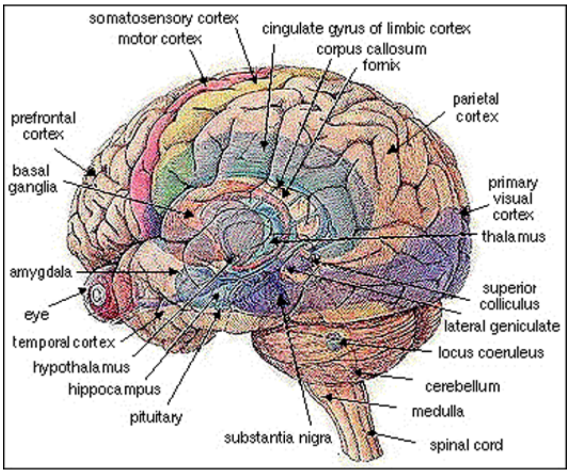
The transition is not difficult to model as a sequence of non-linear bifurcations, in which one emitter-absorber pair becomes committed, but notice that the time parameter we are dealing with lies outside space-time, as it is transforming one space-time diagram into another, yet it is happening experientially in real time. This is because collapse of the wave function is a space-time process. Causality with its symmetry-broken sequential time and supercausality with its time-symmetric handshaking form complementary domains, which is why the model is also called dual-time supercausality (King 1981). Directed and symmetric time thus coexist in the model. Notice also that the past contains causal records as well as superpositions, but the future is purely extrapolation plus superpositions. It is at this point that the influence of the conscious observer and the hard problem become pivotal. This transactional time symmetry is paralleled in the time reversibility of a quantum computation so long as it remains in the original superposition of states contrasted with the time directed nature of classical computation, and with it the definitive results of any quantum computation arising from collapse.

The transactional process connects an emitter at an earlier time to an absorber at later time because a real positive energy photon is a *retarded* particle which travels in the usual direction in time. If you wish, you can think of a negative energy photon travelling backwards in time as the anti-particle of the positive one and it will have just the same effect. The two are thus identifiable in the transaction, just as in quantum electrodynamics above, where time-reversed electron scattering is the same as positron creation and annihilation. One can also explain the arrow of time if the cosmic origin is a reflecting boundary that causes all the positive energy real particles in our universe to move in the retarded direction we all experience in the arrow of time. This in turn gives the sign for increasing disorder or entropy as it is called and the direction for the second law of thermodynamics to work in terms of positive energy. In the pair-splitting experiment, fig 7(b), one can also see that the calcium atom emits in response to the advanced confirmation waves reaching it from both the detectors simultaneously right at the time it is emitting the photon pair. Thus the faster than light linkage is neatly explained by the combined retarded and advanced aspects of the photon having a net forwards and backwards connection which is instantaneous at the detectors.

The equivalence of real and virtual particles raises the possibility that all particles have an emitter and absorber and arose, like virtual particles, through mutual interaction when the universe first emerged. However even if dark-energy, 'quintessence' causes an increasing expansion, or fractal inflation leads to an open universe model in which some photons may never find an absorber, the excitations of brain oscillations, because they are both emitted and absorbed by past and future brain states could still be universally subject to transactional supercausal coupling.

The hand-shaking space-time relation implied by the transactional interpretation makes it possible that the apparent randomness of quantum events masks a vast interconnectivity at the sub-quantum level, reflecting Bohm's (1980) *implicate order.* Although one can readily envisage a non-linear interaction where a sequence of bifurcations of the mutual frustration between the emitters and absorbers, because this connects past and future in a time-symmetric way, it cannot be reduced to predictive determinism, because the initial conditions are insufficient to describe the transaction, which also includes quantum 'information' coming from the future. However this future is also unformed in real terms at the early point in time emission takes place. My eye didn't even exist, when the quasar emitted its photon, except as a profoundly unlikely branch of the combined probability 'waves' of all the events throughout the history of the universe between the ancient time the quasar released its photon, my eye developing, and me being in the right place at the right time to see it. Transactional supercausality thus involves a huge catch 22 about space, time and prediction, uncertainty and destiny. It doesn't suggest the future is determined, but that the contingent futures do superimpose to create a space-time paradox in collapsing the wave function.

The transactional interpretation may combine with quantum computation to produce a space-time anticipating quantum entangled system which may be pivotal in how the conscious brain does its computation (see section 12). The brain is not a marvelous computer in any classical sense. We can barely repeat seven digits. But it is a phenomenally sensitive anticipator of environmental and behavioral change. Subjective consciousness has its survival value in enabling us to jump out of the way when the tiger is about to strike, not so much in computing which path the tiger might be on, because this is an intractable problem and the tiger can also take it into account in avoiding the places we would expect it to most likely be, but by intuitive conscious anticipation.



.Fig 8: Human brain showing key underlying structures (Sci. Am. Sep 92) indicate a massively parallel organization with feedback loops linking major cortical and limbic areas and interfacing them with midbrain centres in the thalamus, and basal brain. The limbic structures of the hippocampus and amygdala are indicated. There are only about ten serial connections between sensory input and motor output.

7: Exploring the 'Three Pound Universe'

The human brain has been described as the 'three-pound universe' (Hooper and Teresi) because, along with some other mammalian brains, it is the single most complex system so far discovered in the entire cosmological realm. It is also the most mysterious. Although we have developed super-computers, their architecture remains that of a simplistic deterministic automaton by comparison with the brain. Despite the vast increases of speed and memory capacity of modern computers, they remain trivial by comparison. Few have more than a few processing units and the communication protocols for parallel processing, outside simple matrix calculations, remain simple procedural farming out. The notion that a computer may some day also become subjectively conscious is at this point a science fiction fantasy.

Theoretical models of neural nets likewise remain trivial by comparison with brain structures. Neurons are frequently modeled as simple additive modules summing their inputs and making synaptic adjustments to their connections in response to stimulus. Continuous nets such as the Hopfield net have only transient dynamics seeking a simple energy minimum as an equilibrium condition, perhaps with some thermodynamic annealing to avoid getting stuck in the 'rut' of a sub-optimal local minimum. Biological neurons by contrast are dynamically active, adaptive single-celled 'organisms', having up to 10,000 synaptic connections each and possessing a variety of excitatory and inhibitory neurotransmitters, as well as both dynamical and pulse-coded means of activation. They display both chaos and self-organized criticality and threshold tuning.

The brain is *par excellence* a distributed parallel processing system in which there are only perhaps four to ten serial links between sensory input and motor output, modulated by connections involving up to 10^{11} cells and 10^{15} synapses. Its protocols are thus 'lateral' rather than 'serial'. The mammalian brain is dominated by the cerebral cortex. We are now beginning to gain some idea of how it processes sensory information through a combination of electrical probing and various types of scans.

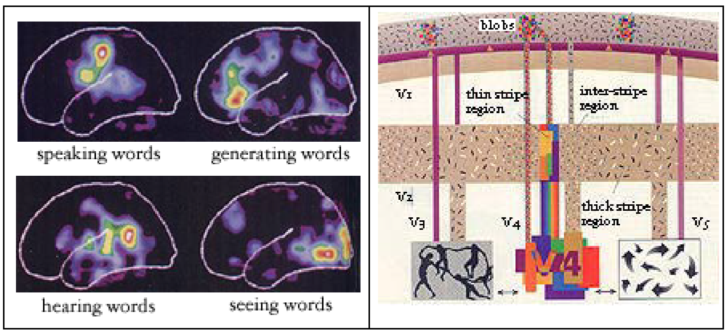


Fig 9: Despite the development of sophisticated techniques for visualizing brain activity such as those for speech (left), and ingenious work tracing connectivity of activity between neurons in the cortex such as that establishing distinct parallel processing regions for colour and movement in vision (right, Zeki 1992), no objective brain state is equivalent to a subjective conscious experience. The difficulty of bridging this abyss is called the hard problem in consciousness research (Chalmers)

The cortex has a dynamic modular organization, in which aspects of sensory 'information' are processed in parallel in distinct areas, including the regions specialized for primary vision and hearing and for somatosensory perception and motor functions. Many of these modular regions can be divided further, for example into specific areas to do with language, such as Wernicke's and Broca's areas for semantic meaning and linguistic articulation. Using active scanning by multi-channel electroencephalograms, positron emission tomography, or functional magnetic resonance imaging, it is possible to follow conscious activity and compare it with modular activation of the cortex, fig 8. Visual processing can be divided into a significant number of distinct modular areas fig 9, complementing the primary visual area, with distinct processing for colour, movement and moving form. These areas can be investigated, both in scans and through people who display sometimes bizarre perceptual anomalies caused by local damage to these areas, such as colourless visual perception, or fragmented motion.

The cerebral cortex is divided between front and rear into broadly motor and broadly perception by the Sylvian fissure, dividing frontal regions and the motor cortex from the somatosensory (touch) and other sensory areas, including vision and hearing. The broadly sensory 'input' and associated areas of the parietal and temporal cortices are complemented by frontal and pre-frontal areas which deal with 'output' in the form of action rather than perception and with forming anticipatory models of our strategic and living futures. These active roles of decision-making and 'working memory' (Goldman-Rakic 1992), which interact from pre-frontal cortical areas complement the largely sensory-processing of the temporal, parietal and occipital lobes with a space-time representation of our 'sense of future' and of our will or intent.

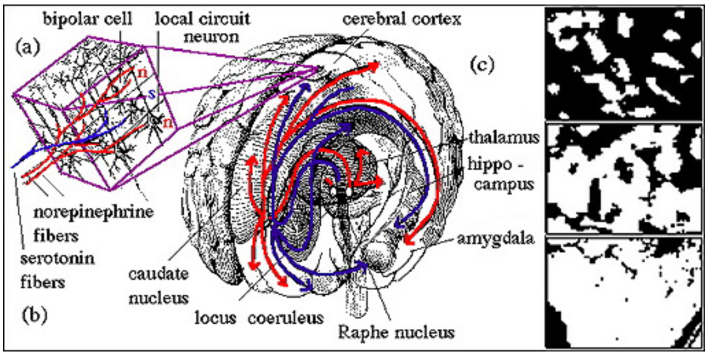


Fig 10: Left: Ascending serotonin and norepinephrine pathways are evidence for a parallel distributed cortex based on dynamical activation of conscious modes. Serotonin receptors are notably involved in psychedelic effects. Right: Neural plasticity of local cortical function, in changes in regions of optical dominance in the visual cortex after the dominant eye is shade support dynamical rather than hard-wired cortical organization. Such plasticity extends across the senses, enabling the assignment of new functions under the demands of new experiential situations such as learning a new language

However these areas are not rigidly hard-wired genetically. Neurogenesis and neurophysiology are dynamic. The allocation of a given region is a dynamical consequence of a series of interactive processes. These begin in embryogenesis, where neurons migrate up the glial cellular scaffold to make specific types of global connection. Neurogenesis is accompanied by growth and migration and also sacrifice in programmed cell death, and removal as well as establishment of synapses. The overall organization is not static, but derived from the dynamics itself. In visual development, the retina and then the geniculate and finally the cortex become organized, each deriving organizing stimulus from the chaotic excitations established at the previous level. This cortical dynamic plasticity is preserved into later life, where injury, compensation, or a major new learned skill can result in development of new functional areas or significant rearrangement of existing areas. A person studied on live PET before and after becoming a real time translator at the UN, for example, showed the development of a whole new language area.

The cortex itself is relatively inert in electrodynamical terms and may actually form a complex boundary constraint on the activity of more active underlying areas such as the thalamus, which contains a number of centers with ordered projections to and from corresponding areas of the cortex. This suggests in turn that the thalamic centres are the driving force of cortical activity.

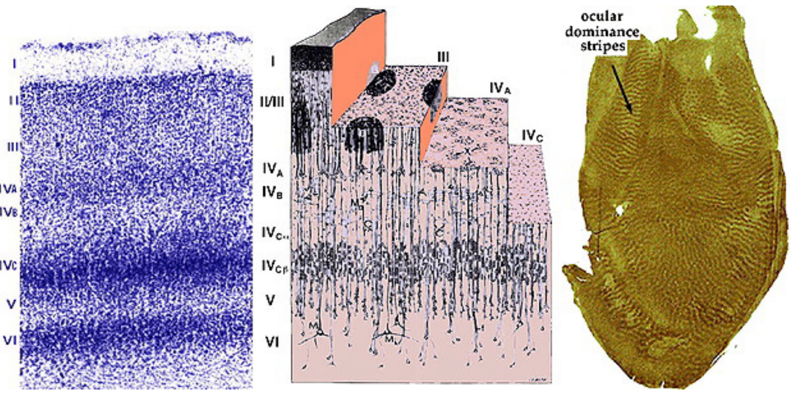


Fig 11: Typical cortical structures (centre) are a combination of five-layers of neurons each composed into columnar modules on a scale of about 1mm on the cortical surface. Such modules are sensitive to particular stimuli such as a line of a given orientation. Blob centres in layer II are also shown (see fig 9). Although specific sensory area have functional and anatomical specializations neural plasticity can enable changes of functional assignment indicating common principles throughout the cortex. Left: anatomical view of the five layers. Right: Ocular dominance columns illustrate functional columnar architecture.

Finally we have the so-called limbic system, fig 8, around the edges of the cortex, involving the hippocampus, amygdala, hypothalamus and areas of the cingulate cortex in a large feedback loop which has becomes associated with emotional mood, flight and fight, cross-sensory integration and the fixation of long-term sequential memory. These structures fall very centrally into our concept of the psyche because they mediate the central emotional orientations which govern our survival and our social interaction with others, including the capacity for love, hate, jealousy, compassion and non-genetic altruism.

The varying modes of alert consciousness, dreaming and deep sleep are generated from deeper brain stem centers which have ascending neural pathways which fan out widely across the cortex into specific cortical layers, thus providing long-term modulation of mood and conscious attention fig 10. Two pathways lead from the Raphe Nuclei and the Locus Coeruleus to diverse cortical areas and involve the modulating neurotransmitters, serotonin and nor-epinephrine. The onset of dreaming sleep is heralded by activity of cells in the Pons and silencing of cells in the Raphe Nuclei and Locus Coeruleus. Similar dopamine paths spread out from the Substantia Nigra selectively into the frontal lobes and motor centers. The ascending pathways have been implicated in mental illness, addiction and motor syndromes such as Parkinson's disease. Dopamine is sometimes associated with pleasure and nor-adrenaline with anxiety. The hallucinogens psilocin and mescalin are serotonin and catecholamine analogues, although both appear to interact primarily with serotonin receptors. These pathways clearly have much to do with modulating conscious states of the cortex as a whole and and understanding of their exact mechanism of action would give a very productive insight into the brain mechanisms supporting consciousness.

Dreaming or REM (rapid eye movement) sleep in which cortical activation alternates with phases of deep sleep is both one of the most singular phases of conscious activity in which experiential feedback appears to be accentuated at the expense of external input, generating episodic subjective realities or 'worlds within'. The nature and function of dreaming consciousness and its wealth of detail remain obscure although the experiences themselves are intense, sometimes in full sumptuous colour vision as evidenced in lucid dreaming (La Berge 1990). There is some indication that these two phases are complementary and involve reciprocal communication between the hippocampus and the cortex in consolidating long-term sequential memories (Winson 1992, Stickgold 1998, New Scientist 28 Jun 2003 29), but the subjective consequences, and the need for them to occur subjectively as well, as functionally remain enigmatic. Accounts of precognitive dreaming (Dunne c1935) challenge our very notions of causality.

8: Chaos and Fractal Dynamics as a Source of Sensitivity, Unpredictability and Uncertainty

Walter Freeman's model of chaos in sensory perception, fig 12(b,c), (Skarda and Freeman 1987, Freeman 1991) gives a good feeling for how transitions in and out of chaos - a so-called ‘edge-of-chaos’ complexity phenomenon (Ruthen 1993), could play a key role in sensory recognition. The olfactory cortex undergoes high energy chaotic excitation in time to form a spatially correlated wave across the cortex, as a rabbit sniffs, causing the cortical dynamics to travel through its phase space of possibilities without becoming stuck in any mode. As the sniff ends, the energy parameter reduces, carrying the dynamic down towards basins in the potential energy landscape. If the smell is recognized, the dynamic ends in an existing basin, but if it is new, a bifurcation occurs to form a new basin (a new symbol is created) constituting the learning process, as illustrated below. The same logic can be applied to cognitive problem solving in which the unresolved aspects of the problem undergo chaotic evolution until a bifurcation from chaos to order arrives at the ‘eureka’ of the solution.

A fundamental reason for any dynamical nervous system to enter chaos is that chaotic systems are arbitrarily sensitive on their initial or external conditions, so a system entering chaos is capable of being acutely responsive to its environment over time, while any stable process heads inexorably towards its equilibrium states or periodicities, entrapped by its very stability. While artificial neural nets invoke thermodynamic ‘randomness’ in *annealing* to ensure the system doesn’t get caught in a sub-optimal local minimum, biological systems appear to exploit chaos to free up their dynamics to explore the ‘phase space’ of possibilities available, without becoming locked in a local energy valley which keeps it far from a global optimum.

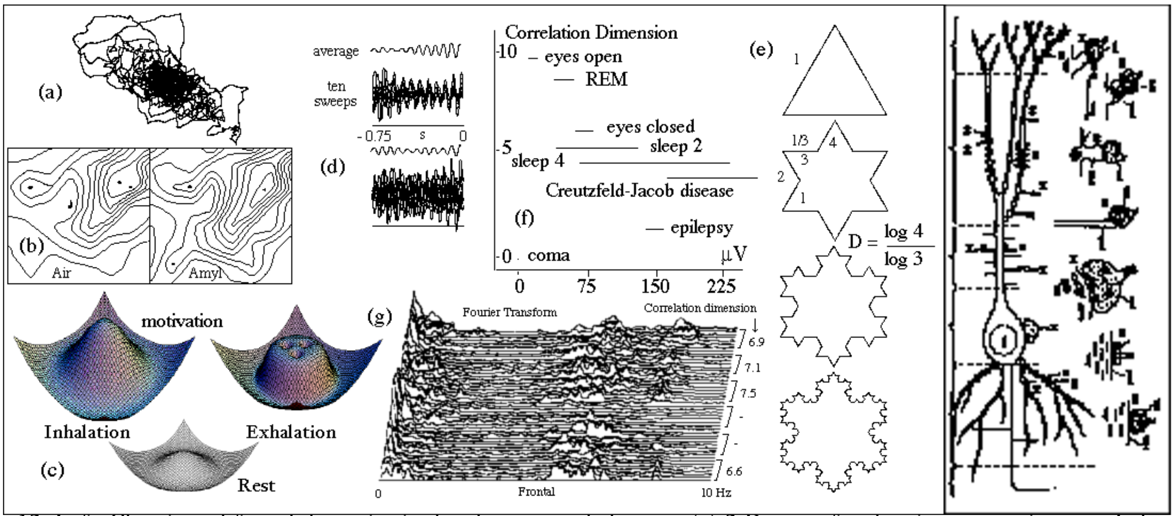


Fig 12: Left: Chaotic and fractal dynamics in the electroencephalogram: (a) 2-D map of a chaotic attractor in stage 4 sleep (b,c) 8x8 matrices of bulb response illustrating topological differences in excitation for air and amyl acetate and phase portrait of the stages of chaotic excitation in the Freeman model. (d) Coherence of EEG recording in anticipated events and desynchronization in the absence of anticipation. (e) Koch flake formed by repeated tessellation of a triangle (f) Typical correlation dimensions of a variety of natural and pathological brain states. (g) Time-evolving 2-D power spectra of electroencephalogram, frontal cortex showing variation with time in the frequency spectrum and the correlation dimension. Right: Neuronal dendrites and their synapses form a fractal architecture and dynamics in the brain in which global and local are interconnected (Schierwagen) Each of the types of synapse engage distinct neurotransmitters. Differing neural types have distinct fractal morphologies related to their firing pattern (Teich 1992).

Several indicators of the use of chaos in neurodynamics come from measurements of the fractal dimension of a variety of brain states, from pathology through sleep to restful wakefulness (Babloyantz et. al. 1985,1986, Rapp 1985, Babloyantz 1989), fig 12(f),. Recordings from single neurons, and from other cells such as the insulin-releasing cells of the pancreas indicate their capacity for chaotic excitation. The organizers of neural systems are also frequently non-pulse coded 'silent' cells capable of continuous non-linear dynamics. Despite the classical result of quasi-linearity of the axonal discharge rate with depolarization, virtually all aspects of synaptic transmission and excitation have non-linear characteristics capable of chaos and bifurcation. For example the acetyl-choline ion channel has quadratic concentration dynamics, requiring two molecules to activate. Many cells have sigmoidal responses providing non-linear sensitivity and are tuned to threshold. Nonlinear feedback between excitatory and inhibitory neurotransmitters in cortical layers is believed to be a source of the electroencephalogram (Freeman 1991). The activity of single neurons has been found to include both cells with activity indistinguishable from noise and also neurons displaying low dimensional chaos (Albano et. al. 1986a). The electroencephalogram itself, although nominally described as having brain rhythms such as alpha, beta, gamma and theta actually consists of broad band frequencies, fig 12(g), rather than harmonic resonances, consistent with a ground-swell of chaotic excitation (King 1991,1996,1997). Broadly speaking neurodynamics is “edge of chaos” in the time domain and parallel distributed in a coherent ‘holographic’ manner (Pribram 1993) spatially. Phase coherence (e.g. in the 40 Hz band) is also associated with perception, providing a mathematical parallel with quantum wave coherence.

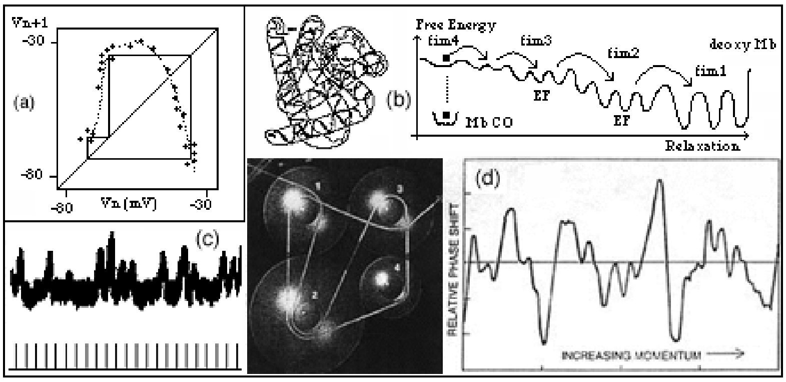
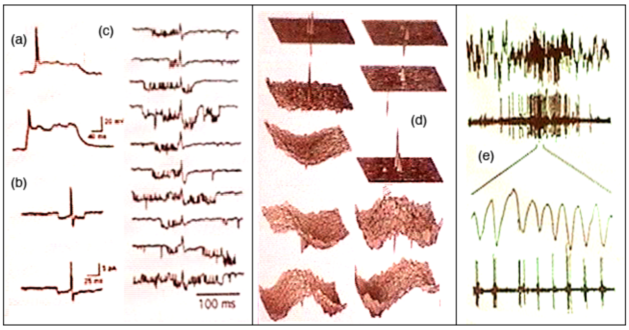


Fig 13: (a) Period 3 indicates chaos. Chaotic excitation in pancreatic cells is demonstrated by perturbing them slightly to period 3 oscillations characteristic of a narrow window of order in the chaotic regime. (b) Fractal molecular structure results in fractal dynamics (Ansari et. al. 1985). Functionally important movements in large protein molecules such as myoglobin occur in an environment of smaller local perturbations due to local fluctuations on fractal scales. (c) Frog retinal cells are sensitive to single quanta (Blakemore) (d) Chaotic variation of phase with increasing momentum in an electron traversing a molecular medium illustrates kinetic chaos in open systems at the quantum level. Enzymes have been shown to use quantum tunneling in their active sites and molecules as large as tetraphenylporphyrin (TPP) ad buckyballs (C60) have been demonstrated to display quantum interference (Ball 2003, Arndt 1999, Hackermüller 2003). At biological temperatures a glycine molecule has a self-refraction angle of about 5°.(King 1981).

Into this picture of global and cellular chaos (Chay and Rinzel 1985) comes a second complementary aspect, the fractal nature of neuronal architecture and brain processes and their capacity for self-organized criticality at a microscopic level. The many to many connectivity of synaptic connection, the tuning of responsiveness to a sigmoidal threshold, and the fractal architecture of individual neurons combine with the sensitive dependence of chaotic dynamics and self-organized criticality of global dynamics to provide a rich conduit for instabilities at the level of the synaptic vesicle or ion channel to become amplified into a global change. The above description of chaotic transitions in perception and cognition leads naturally to critical states in a situation of choice between conflicting outcomes and this is exactly where the global dynamic would become critically poised and thus sensitive to microscopic or even quantum instabilities.



Evidence for complex system coupling between the molecular and global levels. Stochastic activation of single ion channels in hippocampal cells (a) leads to activation of the cells (c). Activation of such individual cells can in turn lead to formation of global excitations as a result of stochastic resonance (d). Individuals cells are also capable of issuing action potentials in synchronization with peaks in the eeg (e) (Liljenström and Svedin 2005).

Because of the intrinsic non-linearity of charge interactions, (see section 9), this fractal process runs all the way from the global brain state to molecular quantum chaos (Gutzwiller 1992). From the synaptic vesicle we converge to the ion channel which in the case of the K^+ voltage channel is determined to have a fractal kinetics (Liebovitch et. al. 1987, 1991), fig 19(b), and further to the structure and dynamics of proteins and their conformational dynamics (Ansari et. al. 1995), fig 13(b), both of which operate on non-linear fractal protocols. The brain is thus an organ capable of supersensitivity to the instabilities of the quantum milieu.

9: Classical and Quantum Computation, Anticipation and Survival

A computational process is intractable if the number of computational steps required grows super-exponentially with the complexity. The travelling salesman problem (Bern and Graham 1989), finding the shortest route round *n* cities illustrates this, growing with $(n\text{-}1)!/2$ A proposition may also be formally undecidable in the sense of Gödel's incompleteness theorem which says that any logical system containing finite arithmetic contains undecidable propositions. Many adaption-survival problems in the open environment are intractable problems, because the number of options rapidly exponentiates. This would leave a gazelle stranded at the cross roads unable to decide which path to take eaten in a 'catatonic' state due to Turing's 'halting' problem - the undecidability of whether a computational process will actually complete. An active organism must complete any processing task within 0.1-1 second if it is going to have survival utility, regardless of its complexity. Such arguments make it clear why dynamic parallel processing is an integral feature of vertebrate nervous systems.

Recent models of the quantum mind attempt to solve this problem by suggesting the brain is capable of a form of quantum computing which may be also associated with conscious awareness. For example Hameroff and Penrose (2003) have suggested that microtubules may permit a form of molecular quantum computing through two-state *q*-bits formed from tubulin monomers which exist in two quantum states. They suggest the tubulin monomers form a type of cellular automaton. While these ideas are exciting, they also introduce new problems. Microtubules are involved in neuronal activity and their pathologies do affect learning and memory, but it remains unclear their changes operate on the rapid time scale of electrodynamical changes and consciousness. The quantum computing model proposes individual cellular quantum computation through quantum isolation of the microtubules within the neuron to prevent decoherence, preventing the quantum computations from being integrable with many-cell resonances and hence the global brain states we naturally associate with conscious awareness.

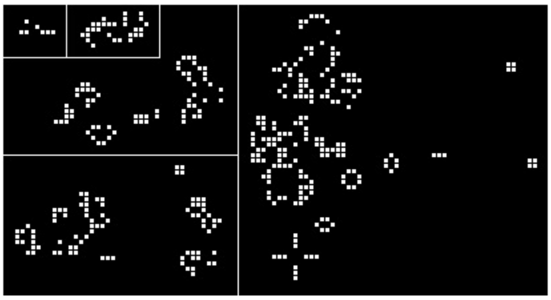


Fig 14: Conway's game of life is a two-dimensional cellular automaton with simple rules. Any cell with 2 or 3 of its 8 possible neighbours alive 'survives' and one with just 3 is 'born'. The rest die. The system, which is a digital version of edge of chaos complexity dynamics is capable of universal computation.

Some of the more challenging aspects of quantum entanglement arise when we consider quantum computation. Classical computation has a problem which is the potentially unlimited time it takes to check out every one of a collection of possibilities. E.g. to crack a code we need to check all the combinations, whose numbers can increase more than exponentially with the size of the code numbers and possibly taking as long as the history of the universe to compute. For example factorizing a large number composed of two primes is known to be computationally intractable enough to provide the basis for public key encryption by which banks records and passwords are kept safe. Although the brain ingeniously uses massively parallel computation, there is as yet no systematic way to boot strap an arbitrary number of parallel computations together in a coherent manner.

However, we may be able to harness the superposition of all the possible states in a single wave function. If we can arrange a wave function to represent all the possibilities in such a computation, superposition might give us the answer by a form of parallel quantum computation. A large number could in principle be factorized in a few superimposed steps, which would otherwise require vast time-consuming classical computer power to check all the possible factors one by one. Suppose we know an atom is excited by a certain quantum of energy, but only provide it a part of the energy required. The atom then enters a superposition of the ground state and the excited state, suspended between the two like Schrödinger's cat. If we then collapse the wave function, squaring it to its probability, as in $P=\varphi^*\varphi$, it will be found to be in either the ground state or excited state with equal probability. This superimposed state is sometimes called the 'square root of not' when it is used to partially excite a system which flips between 0 and 1 corresponding to a logical negation.

Supposing we want to factorize a large number. We devise a single quantum system in two parts. The left part is excited to a superposition. Suppose we have a collection of such atoms which effectively form the 0s and 1s of a binary number - 0 in the ground state and 1 in the excited state. If we then partially excite them all they represent a superposition of all the binary numbers - e.g. 00, 01, 10 and 11. The right half is designed to give the factorization remainder of a test number taken to the power of each of the possible numbers in the left. These turn out to be periodic, so if we measure the right we get one of the values. This in turn collapses the left side into a superposition of only those numbers with this particular value in the right. We can then recombine the reduced state on the left to find its frequency spectrum and decode the answer. As a simple example, you are trying to factorize 15. Take the test number $x = 2$. The powers of 2 give you 2, 4. 8, 16, 32, 64, 128, 256 ... Now divide by 15, and if the number won't go, keep the remainder. That produces a repeating sequence 2, 4, 8, 1, 2, 4, 8, 1 ... with period $n = 4$ we can use this periodicity as an 'interference pattern' to figure $x^{n/2} - 1 = 2^{4/2} - 1 = 3$ is a factor of 15. Quantum parallelism solves all the computations simultaneously.

The essential principles of this calculation may pass over into a general problem solving paradigm. Key is the idea that measurement of part of an entangled system may enable the whole system to collectively solve a problem connecting its entangled parts.

Nevertheless, although it may be able to solve some intractable problems by parallel superposition, (Deutch 1985, Calude and Pavlov 2002), quantum computing alone may not solve the deeper problems of the open environment. Many critical decisions a living animal has to make to survive are not simply a matter of computation because many problems of survival are intrinsically unstable. Each strategy tends to be matched by a competing strategy in another organism, so that a predator may choose a less likely path for the very reason that the prey may be more likely to take it knowing it is safer in computational terms. These many options may not be able to be decided on by optimizing computationally on past histories, as illustrated by neural net 'over fit' errors, when circumstances change. Survival depends more on intuitive anticipation and paranoia taken to a hair-trigger, when the tiger is about to strike, rather than brute-force computation. This is where the evolutionary value of subjective consciousness begins to become apparent. It is thus insufficient to replace a computational model of brain function, as exemplified by 'artificial intelligence', with a form of quantum consciousness which is simply a reflection of quantum computation through non-local molecular automata or other mechanisms. Although quantum computation might act more quickly, avoiding the gazelle becoming stranded catatonically at the cross roads because of computational intractability, it still doesn't go any way to solving the questions of free-will and creative choice, nor does it compensate for the perfidy of the predator. Raw conscious anticipation is the key. Attentiveness and hunch in the shadow of paranoia is the best survival strategy.

Intentional generation of novelty and unpredictability for its own sake is also key to survival in many species, and strongly manifest in *Homo sapiens*. A pivotal aspect of novelty in our own context is that, in all species, decisions are not just made for survival but to express reproductive fitness. Geoffrey Miller (2000) in "The Mating Mind" has suggested that the development of human culture is an indictor of reproductive fitness in which both sexes are 'running while standing still' in a genetic race generated through novelty, music art, story-telling as well as resourcefulness and protection. This theme is further developed in "Sexual Paradox" (Fielder and King 2004). All of these features also need explaining and involve diversity and complexity generation which no computational model, quantum or otherwise, focussing on a fixed 'solution' can generate.

Quantum computing on its own does not solve the problem of 'will' involved in decision-making when many choices are available, several of which may be successful to varying degrees. The capacity to make a decision, given many options is pivotal. To explain free choice, it is also necessary to explain all the manifestations of non-computational complexity, such as the creativity which enables a new musical theme, or an art form, or other innovation to be created. None of this complexifying behaviour is explained by any form of computation which seeks a single optimal outcome or even a specific heuristic array of options. Creative variety is the essence of human diversity and our success as a species. Neither does quantum computing alone indicate why we experience a subjective impression of free-choice central to the exercise of subjective consciousness. In the Hameroff-Penrose OOR model, *reduction* of the wave function is regarded as *orchestrated* and *objective* and is thus independent of the conscious will of the experiencer. If intentional consciousness is only a retrospective reflection of an orchestrated objective collapse, it still has no evolutionary role in terms of selective advantage.

We thus need to explain not just how computation might be accelerated in quantum consciousness, but the origin of will in the subjective affecting and in effecting physical outcomes. We need to deal with dynamics in which many choices are available, not one computational solution, quantum or otherwise, and to explain how 'free will' can achieve real physical choices, and the endless variety of novelty which we associate with living systems and particularly with human culture. We need to consider not only computation but creativity - how the symphony emerges from the composer.

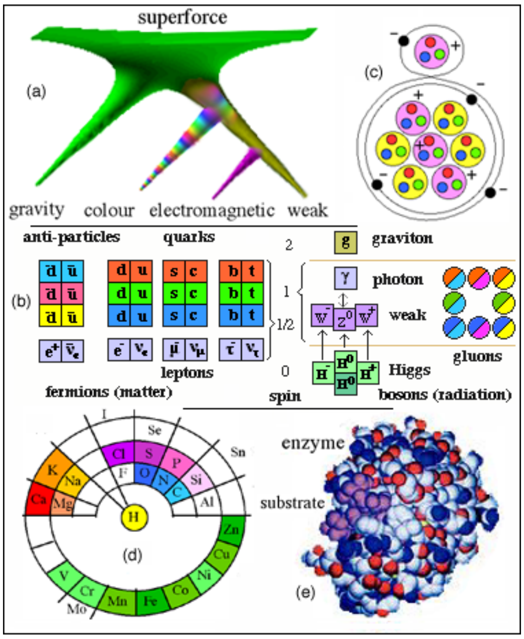


Fig: 15 (a) Cosmic symmetry-breaking as a fractal generator of life (King 1987, 2002). The four forces of nature emerge from a single unified field theory, probably a 10 to 12 dimensional superstring or membrane theory based on supersymmetry - a pairing between the bosons and fermions, which cancels the infinities that would otherwise result in the theory .(b) The standard model showing the key fermions making up matter and bosons making force and radiation. Added to the 4 dimensions of space-time, the dimensions of the internal symmetries of colour, charge-flavour and the Higgs particle give a strong hint of the grand unification. (c) Because the resulting fermions are highly charge asymmetric they associate to form the hierarchical structures of atomic and molecular matter. The non-linear charge interactions result in a cascade of chemical bonding effects, generating higher molecular fractal structures, leading to organelles, cells and tissues. The bioelements form a key symmetry-breaking interaction among the principal orbital types.

10: The Cosmic Primality of Membrane Excitation

Rather than a molecular accident, the emergence of life can be modeled as a tree of critical cosmological quantum bifurcations, or splittings, interactively between quantum features emerging from the interaction of the atomic and molecular structures which arise in turn as complex asymmetric hierarchical structures from cosmic symmetry-breaking itself, fig 15. The non-linear nature of charge interactions results in a succession of bonding effects, from strong covalent and ionic bonds, through, H-bonds, polar and hydrophobic interactions, to van der Waal's effects. Cooperative weak bonding results in globally-interactive enzyme structures, fig 15(e) and in fractally increasing scales, molecular complexes, organelles, cells, tissues and organisms.

The central bifurcation tree, fig 15(d) is an interaction of the 1*s* orbital of H with the $2sp_3$ hybrid orbitals of C, N, and O as most strongly covalent multi-bonding elements. Secondary bifurcation of polarity between C, N, and O in order of increasing electronegativity in relation to H generates the polar non-polar bifurcation in which the phase division leading to the lipid bilayer membrane and ion-based excitation arises. H_2O becomes the optimal formative substrate in terms of its diversity of quantum modes (reflected in high specific heat), and diverse ionic and polar structures, giving rise to the interactive properties which make the polar-hydrophobic phase bifurcation of protein enzymes, fig 15(e), nucleic acid base stacking and lipid membranes, fig 17(b), and hence excitable cells possible.

Subsequent orbital bifurcations divide alkali and alkaline earth metal ions according to ionic radius, secondary involvement of second row elements in S-S weak covalency, PO_4^{3-} dehydration energy and Cl^- ions. Subsequently the d-orbital catalysis of the transition elements completes the orbital symmetry-breaking interaction. This bifurcation pathway leads directly to polypeptides, nucleotides and membranous lipid structures as complexity polymers, with RNA and monomers such as ATP having a central formative replicative role.

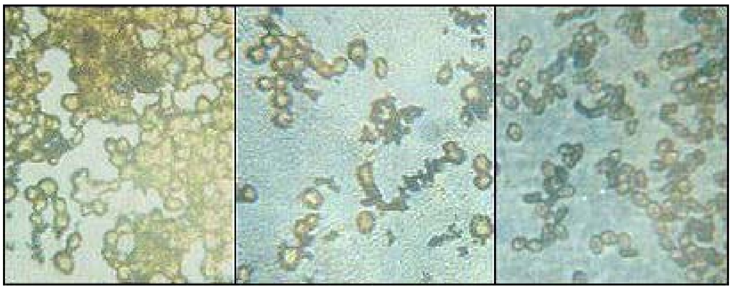


Fig 16: Left and centre: Microcellular formations generated by the author from HCN and HCHO (King). Right: Spores of a psilocybe species at the same magnification for size comparison.

All life as we know it is dependent on maintaining a distinct internal micro-environment as an open far-from-equilibrium thermodynamic system (Glansdorff and Prigogine, Agladze et. al. 1984, Epstein et. al. 1983), through the topological closure of the cell. Viruses for example all depend on cellular life. The structure of the bilayer membrane is a direct consequence of the polarity bifurcation. The formation of amphophilic lipid-like molecules, joining a linear non-polar hydrocarbon section to an ionic or H-bonding polar terminal, leaves 2 degrees of freedom for layer formation. Backing of the non-polar moieties to one another, fig 17(b), completes the bilayer. Cell structure can then arise directly from budding of the bilayer, as illustrated in budding in several types of prebiotic reaction medium. Microcellular structures are abundant in many origin of life syntheses, fig 16. The use of cytosine diphosphate CDP associated with choline, inisotol and lipids in membrane construction is consistent with membrane formation in the RNA era along with the ubiquitous energy molecule the nucleotide adenine triphosphate ATP. The structure of typical biological lipids such as phosphatidyl choline display a modular structure consisting of fatty acid, glycerol, and substituted amine, linked by dehydration and involving phosphate, fig 17(e).

The existence of the membrane as a non-polar structure leads to segregation into ionic and non-polar reaction phases. Ion transport is essential in maintaining the concentration gradients that distinguish the cytoplasm from the external environment and thus must develop in the earliest cellular systems (MacElroy et. al. 1989). Ion transport is a source of significant electronic effects, because the membrane under polarization is piezo-electric and is capable of excitation in the presence of suitable ions. Model systems using the simple 19 unit oligopeptide Na^+ ionopore alamethicin and artificial membranes display action potentials (Mueller and Rudin 1968). Similar results have been reported for microcells produced by prebiotic techniques containing light irradiated chromophores (Przybylski and Fox 1986), demonstrating that such effects are fundamental to the quantum architecture of lipid membranes (King 1990). Four groups of non-polypeptide neurotransmitters: acetyl-choline, catecholamines (epinephrine and dopamine), serotonin and histamine are all amines, the latter three being derived from amino acids tyrosine, tryptophan and histidine by decarboxylation. Two others are amino acids and thus also contain amine groups. This may represent a fundamental chemical bifurcation between basic amines and the acidic phosphate groups in the lipid membrane. Alamethicin also has glutamine amides located in the core of the pore (Fox and Richards 1982). The catecholamines are linked to indoles such as serotonin by a prebiotic pathway, fig 17(c).

Ion transport, the membrane and excitability appear to have a common progenitor in the phase transition to ordered water gels (Pollack 2001) with negatively-charged proteins, under ion gradients which reject Na^+ and attract K^+, the latter leading to a compact ordered water phase transition leading to a stable gel phase cytoplasm without the need to impose a structurally unstable membrane and ion transport mechanism at the birth of the first cell to maintain a far from equilibrium thermodynamic limit cycle.

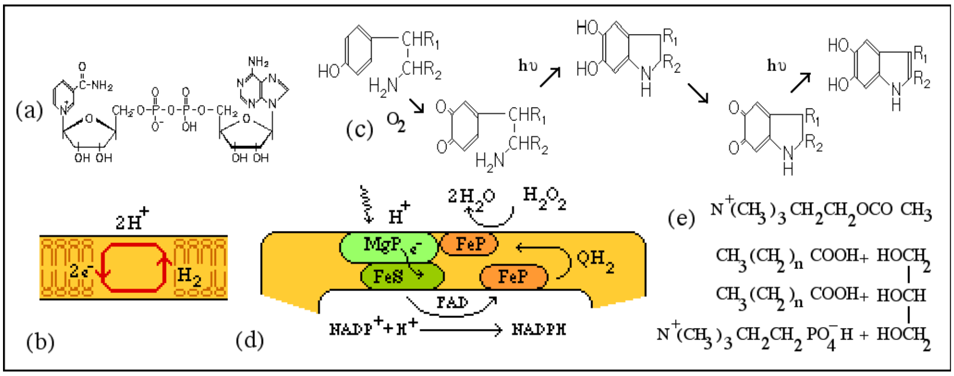


Fig 17: (a) NAD structure permits linkage of other energies to a redox bifurcation. (b) H^+ and e- transport linked by H_2 in membrane due to insolubility of e- and solubility of H^+. (c) Prebiotic link between catecholamines and indole via quinone-type photoreduction. (d) Hypothetical form of primitive electron transport as a non-equilibrium limit cycle. (e) Acetyl-choline and phosphatidyl choline compared. Phosphatidyl choline lipid stacks tail to tail as shown in the clothes pegs (b).

The proton is soluble in water to form the hydrogen ion H^+, but the electron is not, unless attached to another group such as a protein. This causes a physical linkage between the polarity bifurcation and the charge bifurcations associated with electron and proton transfer, fig 17(b) mediated by H transport through quinone reduction, (c). Despite the complexity of modern electron transport in photosynthesis and respiration, there is considerable evidence that membrane electrochemistry could have arisen before translation produced coded enzymes. There is a consistent basis for the existence of many of the components of electron transport during the RNA era. The nucleotide coenzymes provide evidence for this system emerging in the RNA era. Nicotine and flavin adenine dinucleotide NAD, FAD, a nucleotide-bound Mg/Fe-porphyrin ring similar to B_{12}, a cysteine-bound FeS group (Hall et. al. 1974), possibly based on glutathione (g-glutamyl-cysteinyl-glycine) and quinones would provide all the key components of electron transport in an RNA dependent but protein-free form, fig 17(d) (King 1990). The Fe-S-centre has also been cited a basis for prebiotic metabolism. Both porphyrins and quinones have obvious prebiotic syntheses and the primal role of nucleotide coenzymes has already been discussed. Secondly, membrane structure and the solubility differences between the electron and proton guarantee a link between electron and hydrogen ion transport fundamental to quantum symmetry-breaking. Electron transfer does not in principle require the complex coded active sites required to catalyze specific molecular transformations. Model systems using Fe-porphyrins and imidazole can couple oxidative electron transport to phosphorylation (Brinigar et. al. 1966) and photo activated Mg-porphyrin to phosphate (Goncharova and Goldfelt 1990, Lozovaya et. al. 1990). These would initially have used H_2S as a substrate rather than the higher splitting energy of H_2O.

These primal features give a basis for the occurrence of excitable membranes associated with cells as an interactive manifestation of cosmic symmetry-breaking. While this doesn't solve the hard problem, it does go some way towards a description in which the cellular excitability we do associate with consciousness does have a possible cosmological status in physical terms, rather than being an idiosyncratic result of biological evolution alone. We thus next look at the ways evolution may have selected for subjective consciousness.

11: Chaotic Excitability and Quantum Sensitivity as a founding Eucaryote Characteristic.

The evidence of the preceding section suggests that chaotic excitability may be one of the founding features of eucaryote cells dating from the purely replicative RNA era, before coded protein translation (King 1978, 1990). The Piezo-electric nature and high voltage gradient of the excitable membrane provides an excitable single cell with a generalized quantum sense organ. Chaotic sensitive dependence would enable such a cell to gain feedback about its external environment, rather than becoming locked in a particular oscillatory mode. Excitation would be perturbed by a variety of modes - chemically through molecular interaction, electromagnetically through photon absorption and the perturbations of the fluctuating fields generated by the excitations themselves, and mechanically through acoustic interaction. Such excitability in the single cell would predate the computational function of neural nets, making chaos fundamental to the evolution of neuronal computing rather than vice versa. Key chemical modifiers may have been precursors of the amine-based neurotransmitters which span acetyl-choline, serotonin, catecholamines and the amino acids such as glutamate and GABA, several of which have a primal status chemically. The use of positive amines may have chemically complemented the negatively charged phosphate-based lipids in modulating membrane excitability in primitive cells without requiring complex proteins. It is possible that chaotic excitation dates from as early a period as the genetic code itself and that the first RNA-based cells may have been excitable via direct electrochemical transfer from light energy, before enzyme-based metabolic pathways based on protein translation had developed.

The sense modes we experience are not simply biological as such but more fundamentally the qualitative modes of quantum interaction between molecular matter and the physical universe. They thus have plausible cosmological status. Vision deals with interaction between orbitals and photons, hearing with the harmonic excitations of molecules and membrane solitons or piezo-electric excitons, as evidenced in the action potential. Smell is the avenue of orbital-orbital interaction, as is taste. Touch is a hybrid sense involving a mixture of these. The limits to the sensitivity of nervous systems are constrained only by the physics of quanta, rather than biological limits. This is exemplified in fig 13(c) by the capacity of retinal rod cells to record single quanta, and by the fact that membranes of cochlear cells oscillate by only about one H atom radius at the threshold of hearing, well below the scale of individual thermodynamic fluctuations and vastly below the bilayer membrane thickness. Moth pheromones are similarly effective at concentrations consistent with one molecule being active, as are the sensitivities of some olfactory mammals.

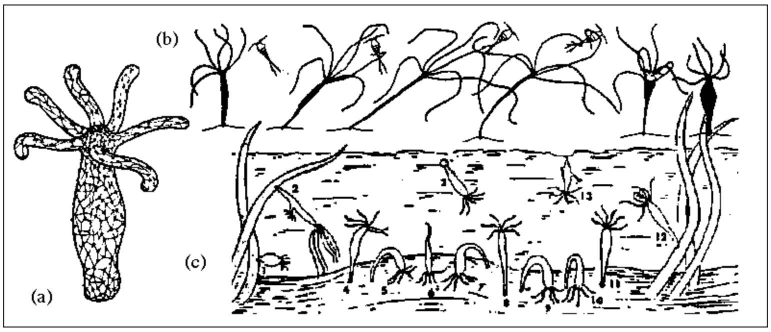


Fig 18: Hydra poses a dilemma for theories of cognitive development based on neural net organization rather than the complex adaptability of individual neurons. Hydra can reassemble ectoderm and endoderm if turned inside out and has a disseminated neural net (a) with no global structure, except for a slight focus around the mouth. Nevertheless it can coordinate eating in a similar manner to an octopus (b) and possesses more diverse types of locomotion than animals such as molluscs and arthropods which have structured ganglia. These include snail-like sliding, tumbling, inch-worm motion and use of bubbles and surface films.

The very distinct qualitative differences between vision, hearing, touch and smell do not appear to be paralleled in the very similar patterns of electrical excitation evoked in their cortical areas. If all these excitations can occur simultaneously in the excitable cell, its quantum-chaotic excitation could represent a form of cellular multi-sensory *synaesthesia*, which is later specialized in the brain in representing each individual sense mode. Thus in the evolution of the cortical senses from the most diffuse, olfaction, the mammalian brain may be using an ultimate universality, returning to the original quantum modes of physics in a way which can readily be expressed in differential organization of the visual, auditory, and somatosensory cortices according to a single common theme of quantum excitability. This is consistent with cortical plasticity which enables a blind person to use their visual areas for other sensory modes.

It is thus natural to postulate that, far from being an epiphenomenon, consciousness is a feature which as been elaborated and conserved by nervous systems because it has had unique survival value for the organism. We are thus led to an examination of how chaotic excitation may have evolved from single-celled animals through the early stages represented by Hydra, fig 18, with its diffuse neural net, to the complex nervous systems of metazoa. We have seen how chaotic excitation provides for exploration of phase space and sensitivity to internal and external fluctuations. However the conservation of consciousness may also involve features expressed only by chaotic systems which are fractal to the quantum level.

It is a logical conclusion that the conscious brain has been selected by evolution because its biophysical properties provide access to an additional principle of predictivity not possessed by formal computational systems. One of the key strategies of survival implicated in brain dynamics is anticipation and prediction of events (King 1978, 1991, Basar et. al. 1989, Llinás 1987, MacLean et. al. 1991). Computational systems achieve this by a combination of deductive logic and heuristic calculation of contingent probabilities. However quantum non-locality may also provide another avenue for anticipation which might be effective even across the membrane of a single cell, if wave reductions are correlated in a non-local manner in space-time.

12: Models of the Global-Molecular-Quantum Interface

The question of free-will in a quantum uncertain universe led several of the early researchers of quantum physics to propose that the brain may be in some way utilizing the uncertainty of individual quanta that appears to violate causality at the foundation of physics (Lockwood 1989), to give rise to a quantum uncertain brain state consistent with free-will. Eddington (1935), for example noted that the uncertainty of position of a synaptic vesicle was large enough to be comparable with the width of the membrane, making synaptic release potentially subject to quantum uncertainty. Walker (1977) noted quantum tunnelling in synaptic transmission and Eccles (1986) noted the relation between mental events, neural events and quantum probability fields.

As noted in section 7, 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. Voltage gated ion channels, fig 19(b), display fractal kinetics (centre) consistent with a quantum fractal model of protein conformational dynamics, illustrated for myoglobin in fig 13(b). 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 the ion channel, which brings us to the realm of kinetic quantum chaos, fig 13(d).

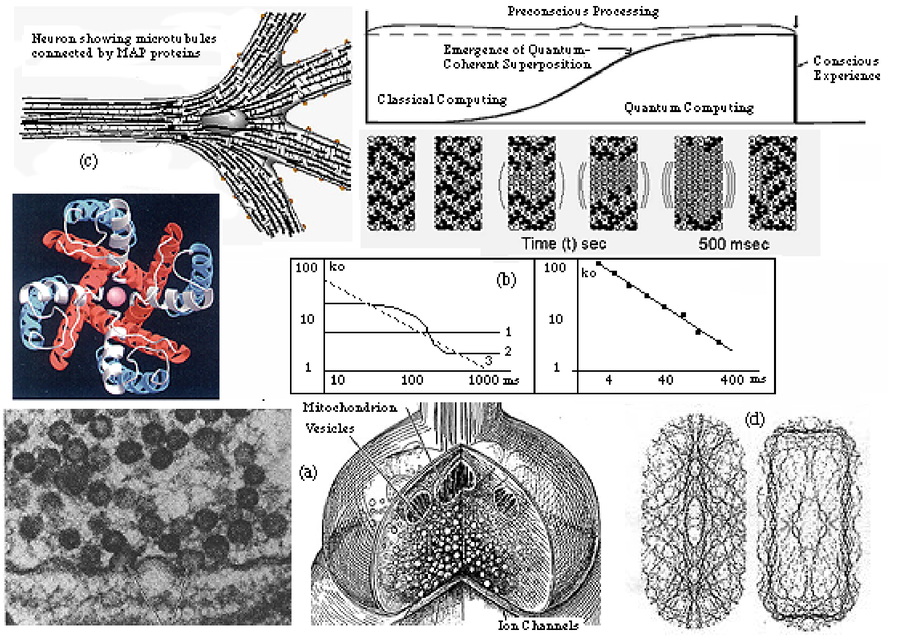


Fig 19: (a) Synaptic vesicle release (Kandel et. al. 2000) and a diagram of the synaptic bulb. (b) Bacterial K^+ ion channel, fractal time kinetics of a voltage-gated K^+ channel (Liebovitch et. al. 1987, 1991) (c) Microtubules and the quantum computation hypothesized in the OOR model of Hameroff and Penrose (2003). (d) Scarring of the wave function of a quantum stadium indicates quantum suppression of chaos (Gutzwiller 1992).

To mount an effective solution to the hard problem requires making a connection between subjective consciousness and the physical world which has mutual explanatory power. The functionally closest phenomena to subjective consciousness we know of are global electrochemical brain processes which appear to be ‘holographically’ distributed, chaotic, and potentially relate to the binding problem of the central theatre of conscious attention through phase coherence. The most promising avenue, given what we have discovered about the quantum world is to look for a bridge between global phase coherences and those we associate with quantum entanglement and transactions. This raises the enticing possibility of linking the paradox of conscious will with the paradox of reduction of the superposition of quantum states to a physical history, thus providing a complementary view of the mystery the hard problem presents both from physical unpredictability and from subjective intentional decision-making.

The fractal dynamics model proposes that the conscious state corresponds to phase coherent, temporally edge-of-chaos, excitations of coupled regions of the cortex, capable of entering a critically poised unstable state if faced with conflicting stimuli which cannot be resolved from learned experience. This would in turn enable quantum fluctuations at the molecular level to become an unstable ‘watershed’ which tips the global state towards a resolution. The fractal model uses the molecular processes of synaptic vesicles and ion channels currently believed to be pivotal in supporting active conscious states. Such a model enables instability at the quantum level to become amplified when the global brain state is critically-poised, in a way which could be possible even though the corresponding excitations are distributed across the cortex. The situation could in principle enable global excitations to be considered as ‘inflated’ quanta - either simple harmonic excitations or solitons, and phase coherence of global brain states to thus be interpreted as coherent quantum states.

The model of Hameroff and Penrose seeks a more specific mechanism in the microtubules of the neuron, fig 19. In particular they have noted 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. Generally when a single cellular system serves two critical, yet differing functions, evolution by gene duplication is likely to occur, so that both characteristics can be selected for independently. It is hard to see how the microtubules can be both involved in active transport and at the same time performing quantum calculations essential to the organism without potential conflicts of interest. These considerations do not apply to membrane excitation and synaptic transduction, which are already directly connected to excitability.

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. Effective quantum computation of even simple problems, such as Shor’s algorithm (Brown) for factoring a number, involve complex boundary constraints, including the capacity to Fourier transform one part of a quantum ‘register’ to represent periodicities in the superimposed states of the other part. It is unclear the microtubular automation can be configured to do this at the same time as serving the active transport of molecules and organelles. The Penrose and Hameroff model suggests 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 means the quantum computation is isolated from the global brain state during the quantum computation cycle. The quantum computation phase would thus be fragmented at the cellular level and could not correspond to the subjectively conscious state.

Quantum computing is subject to decoherence because any quantum interaction with the outside world except the measurement itself disrupts the superposition of states by interacting with it. By contrast, transactional supercausality incorporates contingent interaction foci, in developing the complexity of the subquantum system, and would thus be robust to decoherence.

The fractal model envisages chaotic and unstable processes penetrating the quantum level in a way which minimizes decoherence because of the self-coupling of the brain state to a restricted class of global excitations. A variety of closed quantum systems which correspond to classical chaos, including nuclear dynamics, the quantum stadium and magnetically-perturbed high energy orbitals display inhibition of quantum chaos in phenomena such as scarring of the wave function fig 19(d), in which periodic repelling orbits ‘reclaim’ the probability distribution. However quantum-kinetic interactions in an open molecular system (Gutzwiller 1992) do appear to retain the attributes of chaotic instability, fig 13(d). Unlike the OOR model the transactional model we investigate next envisages subjectively conscious decision-making associated with a global dynamical criticality as capable of participating in ‘anticipatory’ collapse of the wave function and thus actively changing subsequent brain dynamics.

13: Quantum Mind and Transactional Supercausality

Recapitulating on our ideas of transactions we note the following points:

1. Since the first ideas linking quantum uncertainty and free-will were proposed, the non-local space-time spanning manifestations of uncertainty have become more apparent and given rise to the concepts of quantum non-locality and entanglement. A key example of this is the pair-splitting experiment, fig 6, in which a single quantum event releases two particles in the same wave function. If the state of either is measured, the particles' complementary spins or polarizations then become immediately correlated in a way which an exchange of local information limited by the speed of light cannot achieve.

2. The space-time properties of quantum phenomena also have a peculiar hand-shaking potentiality, in which future can affect past as well as past affect future. In fig 5 is an illustration of the Wheeler delayed choice experiment on a cosmic scale in which the route taken by a photon around a gravitational lens can be determined after it has already passed, by rearranging the detection apparatus at the end of its path, reinforcing the notion of future-past hand-shaking. The concept is also fully consistent with quantum field theory formulations as exemplified by Feynman diagrams, fig 4, which themselves can be time reversed, resulting for example in inter-conversion between positrons and electrons.

3. These paradoxes are resolved by the transactional interpretation, fig 7. In this description each contingent emitter of a quantum sends out an offer wave and each contingent absorber sends out a confirmation wave. In reduction of the wave function the interrelationship of all these together throughout space-time collapses (possibly sequentially) into a match-making pairing of real interactions between paired emitters and absorbers as in fig 7(a). The decision-making process results in collapse of the wave function of many possibilities to the actual unique real quantum event. This becomes an interference between one emitter and one absorber superimposing to form the real particle travelling between. In the transactional interpretation, section 5, the absorber, such as my eye looking at a distant star is thus as essential to the transaction as the star which long ago emitted the light. In this view of quantum mechanics there is then a sense in which any quantum emitter is implicitly aware of the future existence of the absorber by the very act of engaging the transaction.

4. The force field is explained through virtual particles (such as the photon) appearing and disappearing through uncertainty. Such particles must necessarily link an emitter and an absorber. The theory of virtual and real particles demonstrates that real and virtual particles are in-principle indistinguishable. If we oscillate the electromagnetic field we elicit a radio broadcast. Virtual photons generating the electromagnetic field have become real ones telling us the news. If the universe emerged from a single wave function all real particles may also be entangled. Even if the universe expands forever and some quanta, such as photons, are disseminated into space, causing a permanent disparity between emitters and absorbers, the kinds of excitons we naturally associate with phase correlations in global brain dynamics are all transient excitations, both emitted and absorbed by the brain and its neurons as boundary conditions as an integral part of dynamical systems feedback.

We have discussed the idea that chaotic excitation was a primal phenomenon which occurred in the first cells, even as the metabolic pathways were becoming established. Chaotic excitation leads to a multi-quantum-mode sense organ responding to external perturbations of the environment by sensitive dependence. The idea is that this sense organ then found that through the exchange of transactional hand-shaking with its own emission and absorption states, a form of quantum anticipation of its own immediate future, resulted. This anticipation then proved to have significant selective advantage for the organism and thus became fixed in evolution as the sentient conscious brain, complementing computational capacity with transactional anticipation through the chaotically fractal central nervous system.

An evolutionary explanation for the role of subjective consciousness intervening in the states of the brain emerges if the brain uses unstable processes and nervous systems can access the laws of quantum non-locality to enable a form of temporal anticipation of pivotal survival value, which would hence be strongly selected as a trait. This could effect global brain states if they are critically poised or have chaotic sensitive dependence. The hard problem then exerts a complementarity between entangled quantum states along with their corresponding contingent transactions, and subjective states, in which conscious choice becomes physical action partly through collapse of the wave function - the component that corresponds to the 'free' component of will not determined by initial conditions or computational constraints. Even if the universe expands forever and some quanta such as photons are disseminated into space, the kinds of excitons we naturally associate with phase correlations in global brain dynamics are all transient excitations both emitted and absorbed by the brain and its neurons as boundary conditions.

The transactional process closely parallels known techniques of quantum computation (Brown 1994) using a superposition of states as boundary condition rather than the finite number of real particles exchanged in transactions. The use by the brain of complex excitons may make it sensitive to an envelope of states spanning immediate past, present and future (Libet 1989) - the anticipatory 'quantum of the conscious present'. We can model the evolving brain dynamic as a complementation between two processes, an ordered process of computation based on the 'initial' conditions forming a skeleton defining the ordered context and a chaotic, uncertain complement. It is thus possible for the brain to utilize all the prevailing contexts in coming to a decision and yet involve some free choice in the outcome. Such excitons might have restricted interactions which would isolate them from quantum decoherence effects (Zurek 1991) as illustrated by quantum coherence imaging (Samuel, Warren) and would also serve to ensure transactional handshaking occurred. The ordered aspect of the dynamic would be a function of initial conditions but the complementary chaotic, uncertain regime would involve inflated future states through transactional handshaking. The uncertainty in the transition from chaos to order representing, perception, or cognitive 'eureka,' corresponds to an inflated reduction of the wave function. The physical model of historicity and the subjective experience of conscious intentional will thus coincide.

The 'binding problem' - how sensory experiences being processed in parallel in different parts of the cortex are bound together to give the conscious expression we associate with our integrated perception of the world - has no direct solution in terms of being hard-wired to some collection point - the ultimate seat of consciousness. Every indication is that consciousness is distributed and bound together by non-linear resonances in the brain which is exactly what we would expect in a situation self-resonances were being used as part of a transactionally super-causal solution to the perception-cognition dilemma.

The problem of consciousness is consummated by the question of free will. What is the function of subjective consciousness if it is only brain states and not the subjective aspect which effect our future physical states? Put in reverse, if subjective consciousness has any evolutionary advantage then it can manifest only by perturbing in some way the physical causality of brain processes. This is the problem of intent. Everyone who sets foot into the world invests in the principal of personal autonomy, that we have subjective control over our physical circumstances. All questions of legal responsibility hinge on it. Yet this implies mind affecting matter, something which mechanistic science struggles to deny. In the transactional model of perception, intention, and will, subjective consciousness enters into the picture as the inner complement of the quantum non-local hand-shaking process which violates the causality of initial or former states determining future states, which we associate with the Newtonian universe and temporal determinism. This occurs as a consequence of special relativity and the fact that the boundary conditions of collapse include future contingent absorbing states.

Since the quantum transaction is a fundamental interpretation of all quanta, it is general to all quantum interaction. Its manifestation in resolving the fundamental questions of interaction with the physical world thus adopts a cosmological dimension, in which the sentient conscious brain becomes a central avenue for the expression of subjectivity through quantum non-locality in space time.

At the same time, the brain has been evolving towards a type of universality expressed in flexible algorithms for multi-sense processing and modeling, which experiencers of synaesthesia can witness are capable of coexisting in one multi-sense perception mode. A huge cosmological question is now raised. Is evolution simply adventitious accident, or is it part of the way the quantum universe explores its own phase space of possibilities in reaching towards a universal expression of the quantum entangled physical universe. In a quantum universe we have the dilemma of the many-universes problem. How does reduction of the wave packet result in one history or another occurring?

Transactional supercausality explains the cat paradox, fig 3, by interlacing contingent emitters and absorbers across space-time in a hand-shaking to form a complex subquantum system whose outcomes are naturally distributed according to the wave amplitude because they are the result of bifurcations of offer and confirmation waves dependent on their relative amplitudes. Reduction of the wave function corresponds to a particular matching of emitter and absorber for one exchanged wave-particle. Determining which part of the wave function a particle appears in is converted into the combinatorial one of which emitter and absorber pair are matched up. One can model the transition from many-to-many to one-on-one in terms of a non-linearity in which pairs become 'mated' in sequence. However this process cannot be resolved causally based on initial conditions because of the hand-shaking, leaving a loophole which only the 'anticipatory' mind and not computation per se can resolve. The many probability multiverses thus become resolved from superimposed multiverse super-abundance by hand-shaking across space-time sequentially, reducing the packet of all possible emitter-absorber connections to a sequence of 'happy marriages' as illustrated in fig 7(a).

The transactional principle also teaches us that modeling the interior domain of the quantum entanglement even if it can be understood as an interactive sequence of emitter-absorber reductions, will only give indeterminate predictions if only past boundary conditions are defined. It also shows us how symmetric hand-shaking time occurring in reduction fits with the sequential arrow of time defined by real, retarded, positive energy particles. The universe, thus becomes experientially historical through the uncertainty of free choice and perception itself in distinguishing the perceived from the uncertain background. Napoleon does not win the Battle of Waterloo, but Briatain wins Trafalgar, despite the feigned uncertainty of Nelson's blind eye. The same goes for all the hopeful monsters of evolution that never came to be. Quantum non-locality thus appears to have a method through space-time hand-shaking of determining which one of the multi-verses hovering in the virtual continuum will actually manifest. The role of consciousness as a cosmological process appears to mediate effectively between the world of the cosmic subjective, represented in physics as quantum non-locality, with the uniqueness of historicity, which never fully converges to the statistical interpretation of the cosmic wave function, because each change leads to another, throughout cosmic epochs.

This leads to a deep question shared by all human cultural traditions from the dawning of shamanism, through Vedanta to the Tao and even in the Judeo-Christian prophetic tradition, that mental states of awareness and subsequent physical happenings are interrelated by an anticipatory principle. If historicity is interactive with both the quantum realm and the existential condition, what are the consequences for science, society and cosmology itself? The description of reality here suggests that the physical universe has a complement - the subjectively conscious existential condition. Such a view both of the cosmological role of evolution to sentience and the brain as an interface between the cosmic subjective and the physical universe puts us right back into the centre of the cosmic cyclone in a way which Copernicus, Galileo, Descartes, Leonardo and Albert Einstein would have all appreciated.

Consciousness is then not just a globally-modulated functional monitor of attention subject helplessly to the physical states of the brain, but a complementary aspect to physical reality, interacting with space-time through uncertainty and quantum entanglement in a manner anticipated by Taoist (Wilhelm 1951) and Jungian ideas of synchronicity (Jung 1952). The same considerations apply to the use of chance oracles such as the I Ching, and the Hebrew Urim and Thummim, both of which use chaotic processes to divine an uncertain outcome. It is also possible to model hunches or premonitions as perceptions of partially collapsed contingent transactional ensembles, making certain perceived outcomes more likely than they would have been had no the perception occurred. The anthropic cosmological principle (Barrow and Tipler 1988) declares that possible universes are constrained by the existence of observers. In the weakest terms the anthropic principle ensures laws of nature compatible with the complexity of life. In stronger forms the existential nature of the universe is partially dependent on the existence of conscious observers. In transactional supercausal forms, conscious perception is resulting in the collapse of multiverses to the historical physical universe we experience. These observations illustrate anthropic aspects of the subject-object complementary hard problem model.

Although subjective consciousness, by necessity, reflects the constructive model of reality the brain adopts in its sensory processing and associative areas, this does not fully explain the subjective aspect of conscious experience. Conscious experience is our only direct avenue to existence. It underlies and is a necessary foundation for all our access to the physical world. Without the consensuality of our collective subjective conscious experiences as observers, it remains uncertain that the physical world would have an actual existence. It is only through stabilities of subjective conscious experience that we come to infer the objective physical world model of science as an indirect consequence. For this reason, subjective consciousness may be too fundamental a property to be explained, except in terms of fundamental physical principles, as a complementary manifestation to quantum non-locality, which directly manifests the principle of choice in free-will in generating history.

14: Complementarity and the Sexuality of Quantum Entanglement

This cosmology is intrinsically sexual and gives rise to cosmological prisoners' dilemma paradoxes similar to those of sexually antagonistic coevolution in which ant attempt to mount a description based on only one aspect results in impasse (Fielder and King 2004). This sexuality is manifest in wave-particle complementarity and successive complementarities in physics from advanced and retarded solutions, through boson-fermion complementarity. It is also manifest in subject-object complementarity.

Subject-object complementarity is different from either panpsychism or Cartesian duality. The subjective distinction is described as complimentary to the physical 'loophole' of quantum uncertainty and entanglement, just as the wave and particle aspects of the quantum universe are complementary. Subjective and objective are interdependent upon one another with neither fully described in terms of the other. Furthermore, the transactional interpretation is intrinsically sexual in the sense that all exchanges are mediated through entangled relationship between an emitter and an absorber in which reduction of the wave function is a match-making sequence of marriages. This sexual paradigm is not simply an analogy, but is a deep expression of the mutual complementarity and intrinsic relationship manifest in the existential realm, physically and subjectively and between.

Extrapolating, the theory suggests the evolution of gendered recombinational sexuality, as it is found in biology in the metaphyta, is not simply an analogy with quantum complementarity, but is an emergent expression of the same complementarity principle. The single ovum, by necessity, is driven to seek fertilization through a solotonic wave of excitation which extends across the membrane. The multiple sperm, by contrast, are particulate packets of molecular DNA, without a cellular cytoplasmic contribution. Thus biological sexuality is utilizing quantum complementarity in the symmetry-breaking of gender.

In Tantra, the subject-object relation is an intimate sexual union, which, in its retreat from complete intimacy, spawns all the complexity of the existential realm. In the Taoist view the same two dyadic principles are the creative and receptive forces which in their mutual transformation give rise to all the dynamic states of existence. In Taoist thought, the cosmological principle is manifest in three phenomena, chance, life and consciousness, the very phenomena appearing in physical terms in quantum physics, evolution and brain dynamics. The transactional principle clearly establishes the marital dance of emitter and absorber as the foundation of historicity - the collapse of the infinite shadow worlds of multiverses into the one line of history we experience in life, evolution, consciousness and social and natural history.

Randomness remains a scientific mystery, explained ultimately in cosmological terms by quantum entanglement. The source of the scientific concept of randomness lies in theories, such as probability theory, statistical mechanics, and the Copenhagen interpretation of quantum mechanics which draw generalities from an incomplete knowledge of the system. However the source of supposedly random events in the real world lies either in highly unstable systems, which themselves may draw their uncertainty from the quantum level, or directly from the phenomena of reduction of the wave function under the probability interpretation. The transactional approach seeks to explain the sub-stratum of entanglement in a deeper interaction. This complex system could provide an ultimate explanation for the origin of randomness.

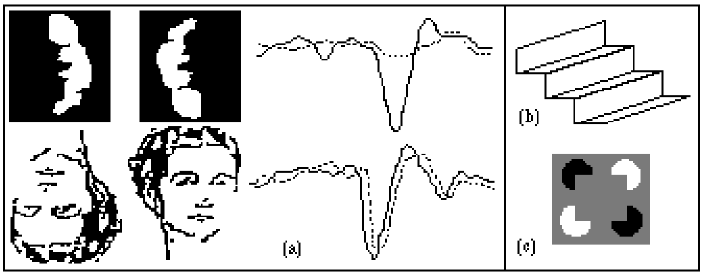


Fig 21: (a) Correspondence between brain states and subjectively perceived differences, is illustrated by the differing evoked potentials (averages of many recordings triggered by the same stimulus) when an inverted face is easily recognized as below, from the ambiguous image above. However the differing electrical potentials are qualitatively quite distinct from the differing subjective experiences in the two cases. Conscious experience cannot thus be reduced to brain states. Right: Visual illusions stimulate neurons that code explicitly for illusory contours (c), and mutually-interfering 3-D perspectives (b).

15: The Hard Problem: Subjective Experience, Intentional Will and Quantum Mind Theories

This paper proposes that the existential realm is a complementarity between subjective consciousness and the objective physical universe, of a founding cosmological nature. It advances a basis for natural selection of subjective awareness through a quantum entangled form of anticipation independent from computation as such. This presents a unique solution to the hard problem, not by attempting to explain subjective consciousness through objective brains states (the ‘classical’ error), but by elaborating a theory based on the complementarity between subjective consciousness and physical brain states, in which two key features are complementary views of existential reality as are wave and particle in the physical realm. These are manifest in the subjective aspect in conscious perception and intentional will and in the objective aspect in physical indeterminacy accompanied by reduction of the wave packet and the consequent historicity of the universe collapsing the quantum superabundance of multiverses to the physically historical world we experience.

In this view, subjective awareness is not identifiable with quantum entanglement but is complementary to it. Through chaotic instability and its fractal interaction with quantum uncertainty, a loophole is created in the physical description which allows subjective consciousness to have anticipatory selective advantage. This advantage is in turn given expression in the physical world through the capacity to intend, or ‘will’. Neither is willing performed exclusively by the subject, for if a person’s mind is already made up either by prejudice or by the logic of the circumstances, we are not discussing the ‘free’ aspect of will, but rather when they are making a genuine choice in spite of all the prevailing circumstances, even by hunch or intuition. Here intentional will is not any kind of specific drive possessed or directed by the organism, but the very capacity for subjective experience to, in turn, affect the physical universe and the future potentialities it may perceive, by an act of free-will. Subjective consciousness transforms incoming sensory and other forms of perception into the outgoing expression of creative consequences in intentional action. The freedom of will also means it is not entirely under ordered conscious control. We depend on a founding sense of personal autonomy to be able to act as sane individuals, without which we might all become catatonic or robotic automata. Intentional will is a mystery, both from the objective physical description, and from subjective existence. Just as uncertainty and unpredictability open the loop hole making free-will possible in the quantum universe, so the subjective aspect of will remains potentially as free of internal conditioning by drive or ego as it is potentially free of becoming completely conditioned by the circumstances of the physical world. In so far as we, as sentient conscious individuals, treat love and will as mysteries in their own right, so they become the subjective complement of an integrated expression of quantum non-locality and an entanglement which permeates the entire universe. In applying our free will, we each contribute collectively to the collapse of the infinite possibilities of the multiverses before us into a beneficent or sterile outcome. Just as the choice is ours at all points to enhance or diminish the diversity and abundance of life, so our world history becomes one of abundance or poverty.

We also have to consider how sensory information which may be pre-conscious achieves a level of consensual arousal e.g. through ‘phase coherence’ sufficient to draw attention to itself and become a fully fledged conscious experience. As Libet (1989) has noted, this may involve backward time referral of a conscious experience to its first pre-conscious manifestation.

The transactional perspective stands unique among quantum theories in providing an explanation for anticipatory consciousness which can effect the future of the physical universe through will. The Copenhagen interpretation, being essentially a theory of our knowledge, rather than the universe itself, can say nothing on this question of interactivity between subjective and objective aspects. Many worlds interpretations, having no process of collapse provide no mechanism whatever for consciousness to interact to influence the physical future. The Bohm pilot wave theory being a semi-quantum theory with a classical underpinning in the quantum potential likewise remains a purely objective description, which also has specific problems dealing with situations which can generate new quantum degrees of freedom such as a high energy photons creating a particle anti-particle pair. Penrose and Hameroff’s (2003) OOR model likewise provides an objective reduction process driven in the limit by gravitational decoherence (the gravitational self-energy between the differing mass distributions of the outcomes), which permits subjective consciousness (or the transition from the pre-conscious state) only to reflect the objective reduction , and thus cannot explain how intentional conscious can effect the physical universe.

Hameroff and Penrose concentrate on the microtubule as a possible basis for quantum computation using two states of the tubulin monomer, in the form of a quantum cellular automation, because it displays convenient automata-like structure. Certainly this is an interesting hypothesis and the possible involvement of microtubules in conscious states is a significant area of research, however the hypothetical process requires the isolation of microtubules to avoid decoherence, possibly through de-linking of MAP protein connections with the excitable membrane. This effectively reduces any form of quantum consciousness to collections of isolated cell interiors, preventing a direct feedback between the electrodynamical global brain resonances we identify with active conscious states (e.g. in the 40 Hz region) and quantum non-locality. Microtubules possess many interesting properties, including possible solitonic interactions. It has also been suggested microtubular proteins might possess topological quantum computing properties (Freedman et. al. 2002) of non-commutative anyons (Kitaev 2003), which would be robust to quantum decoherence (Zurek 1991). However their primary functions are transport of essential chemicals and components such as vesicle and maintaining structural integrity of graduated processes such as synaptic adaption and long term potentiation.

What is really needed is a quantum mind theory capable of linking the fast electrodynamical resonances we associate with active conscious states directly to an anticipatory form of quantum non-locality. The supercausal version of transactional quantum theory, which allows for mutual collapse of an entangled transaction to specific real connections between emitters and their future absorbers, is unique in providing such a possibility. The use of chaos and fractal dynamics provides mechanisms to inflate quantum uncertainties and the use of wave coherence in global brain states forms a direct basis for exciton exchange between emitters and absorbers consisting of immediate past and future brain states, thus linking them into a handshaking resonant system.

16: Consciousness and Neurocosmology

The diversity of wave-particles resulting from symmetry-breaking of the four fundamental forces, the weak and colour nuclear forces, electromagnetism, and gravitation, finds its final interactional complexity, in which all forces have a common asymmetric mode of expression, in complex molecular systems. It is thus natural that fundamental principles of this quantum interaction may be ultimately realized in the most delicate, complex and globally interconnected molecular systems known - those of the conscious brain. The brain may be one of the few places where the supercausal aspects of wave packet reduction can be clearly manifest, as a result of its unique capacity to utilize entanglement in its dynamics. Although other unstable systems, from the weather to axionic dark-matter condensates (Ryquist) may also display, or amplify, features of non-locality, it is difficult to conceive of a physical system which could in any way match the brain as a potential detector of correlations and interrelationships within the domain of quantum mechanics. Cosmology is not simply a matter of vast energies, but also quantum rules. In these rules of engagement, more fundamental even than symmetry-breaking, the stage appears to be set for the emergence of sentient organism as the culminating manifestation in complexity of quantum interaction. In this sense the conscious brain may be the ultimate inheritor and interactive culmination of the quantum process at the foundation of the universe itself. This is the consummation of cosmology, not in the alpha of the big-bang, nor in the omega of finality but in the sigma of its interactive complexity, fig 22(c).

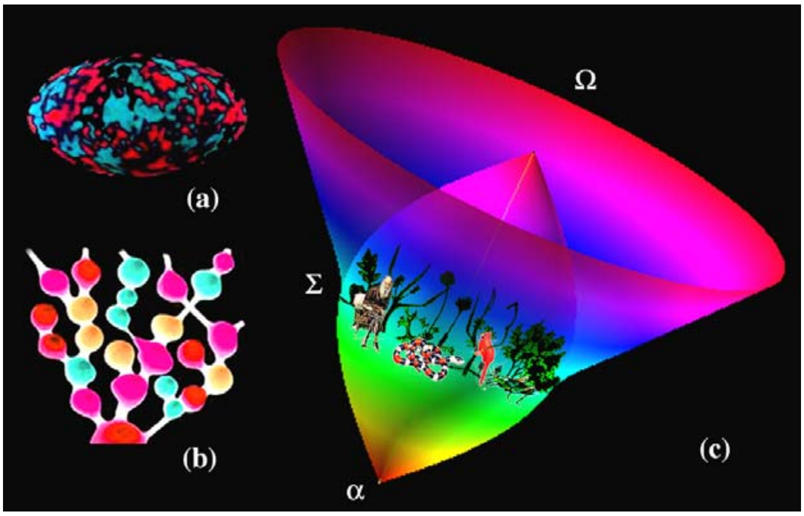


Fig 22(a): The cosmic background - a red-shifted primal fireball. This radiation separated from matter, as charged plasma condensed to atoms. The fluctuations are smoothed in a manner consistent with subsequent inflation. (b) Fractal inflation model leaves behind mature universes while inflation continues. (c) Darwin in Eden: "Paradise on the cosmic equator." - life is an interactive complexity catastrophe resulting from force differentiation representing the Σ of interactive complexity rather than the α cosmic origin or the Ω of final culmination.

The deepest question which can be posed about cosmology is precisely that of the hard problem: What is the relationship between the existential observer and the universe at large? What is the relation between conscious subjectivity and the objective physical world? This is a question which has plagued philosophers and scientists from the early Greeks through Bishop Berkeley and Descartes to David Chalmers' (1995, 1996) description of the 'hard problem in consciousness research' as a fundamental philosophical chasm which can only be crossed through a greater description of reality.

Despite the advances of modern scanning techniques such as PET (positron emission tomography) and fMRI (functional magnetic resonance imaging) and electro- and magneto-encephalographic studies, a chasm still remains between the brain states under a researchers probe and the subjective experiences of reality we depend on for our awareness of the physical world. This comes on top of a fundamental complementarity upon which we depend for our existence. Although we live as biological organisms, raise families, navigate our lives and perform our science on the assumption of the existence of the physical world, we access physical reality only through our subjective sensory experiences. Without the direct veridical access we have to subjective experience, there would be no conscious 'observers'. It remains unclear under these circumstances that one could establish that the physical universe would exist in any objective 'sense'.

Ironically a purely objective physical world description considers only brain states, leaving subjective consciousness to the perilously ephemeral status of an epiphenomenon, or not existent at all. However the physical world is really a consensual stability property of our conscious experiences, despite the fact that we are physical organisms whose consciousness appears to depend on our remaining alive. We can both consciously agree that the table is made of wood, or that we will bleed if cut, so the subjective aspect is capable of representing the objective. The objective is capable in turn of 'incorporating' the subjective in terms of uncertainty in the physical. A fully cosmological theory thus has to encompass both realms.

This access to the subjective is profoundly augmented by a variety of subjective states, some of which have no direct correlate in the physical world, yet can be commandingly real to the observer. Firstly consciousness is constructive, and fills in details to generate a subjective description of reality which can often lead to peculiar results as illustrated by visual illusions, fig 21. More significantly we have states of meditative trance, psychedelic hallucination and the intense phases of dreaming. Although various tests can be made by the astute subject to distinguish dreaming from waking reality, the very fact of dreaming as an alternative veridical reality raises a deep question about the nature of the everyday world we perceive. Is it nothing but an internal dream state anchored by additional stability constraints provided by sensory input? If we are actually witnessing exclusively and only our internal model of reality, what then is the manifest nature of the physical world?

REFERENCES

1. Agladze K., Kinsy V., Pertsov A. (1984), *Chaos in the non-stirred Belousov-Zhabotinsky reaction is induced by the interaction of waves and stationary dissipative structures* Nature **308**, 834-5.
2. Albano A.M., Abraham N., de Guzman G.,Tarroja M., Bandy D., Gioggia R., Rapp P.E., Zimmerman I., Greenbaun N., Bashore T., (1986a), *Lasers and brains : Complex systems with low-dimensional attractors, in Dimensions & Entropies* in Chaotic Systems Ed. Mayer-Kress G. Springer-Verlag, Berlin 231-240.
3. Albano A.M., Mees A., de Guzman G., Rapp P.E., (1986b), *Data requirements for reliable estimate of correlation dimensions* in Chaos in Biological Systems ed. Degn H., Holden A.,V., Olsen L.F. , Plenum Press, New York, 207-220.
4. Ansari A, Berendzen J., Bowne S., Frauenfelder H., Iben I., Sauke T., Shyamsunder E., Young R., (1985), *Protein states and protein quakes*, Proc. Nat. Acad. Sci. 82 5000-4.
5. Arndt, M. et al. (1999) *Wave-particle duality of C60 molecules*. Nature **401**, 680.
6. Aspect A., Dalibard J., Roger G., (1982), *Experimental tests of Bell's theorem using time-varying analysers*, Phys. Rev. Lett. **49**, 1804.
7. Babloyantz A., (1989), *Estimation of correlation dimensions from single and multichannel recordings*, in Basar E., Bullock T.H. eds. Brain Dynamics Springer-Verlag, 122-130.
8. Babloyantz A. & Salazar J.M., (1985), *Evolution of chaotic dynamics of brain activity during the sleep cycle*, Phys. Lett. 111A, 152 - 156.
9. Babloyantz A. & Destexhe A., (1986), *Low-dimaensional chaos in an instance of epilepsy*, Proc. Nat. Acad. Sci. 83, 3513 - 3517.
10. Ball, Philip 2003 *Molecules of life come in waves: Compounds found in cells show quantum behaviour* Nature 5 Sept.
11. Barrow John, Tipler Frank 1988 The Anthropic Cosmological Principle, Oxford Univ. Pr., Oxford.
12. Basar, E. (1990). *Chaotic dynamics and resonance phenomena in brain function : Progress, perspectives and thoughts*. In E. Basar (Ed.) Chaos in brain function. (pp. 1-30). Heidelberg: Springer-Verlag.
13. Basar, E., Basar-Eroglu, J., Röschke, J., and Schütt, A. (1989). *The EEG is a quasi-deterministic signal anticipating sensory-cognitive tasks*. In Basar E., Bullock T.H. (Eds.), Brain dynamics.(pp 43-71). Heidelberg: Springer-Verlag.
14. Bell John S. (1966) Rev. Mod. Phys. **38/3**, 447.
15. Bern M. & Graham R., (1989), *The shortest network problem*, Sci. Am. **Jan**, 66 - 71.
16. Blakemore C. (1991) Sir Douglas Robb Lectures, Auckland N.Z.
17. Bohm D. (1952), *A suggested interpretation of the quantum theory in terms of 'hidden' variables, I & II*, Phys. Rev. **85** 166-93.
18. Bohm D. (1980), Wholeness and the implicate order London, Boston and Henley, U.K. Routeledge & Kegan Paul.
19. Brinigar W., Knaff D., Wang J. (1966), *Model reactions coupling oxidation to phosphorylation* Biochemistry 36-42.
20. Brown J. (1994) *A quantum revolution for computing* New. Scientist **Sept 24**
21. Calude C., Pavlov B. (2002) *Lightspeed computing* in New Scientist **6 Apr**.
22. Chalmers D. (1995) *The Puzzle of Conscious Experience* Scientific American **Dec**. 62-69
23. Chalmers, D.J. (1996) The Conscious Mind. Oxford University Press.
24. Chay T.R., Rinzel J. (1985), *Bursting, beating and chaos in an excitable membrane model*, Biophys. J. **47**, 357-366.
25. Chown, Marcus 2004 *Quantum Rebel*. New Scientist, 183 **2457** 24th July 30.
26. Clauser, J.F., and Shimony, A. (1978). *Bell's theorem : Experimental tests and implications*. Reports in the Progress of Physics, **41**, 1881 - 1927.
27. Cramer J.G., (1986), *The transactional interpretation of quantum mechanics*, Rev. Mod. Phys. **58**, 647 - 687.
28. Crick F, Koch C. (1992) *The Problem of Consciousness* Sci. Am. **Sep**. 110-117.
29. Dennett D. C. (1991) Consciousness Explained Little Brown & Co., Boston.
30. Deutsch D., (1985), *Quantum theory, the Church-Turing principle and the universal quantum computer*, Proc. Roy. Soc. Lond. **A400**, 97-117.
31. Dunne J. W. (c 1935) An Experiment With Time Faber, (c1935 1st ed).
32. Eccles, J.C. (1986) *Do men tal even ts cause neural events analogously to the probability fields of quan tum mec hanics?* Proc. R. So c. Lond. **B 227** , 411–428.
33. Eddington, A.S . (1935). New pathways in science Cambridge University Press Cambridge.
34. Epstein I., Kustin K., DeKepper P., Orbán M. (1983), *Oscillating chemical reactions* Sci. Am. **Mar**, 112-123.
35. Fielder, Christine & King, Chris (2004) Sexual Paradox 490pp http://www.dhushara.com/
36. Fox R.O., F. Richards (1982) *A voltage-gated ion channel model inferred from crystal structure of alamethicin at 1.5A resolution* Nature **300** 325-330.
37. Freedman M., Kitaev A., Larsen M., Wang Z. (2002) *Topological Quantum Computing* ArXiv:quant-ph/0101025.pdf
38. Freeman, W. (1991). *The physiology of perception*. Sci. Am. **264**, Feb 35-41.
39. Glansdorff P., Prigogine I. (1971) Thermodynamic Theory of Structure, Stability and Fluctuations Wiley-Interscience, Lond.
40. Goldman-Rakic P. (1992) *Working Memory and the Mind* Sci. Am. **Sep** 73-79.
41. Goncharova N., Goldfelt M. (1990) *Mg-porphyrin as possible photosensitizer of macroergic phosphate bonds formed during prebiotic evolution* Origins of Life **20**, 309-319.
42. Gutzwiller, M.C. (1992). *Quantum chaos*. Sci. Am. **266**, 78 - 84.
43. Hackermüller, L. et al. (2003) *Wave nature of biomolecules and fluorofullerenes* Physical Review Letters **91**, 090408.
44. Hall D., Cammack R., Rao K. (1974) *The iron-sulphur proteins: Evolution of a ubiquitous protein from model systems to higher organisms*. Origins of Life **5**, 363-386.
45. Hameroff, Stuart; Penrose, Roger (2003) *Conscious Events as Orchestrated Space-Time Selections* NeuroQuantology; **1**: 10-35
46. Hawking, Stephen (2001) The Universe in a Nutshell Bantam Press. N.Y.
47. Hooper J. & Teresi D., (1986), The Three-Pound Universe, MacMillan New York .
48. Jung, Carl (1952) *Synchronicity an acausal connecting principle* in The Structure and Dynamics of the Psyche, Routledge & Kegan Paul, London.
49. Kandel E., Schwartz J, Jessel T (2000) Principles of Neural Science 5th ed. McGraw Hill NY.
50. King C.C., (1978), *Unified field theories and the origin of life*, Univ. Auck. Math. Rept. Ser. **134**.

51. King C.C. (1989), *Dual-time supercausality*, Phys. Essays **2**, 128 - 151.
52. King C.C. (1990), *Did membrane electrochemistry precede translation?* Origins of Life Evol. Biosph. **20**, 15.
53. King C.C. (1991), *Fractal and Chaotic Dynamics in the Brain* Prog. Neurobiol. **36** 279-308.
54. King C.C. (1996), *Fractal Neurodynamics and Quantum Chaos* in Fractals of Brain Fractals of Mind Adv. in Consciousness Research **7** (ed.) MacCormac E., Stamenov M. 179 - 233.
55. King C.C. (1997), *Quantum mechanics, Chaos and the Conscious Brain* J. Mind and Behavior **18**, 155-170.
56. King C.C. (2001) Codex of the Tree of Life WED Monographs **1** 1-775 http://www.dhushara.com
57. King C.C. (2003), *Chaos, Quantum-transactions and Consciousness: A Biophysical Model of the Intentional Mind* Neuro-Quantology **1** 129-148.
58. King C.C. (2002) *Biocosmology Part 1 Prebiotoic Epoch: Symmetry-Breaking and Molecular Evolution.* WED Reviewed Monographs http://www.dhushara.com **2/1** 1-20
59. King C.C. (2002) *Biocosmology Part 2 Evolutionary Epoch: Chaos, Complexity and Complementarity.* WED Reviewed Monographs http://www.dhushara.com **2/2** 21-30.
60. Kitaev Alexei (2003) *Fault tolerant computation by anyons* Annals of Physics 303 2-30.
61. LaBerge S., (1990), Exploring the World of Lucid Dreaming , Ballantine Books, Random House, New York.
62. Libet B. (1989) *The timing of a subjective experience* Behavioral Brain Sciences **12** 183-5.
63. Liebovitch L.S., Fischbarg J., Konairek J.P., Todorova I., Wang Mei, (1987a), *Fractal model of ion-channel kinetics*, Biochim. Biophys. Acta **896**, 173-180.
64. Liebovitch L.S., Sullivan J.M., (1987b), *Fractal analysis of a voltage-dependent potassium channel from cultured mouse hippocampal neurons*, Biophys. J. **52**, 979-988.
65. Liebovitch L.S., T. Toth (1991) *A model of ion channel kinetics using deterministic chaotic rather than stochastic processes* J. Theor. Biol. **148**, 243-267.
66. Liljenström Hans, Svedin Uno 2005 Micro-Meso-Macro: Addressing Complex Systems Couplings Imperial College Press.
67. Llinás R., (1987) in Blakemore C., Greenfield S., Mindwaves Basil Blackwell, Oxford.
68. Lockwood M., (1989), Mind, Brain & the Quantum, Basil Blackwell, Oxford.
69. Lozovaya G., Masinovsky Z., Sivash A. (1990), *Protoporphyrin IX as a possible ancient photosynthesizer : spectral and photochemical studies* Origins of Life **20**, 321-330.
70. MacElroy R., Morowitz H., Pohorille A. *Ion transport mechanisms and prebiotic membranes* Orig. of Life **19**, 295-296.
71. MacLean, P. (1991). *Neofrontocerebellar evolution in regard to computation and prediction: Some fractal aspects of microgenesis*. In R. Hanlon (Ed.), Cognitive microgenesis : A new psychological perspective 3-33 New York: Springer-Verlag.
72. Miller, Geoffrey 2000 The Mating Mind Doubleday NY.
73. Mueller, Rudin (1968), *Action potentials induced in a bimolecular lipid membrane* Nature **217**, 713-719.
74. Penrose R., (1989), The Emperor's New Mind, Oxford University Press.
75. Penrose, R. (1994). Shadows of the mind. Oxford : Oxford University Press.
76. Pollack, Gerry (2001) Cells, Gels and the Engines of Life Ebner and Sons, Seattle WA 98105, USA
77. PribramKarl H. Ed. (1993) Rethinking neural networks : quantum fields and biological data Erlbaum, Hillsdale, N.J.
78. Przybylski A., Fox S.W. (1986),*Biomimetic properties of stimulated protomembranes* Origins of Life **16**, 395-396.
79. Rapp P.E., Bashore T., Martinerie J., Albano A., Zimmerman I., Mees A., (1989), *Dynamics of Brain Electrical Activity*, Brain Topography 2 99-118.
80. Ruthen, R. (1993) *Adapting to Complexity* Scientific American, **268**, 110-117.
81. Ryquist R. (2003) *A Dark Matter Model of Consciousness* Yanniru Foundation. Quantum Mind 2003 Poster Session.
82. Samuel E. (2001) *Seeing the seeds of cancer* New Scientist **24** Mar 42-45.
83. Schierwagen A.K., (1986) *Dendritic branching patterns*, in Chaos in Biological Systems ed. Degn H., Holden A.,V., Olsen L.F. Plenum Press, New York, 191-193.
84. Schuster, H.J. (1986). Deterministic Chaos Berlin: Springer-Verlag.
85. Skarda C.J., Freeman W.J., (1987), *How brains make chaos in order to make sense of the world*, Behavioral and Brain Sciences **10**, 161-195.
86. Stewart I., (1989), Does God Play Dice? Basil Blackwell, Oxford.
87. Stickgold R., (1998) *Sleep: off line memory reprocessing* Trends in Cognitive Sciences **2**, 484
88. Teich M. (1992) *Fractal neuron firing patterns* 589-625 in McKenna T., Davis J.,Zornetzer S. in Single Neuron Computation, Academic Pr. San Diego.
89. Walker, E.H. (1977) *Quan tum mechanical tunneling in synaptic and ephaptic transmission* In t. J. Quan t. Chem. **11** ,103–127.
90. Warren W. (1998) *MR Imaging contrast enhancement based on intermolecular zero quantum coherences* Science **281** 247.
91. Wilhelm R. (1951) The I Ching, Routledge & Kegan Paul, N.Y.
92. Winson J. (1990) *The meaning of dreams* Scientific American **Nov**, 42-48.
93. Zeki S. (1992) *The visual image in mind and brain* Sci. Am. **Sep** 43-50.
94. Zurek W. (1991) *Decoherence and the Transition from Quantum to Classical* Physics Today **Oct.**